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Główny Urząd Miar

POLISH METROLOGICAL UNION

POLITECHNIKA LUBELSKA
LUBLIN UNIVERSITY OF TECHNOLOGY

The International Metrological Conference

NEW TRENDS IN METROLOGY 2024

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Development trends of metrology in modern science and economy

Book of Proceedings

Editor: Jerzy Józwik

Lublin, 2024

The International Metrological Conference „New Trends in Metrology”

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ADVANCING METROLOGY THROUGH EU-FUNDED RESEARCH: ACHIEVEMENTS AND CHALLENGES

Miruna Dobre

EURAMET e.V., Belgium

This talk aims at providing background information on the long-term collaboration in research of Europe's metrology community. EURAMET, the European Association of National Metrology Institutes, has pioneered cooperation in metrology research in recent years through major European Metrology Research Programs worth over 1 billion euros jointly funded by national governments and the European Union. The redefinition of the International System of Units (SI) has been a focus of EU-funded metrology research. The 3 successive programs (EMRP, EMPiR and ongoing EMP) have supported numerous projects aimed at developing and refining measurement standards based on fundamental constants of nature. Key areas of research include the realization of the kilogram using the Kibble balance, advancements in quantum electrical standards for the ampere, and innovative methods for temperature measurement to redefine the kelvin. Additionally, projects have explored optical clock technologies to enhance the precision of timekeeping. This collaborative research, involving national metrology institutes, academia, and industry, has not only facilitated the successful redefinition of the SI units but also ensured their practical implementation and traceability. Nevertheless, metrology is an everlasting key enabling science and new challenges from emerging research areas have set new metrology research goals such as directly deliver the SI at the point of use, by utilizing quantum and digital technologies or provide primary realizations of the units within an industrial facility. For next decade, EURAMET has identified four key areas that will generate needs for a comprehensive, strategic, and coordinated metrology agenda for Europe – green deal, competitive and resilient industry, health and cohesion and infrastructure – and has published a white paper “Metrology for a stronger Europe”. The overall vision of the white paper combined with the strategic research agendas developed and maintained in priority application fields by the experts of European Metrology Networks are the building blocks of a coherent research intensive European metrology community.

Speaker biography

Miruna Dobre serves as the Research Manager since 2013 and Head of the Thermometry Laboratory at the Belgian National Metrology Institute (SMD). Before joining SMD in 2003, Miruna spent several years conducting research at UCLouvain in Belgium, where she completed her PhD in applied sciences. During this time, she was involved in the theoretical and experimental design of ultrasonic atomisers. Presently, her main research interests are in the field of thermodynamic temperature dissemination and environmental applied metrology. From the very beginning of her career in metrology, Miruna understood the importance of cooperation in EURAMET and committed herself to actively contribute, first in the technical committee of thermometry, later on in the Interdisciplinary Committee that she chaired. Since 2022 Miruna Dobre holds the position of Vice-Chair of EURAMET and plays a pivotal role on supporting members to meet their national requirements through collaboration in research and capacity building.

NANOTECHNOLOGY FOR FOOD ANALYSIS

Beata Godlewska-Żyłkiewicz

Wydział Chemii, Uniwersytet w Białymstoku, Polska

Nanometrologia jest nową gałęzią metrologii, której specyfika jest związana z nanometryczną skalą (1-100 nm) mierzonych obiektów, a także powiązaniem metrologii chemicznej i fizycznej. Obiekty w skali nano mają odmienne właściwości fizyczne i chemiczne od obiektów w skali makro. Nanomateriały (NMs), ze względu na unikalne właściwości, znajdują szerokie zastosowanie w rolnictwie i przetwórstwie żywności jako składniki nawozów mineralnych i środków ochrony roślin, dodatki do pasz i żywności stosowane w celu poprawy jej jakości, w tym zwiększenia bioprzyswajalności składników odżywczych, wydłużenia okresu przydatności produktów do spożycia, a także w produkcji przyjaznych dla środowiska opakowań do żywności. Korzyściom płynącym ze stosowania nanocząstek (NPs) mogą jednak towarzyszyć efekty negatywne związane z ich szkodliwym wpływem na zdrowie człowieka. Wiadomo, że toksyczność NPs zależy od ich składu chemicznego, kształtu, rozmiaru, stężenia masowego i liczbowego, trwałości oraz sposobu otrzymywania. Ocena bezpieczeństwa żywności związana z obecnością NPs wymaga zatem stosowania do ich oznaczania w produktach spożywczych miarodajnych metod analitycznych. Jedną z rekomendowanych metod jest spektrometria mas z jonizacją w plazmie sprzężonej indukcyjnie do pomiaru w trybie analizy pojedynczej cząstki (sp-ICP-MS) (ISO/TS 19590:2017). Ta zaawansowana technika pomiarowa pozwala na analizę NPs w roztworach wodnych dostarczając informacji o ich rozmiarze, liczbowym rozkładzie wielkości, liczbie cząstek, stopniu agregacji oraz stężeniu analitu w formie jonowej. Niedogodnością pomiarów jest ich zależność od wielu parametrów, takich jak rodzaj i skład matrycy próbki, występowanie interferencji spektralnych, wpływ parametrów aparaturowych, czy brak odpowiednich materiałów odniesienia do prowadzenia kalibracji pomiarów. Z drugiej strony sp-ICP-MS posiada szereg zalet, takich jak pomiar rozmiaru każdej cząstki zarejestrowanej w sekwencji pomiarowej, możliwość rejestrowania dużej populacji NPs oraz pomiarów próbek polidyspersyjnych. Konieczne jest jednak jej dalsze doskonalenie pod kątem spełnienia wymagań metrologicznych, tak by docelowo mogła być wdrożona w badaniu żywności. W referacie omówione zostaną problemy metrologiczne występujące podczas oznaczania NPs w żywności. Przedstawione zostaną również problemy występujące podczas oznaczania nanocząstek metali (np. AgNPs, AuNPs, TiO2NPs) techniką sp-ICP-MS i zaproponowane sposoby ich rozwiązania. Podane również zostaną przykłady zastosowania tej techniki do oznaczania NPs w roślinach jadalnych oraz w nowej żywności (glony, owady jadalne), a także do badania translokacji i biotransformacji NPs w roślinach [1-4].

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Biografia prelegenta

Kierownik Katedry Chemii Analitycznej i Nieorganicznej na Wydziale Chemii Uniwersytetu w Białymstoku. Zainteresowania naukowe Pani Profesor skoncentrowane są wokół wykorzystania metod spektrometrii atomowej oraz cząsteczkowej w analizie śladowych ilości pierwiastków w próbkach biologicznych i środowiskowych oraz żywności (UV-Vis, ETAAS, HR CS AAS, ICP MS), a także technik sprzężonych w analizie specjacyjnej metali (HPLC-ICP MS). W spektrum jej zainteresowań znajduje się również analiza nanocząstek metalicznych za pomocą technik spektrometrycznych, a także badania ich pobierania i translokacji przez rośliny. Rozwija także metody przygotowania próbek do analizy metali, takie jak ekstrakcja do fazy stałej z wykorzystaniem mikroorganizmów, polimerów z odwzorowanymi jonami metali, uporządkowanych materiałów krzemionkowych, czy zatężanie elektrochemiczne. Zajmuje się również zagadnieniami związanymi z wykorzystaniem zasad metrologii w pomiarach chemicznych i zapewnieniem jakości pomiarów. Prof. dr hab. Beata Godlewska-Żyłkiewicz jest: Członkinią Rady Uczelni Uniwersytetu w Białymstoku, Przewodniczącą Wydziałowej Komisji ds. Rozwoju Kadry oraz Członkinią Komitetu Chemii Analitycznej Polskiej Akademii Nauk, Komitetu Chemii PAN oraz Komisji Nauk Chemicznych i Fizycznych PAN Odział w Olsztynie i w Białymstoku. Pani Profesor jest również autoryzowaną trenerką zespołu TrainMic (Training in Metrology in Chemistry) powołanego przy Institute for Reference Methods and Measurements (IRMM) w Belgii, a także przewodniczącą komitetu organizacyjnego Konwersatorium Spektrometrii Atomowej KOSAT, które cyklicznie odbywa się na UwB. W latach 2017-2019 uczestniczyła w Management Commitee COST (European Cooperative for Science and Technologia) akcji TD 1407 Pierwiastki Krytyczne Technologicznie. Prof. dr hab. Beata Godlewska-Żyłkiewicz jest Członkinią Rady Programowej Wydawnictwa MALAMUT oraz Regionalnej Komisji do spraw Ocen Oddziaływania na Środowisko.

RADIO IMAGING INSTRUMENTATION QUALITY CONTROL FOR MAINTENANCE: METROLOGICAL CHARACTERIZATION FOR HARDWARE AND OUTCOMES PROCESSING

Aimé Lay-Ekuakille

University of Salento, Italy

The diagnostic instrumentation used in radiology, for biomedical applications, and well as for industrial ones, needs regular and pre-established maintenance cycles to keep it efficient. Quality control is a series of measurement and characterization to be carried out in the effort to evaluate the outcome performance. The interested instrumentation is generally based on X-rays, CT, NMR, PET-CT, SPECT, Scintigraphy, and for treatment, we have to include linear accelerators. A lack of quality control activities can heavily affect the instrumentation operating modes, and perhaps the patient conditions. After verifying and testing the instruments/machines, it is also necessary to check the quality of the outcomes, that is, the images. The lecture proposes some practical examples in terms of hardware measurements, and the assessment of the results delivered by the equipment. The norms and technical legislations are mandatory for the experts working in this field.

Speaker biography

Aimé Lay-Ekuakille (SM'12), received the first M.D. degree in Electronic Engineering (control technology and automation) from the University of Bari, Bari, Italy, in 1988, the second M.D. degree in Clinical Engineering from the University of L'Aquila, L'Aquila, Italy, in 2002, a M.D. (h.c.) in Environmental Management and Sanitation from IFAD Institute, Kinshasa, DRC in 2020, and a Ph.D in Electronic Engineering from the Polytechnic of Bari, in 2001. From 1989 up to 2000, he was serving as Technical Top Manager for private and public institutions in the following main areas: construction and maintenance of industrial plants, Environment, Biomedicine, Nuclear for civil and heath applications, Robotics, and Instrumentation. He is with the Dept of Innovation Engineering, University of Salento, Italy, since 2000, and the Director of Instrumentation and Measurement Lab I. Prof. Aimé Lay-Ekuakille is a Senior Member of IEEE. His main areas of research are: (i) Instrumentation and Measurements for

Biomedical, Environmental and Industrial applications, (ii) Sensors and Sensing Systems, (iii) Nanotechnology, (iv) Artificial intelligence for Instrumentation and Measurement, and (v) Ageing and Characterization of Photovoltaic Panels. He authored and co-authored more than 360 papers on indexed international conferences and journals, as well as 5 international books. He serves as, Senior Editor of Measurement: Food (Elsevier, NL), Editor of Measurement Journal (Elsevier, NL), Editor of Measurement: Sensors (Elsevier, NL), Associate Editor of IEEE Sensors Journal (USA), Editor of IEEE Transactions on Nanobioscience, Associate Editor of International Journal on Smart Sensing and Intelligent Systems (USA), Associate Editor of Mathematical Problems in Engineering published by Hindawi (UK), and Editor of Sensors (Mdpi, CH), Board member of American Journal of Biomedical Engineering published by SAP (USA), and Medical Robotics (HK, China). Prof. Aimé Lay-Ekuakille is the Chairman of Imeko TC19 on Environmental Measurements, Chairman of IEEE IM Society TC34 on Instrumentation and Measurement in Nanotechnology, IEEE IMS Representative within IEEE Nanotechnology Council, and Chairman of the Nanosensors TC within the Italian chapter of IEEE Sensors Council. He is also an active member of the Italian Institute of Robotics and Intelligent Machines (I-RIM), being the co-Chair of the WG on Assistive, Rehabilitation & Physical Medicine Robotics. He has been included in the 2020 Top 2% of the best world scientists by the University of Stanford (USA):

He is/was Visiting and Adjunct Professor in different international universities, namely, MMU of Kenya, Chemnitz Technical University (Germany), ISTA University (DRC), Panamerican University in Aguascalientes (Mexico), VUB - Free University of Brussels (Belgium), University of Navarra (Spain). He mentors different Ph.D students in Italy and international universities. He continues to serve as scientific consultant for national and international institutions.

COMPRESSED SENSING-BASED DATA ACQUISITION: AN OPPORTUNITY FOR DISTRIBUTED SYSTEMS, IOT AND DIAGNOSTICS

Luca De Vito

University of Sannio, Italy

The emerging compressed sensing (CS) theory offers a way to significantly reduce the number of sampling points required to capture data, leading to the elimination of redundant information. This allows for the development of efficient stand-alone and network-centric applications in the Internet of Things (IoT) with fewer resources. CS relies on the fact that many natural signals satisfy a property called sparseness in a specific transformation domain. Thanks to this property, it has been proven that information contained in the signal could be obtained from the compressedly sampled signals, as well as the whole signals sampled by Nyquist theory. The lecture will present the concept of compressed sensing applied to the design and deployment of data acquisition systems, with the aim of either enlarging the observation bandwidth or reducing the output data rate. The advantages these new acquisition systems will be shown with examples in the field of Internet of Things, distributed measurement systems and diagnostics. In particular, the research activities developed at the Laboratory of Measurement and Signal Processing of the University of Sannio on this topic will be presented, dealing with personal health monitoring, structural health monitoring and diagnostics.

Speaker biography

Luca De Vito received the master's (cum laude) degree in software engineering and the Ph.D. degree in information engineering from the University of Sannio, Benevento, Italy, in 2001 and 2005, respectively. In 2002 he joined the Laboratory of Signal Processing and Measurement Information, University of Sannio, where he was involved in research activities. In 2008, he joined the Department of Engineering, University of Sannio, as an Assistant Professor in electric and electronic measurement. He became Associate Professor in the same Department in Jan. 2020. In Aug. 2018 he received the National Academic Qualification as Full Professor. He is member of the IEEE since 2010, he is member of the IEEE Instrumentation and Measurement Society (IMS), of the IEEE Aerospace and Electronic System Society, and of the IEEE Standards Association. He is Senior Member of the

IEEE since 2012. He is member of the AFCEA and he is Vice-President of the AFCEA Naples Chapter. He is co-Editor-In-Chief of Measurement:Sensors (Elsevier), and Editor of Measurement (Elsevier). He is Member-At-Large of the IMS AdCom for the term 2022-2025 and member of the IMEKO Technical Committee 4 (TC-4). He published more than 220 papers on international journals and conference proceedings, mainly dealing with measurements for telecommunications, data converter testing and biomedical instrumentation.

HOW THE JOINT RESEARCH CENTRE SUPPORTS EU POLICIES WITH PRE-NORMATIVE RESEARCH, AND WHY COOPERATION WITH METROLOGICAL INSTITUTIONS, ACADEMIA AND MEMBER STATES' RESEARCH CENTRES IS WELCOMED

Harald W. Scholz

European Commission, Joint Research Centre, Belgium

Speaker biography

Senior Scientist

Project Leader Smart Energy Solutions and Energy Communities (SMARTEN). SMARTEN runs the European Interoperability Centre for EVs, Smart Homes and Smart Grids, EIC.

European Commission, Joint Research Centre (Directorate General).

Directorate for Energy, Mobility and Climate.

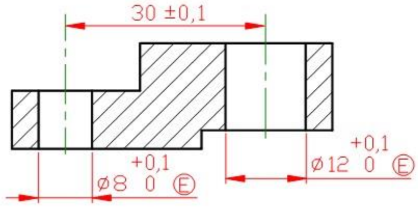
Skills and expertise: Energy Efficiency, Sustainability, Photovoltaic Monitoring, Electromagnetic Compatibility, Interoperability, Renewable Energy Technologies, Vehicle Testing, Electromobility.

WHY DOES A METROLOGIST NEED GEOMETRICAL TOLERANCES ON PRODUCT DESIGN DRAWING?

Zbigniew Humienny

University of Warsaw, Poland

Tolerancing the geometry of products by the specification of dimensions and their limit deviations does not reflect how the parts are assembled and work in an assembly. The ambiguity of tolerancing by applying limit deviations (Fig. 1) to control characteristics other than sizes means that a metrologist may develop several measurement procedures for product verification that may produce different conformity assessment results. Disputes and clashes between design, manufacturing and inspection departments as well as between suppliers and customers are inevitable. A clear unambiguous language of communication between the designer, manufacturing engineer and metrologist should be used to minimise and eliminate discrepancies. For more than twenty years Technical Committee ISO/TC 213 Dimensional and geometrical product specifications and verification has been developing and revising the standards that establish ISO GPS system [1]. This presentation made it clear that geometrical tolerances should be used to determine unambiguously how much the geometry of a manufactured product may deviate from the nominal geometry. The tolerances of orientation, location, run-out and profile of a surface/line require the specification of datum or datum system i.e. the functional geometrical features, to be considered during measurements. The form tolerances applied to geometrical features such as surfaces or holes allow unique indications of permissible flatness and cylindricity deviations, which is impossible with the specification of dimensions and their limit deviations. Another advantage of specifications with the application of geometrical tolerances is that the modifiers can be used to provide comprehensive control over allowable geometrical-dimensional variability. The maximum material requirement is shown whose intended function is to secure the assemblability which depends on the combined effect of size deviation and geometrical deviation. The summary highlights, among other things, new challenges related to the specification of geometrical tolerances in 3D technical product documentation and filtration of the point clouds obtained from measurement using coordinate measuring systems. It is also emphasised that application of geometrical tolerances ensures the quality of products, and eliminates disputes between supplier and customer thus reducing cost and time to the market.



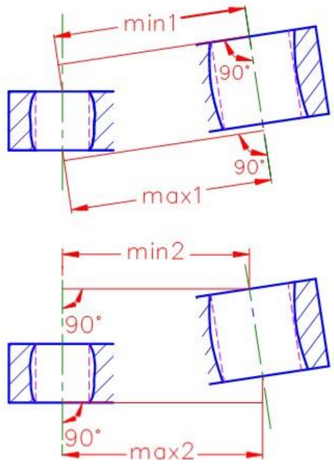


Fig. 1.
Tolerancing using limit deviations (plus/minus tolerancing) does not secure unambiguous verification of the specification.

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Speaker biography

Ph.D. Eng., D.Sc. Zbigniew Humienny works at the Institute of Machine Design Fundamentals at the Faculty of Automotive and Construction Machinery Engineering at Warsaw University of Technology (WUT). He graduated from the Precision Engineering Faculty at WUT and received Ph.D. and D.Sc. degrees at Warsaw University of Technology. His main scientific interests include dimensional tolerancing, geometrical tolerancing and their verification, in particular using coordinate measuring techniques. He is an author or co-author of over 150 scientific papers published in scientific journals and conference proceedings. He led the European project under the Leonardo da Vinci programme, which resulted, inter alia, in the monograph Geometrical product specifications (GPS) – European handbook (Humienny Z. (ed.), Osanna P.H., Tamre M., Weckenmann A., Blunt L., Jakubiec W. et al., WNT 2004). He is co-author of the University textbook Metrology with fundamentals of geometrical product specifications (GPS), for which he wrote the author's chapter Geometrical tolerances and together with Prof. S. Białas and Dr K. Kiszka, prepared the other chapters (2nd edition, Publishing House of the Warsaw University of Technology 2021). He was twice elected Chairman of Technical Committee TC 48 on Machine Design Fundamentals at the Polish Committee for Standardisation, PKN, (from 2018, in the years 2004-2018 he served as a deputy chairman). In 2000 he was nominated as an expert of the Polish Committee for Standardisation in the Technical Committee ISO/TC 213 Dimensional and geometrical product specifications and verification. He has participated in many ISO/TC 213 meetings as the PKN representative and is currently PKN's nominated expert for eleven working groups at Technical Committee ISO/TC 213. In 2010, he was appointed by the President of PKN as a member of the Technical Committee TC 257 on General Metrology to support the work of TC 257 on the metrology of geometrical quantities. He works closely with the automotive, aerospace and defence industries. Since 2006, he has delivered many two-day seminars on geometrical tolerances in both Polish and English for designers, manufacturing engineers and quality staff directly involved in production. He has received fellowships at the University of North Carolina at Charlotte at the Centre for Precision Metrology (USA) and DAAD at the Department of Engineering Design/CAD at the University of Saarland in Saarbruecken (Germany). He is a member of the scientific committees of four international conferences; including CIRP Conference on Computer Aided Tolerancing. Dimensional and geometrical tolerances, in which he is a respected expert, are both his job and his passion.

MEASURING THE INVISIBLE: HARNESSING EXPLAINABLE AI TO REVEAL HIDDEN PATTERNS

Piotr Sobecki

GUM, Poland

The power of AI to detect and quantify what is invisible to the human eye is transforming the fields of metrology, industry, and medical diagnostics. In this keynote, we will explore how AI-driven solutions in prostate cancer diagnosis, IoT-based metrology systems, and advanced CT data analysis uncover hidden patterns in complex radiological assessments and intricate industrial measurements. We will examine the critical role of these innovations in enhancing metrological accuracy, turning previously subjective interpretations into precise, actionable data. Additionally, the keynote will introduce the concept of virtual sensors powered by explainable AI, which provide deeper insights into measurement data, ensuring transparency and trust in AI-driven conclusions. Together, these advancements illustrate how AI is not only broadening the scope of what can be measured but also making these measurements more understandable and reliable for critical decision-making.

Speaker biography

Assistant Professor and Head of the Laboratory of Applied Artificial Intelligence and the Innovation Center for Digital Medicine at the Information Processing Center.

Counselor for Artificial Intelligence-based Metrology Solutions and Head of the Artificial Intelligence Laboratory in the Department of Digital Technologies at the General Office of Measures.

He is involved in the development of methods to assist medicine using artificial intelligence tools. His professional experience includes leading departments, projects and teams as well as working as a software developer and designer. He leads a team focused on collaborating with metrologists to improve processes, overseeing the development of precision Internet applications (e.g., IoT platforms), developing metrology solutions based on artificial intelligence, and creating a strategic vision aligned with organizational goals. He devotes much of his work to exploring the use of artificial intelligence in healthcare, particularly in diagnostics, where he seeks to contribute significantly to advances in digital medicine.

His academic background includes a Ph.D. Eng. in Computer Science, a Master's in Psychology, and an Executive MBA, equipping him with a diverse skill set for innovative problem-solving.

LASER SCANNING IMPLEMENTATION IN THE AUTOMATION OF MEASUREMENT PROCESSES

Dariusz Brzozowski[1*], Mateusz Matuszak[1*]

[1] ITA spółka z ograniczoną odpowiedzialnością Sp. k.

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Laser scanning is one of the methods of data acquisition during the assessment of the conformity of manufactured elements and during reverse engineering.Due to its undoubted advantages, which include: no need for special preparation of details for measurement, resistance to shocks, mobility, laser scanners are becoming increasingly popular in the industry.

During the tutorial, the measurement capabilities of the Creaform MetraSCAN BLACK scanner will be presented. The device was designed with the most demanding users in mind, it sets new standards in the digitization of even very complex objects in production conditions. The system is equipped with a blue laser light source and high-resolution cameras. Thanks to this, the new MetraSCAN ensures almost four times higher scanning speed and higher resolution and measurement precision. The software functions introduced at this time allow for increased efficiency and even more flexible work. The first part of the tutorial will present theoretical information on laser scanning technology. Then, recipients will be able to see what the scanning process looks like from the moment of data collection to the final measurement report, and in the case of reverse engineering to the finally obtained 3D model. The next point will be to present the possibilities of automating optical measurements, for which laser scanners are ideally suited due to the high measurement speed and the possibility of using this technology directly on production lines.

Speakers biography

Dariusz Brzozowski has nearly 20 years of experience in metrology, over 15 years of experience in optical metrology. From the beginning of his career, he has worked with ITA in various positions, which gave him the opportunity to gain not only theoretical, but above all practical knowledge in the field of metrology.

Mateusz Matuszak has over 10 years of experience in 3D scanning technologies in metrology and reverse engineering. Since the beginning of his career, he has been working with ITA implementing 3D laser scanning systems in the Polish market.

AUTOMATION OF COORDINATE MEASUREMENTS IN QUALITY CONTROL

Dominik Szała

ZEISS Industrial quality solutions, POLAND

There is a significant trend in industry to move quality control into the production space and even onto production lines. So what is the motivation and what is the benefit of such integration of metrology in production? The most important reason is that every part produced is measured fully automatically and the results of measurements or inspections can be obtained immediately. With continuous monitoring of the process and real-time transfer of results, production can react quickly if errors occur. Eliminating logistical operations, such as picking parts from production, transporting them to the measurement lab and returning, saves a lot of time

Speaker biography

Product manager responsible at Carl Zeiss for coordinate measurement automation, both in the quality control laboratory and on production lines. He is responsible for selecting the right solution, leading and coordinating projects.

TRAINING PATH FOR COORDINATE METROLOGIST

Robert Sowiński

CARL ZEISS, SP. Z O.O., POLAND

In a dynamically changing environment and high personnel changes, many companies struggle to provide the right level of engineers and technicians. To support customers ZEISS has provided a variety of knowledge transfer solutions, enabling the effective use of measuring systems. In an global world, the standardization of training products is a key aspect – so that the knowledge transferred worldwide is based on the same scope and approach. ZEISS has additionally developed measurement tasks dependent training paths for metrologist – which also include general metrology knowledge (AUKOM courses) and technical drawing training (AUKOM GDT), enabling companies to completely train their measuring system operators. AUKOM licensed training courses (general metrology knowledge at various levels and GDT) are an highly important part of the process. AUKOM is the international association that standardizes knowledge and training in coordinate metrology. AUKOM is also an internationally recognized metrology courses certified by the association.

Speaker biography

Robert Sowiński works at Carl Zeiss sp. z o.o. as Head of Applications Department. He manages a team of more than 20 engineers performing trainings, contract measurements, different types of customer support and demonstrations of CMMs and software. In the last year, the Applications Department has issued over 1,000 certificates to trainees. He managed and participated in projects involving the implementation of complex solutions as well as long-term programming.

He is an expert in geometric measurements on tactile coordinate measuring machines and in the measurement of gears, turbine blades and profiles. He is having experience with aerospace, automotive, mechanical and plastics industry and others. Expert in processing, visualization and analysis of measurement data.

He has defined and implemented ERP and CRM business management systems. Involved in process optimization to ensure maximum team efficiency. He have taken participation in a number of international ZEISS teams on technical, organizational and personnel formation issues. Experience in legal analyses of contracts and confidentiality agreements.

As part of ZEISS' cooperation with the Technical Universities, R. Sowinski organized internships for students as supervisor. He published several articles in the journal Mechanik. He participated in Metrology Conferences as speaker and participant. His first contact with coordinate measuring technology was in 1993 during his studies at the Technical University of Lublin / Faculty of Mechanical Engineering. The subject of his master's thesis was the implementation of an SPC process in one of the local companies.

CAPTURE HIGH QUALITY PROCESS DATA FROM YOUR CNC CONTROLLER

Piotr Orlik

Siemens Sp. z o.o., Digital Industries, RC-PL DI MC MTS, Poland

Machining process optimization is important for all types of production – from single part to serial. When dealing with large, expensive workpieces or expensive materials, such as titanium, correcting machining processes by trial and error can be very expensive. The PC software Analyze MyWorkpiece/ Toolpath makes it possible to visually detect and analyze possible disturbances of the machining process already in work preparation based on G-Code or data generated by a digital twin of the machine. This saves time and material and can be done in parallel to production.

With Analyze MyWorkpiece /Capture for Industrial Edge for Machine Tools the user can select from a wide range of variables – such as axes positions, drive torques, and tool parameters. This enables a very specific and targeted data collection. Moreover, recording jobs can be scheduled either manually or automatically, according to the state of the manufacturing process.

Speaker biography

Piotr Orlik – Graduated in Mechanical Engineering from Wroclaw University of Technology and postgraduated in Automation from Warsaw University of Technology. Continuously involved in machine tool industry for 10 years, gaining experience in various market segments: oil&gas, automotive, mould&die, military, general machining. Worked in Poland as a CNC operator and technologist, then abroad as an implementation & automation engineer until becoming a technical sales consultant for a cutting tool company. Currently involved in dealer support for SINUMERIK CNC machine tools, including coordinating national and international market activities in this field.

POLISH METROLOGICAL UNION

Jerzy Józwik

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Słowa kluczowe: metrologia, Polska Unia Metrologiczna, infrastruktura metrologiczna, promocja, transfer wiedzy.

Polska Unia Metrologiczna (PUM) została powołana z inicjatywy Ministerstwa Edukacji i Nauki. Na podstawie zlecenia Ministra z dnia 30.08.2021r. Politechnika Lubelska zobowiązała się do wykonania zadania pn.: „Utworzenie i koordynowanie działalności Polskiej Unii Metrologicznej (PUM)". Głównym celem jej utworzenia było sieciowanie i pozycjonowanie działań w obszarze polskiej metrologii, wyznaczanie kierunków badań i rozwoju oraz promocja innowacji, wsparcie rozwoju kadr, organizacja forów, konferencji i kongresów. Pierwsza edycja Zadania zaplanowana była na lata 2021-2023. To właśnie w tym czasie do PUM dołączyło 38 jednostek stowarzyszonych.

Nowa edycja programu Polska Unia Metrologiczna zaplanowana na lata 2024-2026 to kontynuacja dotychczasowych kluczowych założeń i nowe projekty odpowiadające potrzebom środowiska. Na podstawie zlecenia Ministra Nauki Politechnika Lubelska zobowiązała się do wykonania zadania pn. „Wzmocnienie i ugruntowanie działalności Polskiej Unii Metrologicznej (PUM) w Polsce" polegającego na zwiększeniu poziomu aktywności uczniów szkół ponadpodstawowych, studentów, towarzystw i stowarzyszeń, otoczenia społeczno-biznesowego i przedsiębiorców w obszarze metrologii.

Zgodnie z założeniami nowego zadania Polska Unia Metrologiczna swoimi działaniami dąży do zwiększenia dostępności do informacji o posiadanym przez jednostki naukowe i możliwym do wykorzystania dla wszystkich grup docelowych zapleczu badawczym poprzez opracowanie i wdrożenie Kiosku Usług Metrologicznych. Jest to forma udostępnienia usług badawczych z wykorzystaniem stworzonej w poprzedniej edycji programu – Bazy Infrastruktury Metrologicznej. BIM będzie stanowiło jądro nowego systemu usług. Dzięki temu Kiosk Usług Metrologicznych będzie oferował najnowszą kluczową infrastrukturę metrologiczną. Budowa Kiosku Usług Metrologicznych pozwoli na efektywny przepływ informacji o posiadanym i możliwym do wykorzystania zapleczu badawczym.

PUM organizuje – na wyraźną prośbę metrologów – dwie międzynarodowe konferencje metrologiczne „New Trends of Metrology" oraz Kongres Gospodarczy „Metrologia Przyszłości". Konferencja będzie nawiązywać do cieszącej się dużym zainteresowaniem konferencji „New Trends in Metrology

2022”. Z kolei kolejny już Kongres Gospodarczy z pewnością przyczyni się do zainicjowania współpracy i promowaniu doktoratów wdrożeniowych, a także stworzy możliwości zdobywania przez doktorantów praktycznego doświadczenia w przedsiębiorstwach przemysłowych, w tym również przy wykorzystania potencjału laboratoryjnego Głównego Urzędu Miar.

Ponadto zaplanowane są minimum trzy edycje Warsztatów Metrologicznych dla młodych pracowników nauki oraz studentów i uczniów szkół ponadpodstawowych z wykorzystaniem infrastruktury metrologicznej Głównego Urzędu Miar oraz laboratoriów wiodących ośrodków naukowych.

Polska Unia Metrologiczna dąży, aby informacje o istotnej roli metrologii dla rozwoju i funkcjonowania współczesnego świata dotarła do jak najszerszego grona odbiorców. W realizacji powyższego celu kluczowa jest obecność przedstawicieli PUM na różnego rodzaju piknikach naukowych, eventach związanych z tematyką metrologiczną oraz współorganizowanie konkursu wiedzy metrologicznej dla uczniów szkół ponadpodstawowych.

PUM przewiduje również organizację mobilnych laboratoriów metrologicznych, które pozwolą na wykorzystywanie narzędzi pomiarowych i zwiększy dostęp do nowoczesnych metod dydaktyczno-badawczych. Mobilne Laboratoria Metrologiczne będą bazowały na walizkowych zestawach pomiarowych, które zostaną wyposażone w sprzęt pomiarowy łatwy do przemieszczania i realizacji pokazów oraz ćwiczeń w szkołach i organizacjach zajmujących się kształceniem młodzieży. Głównym zadaniem Mobilnych Laboratoriów Metrologicznych jest docieranie do szkół ponadpodstawowych i jednostek kształcenia młodzieży o ograniczonym dostępie do aparatury pomiarowej i badawczej (w tym m.in z obszarów wiejskich i małych miasteczek) oraz rozbudzanie wśród młodzieży zainteresowania metrologią, kształtowanie świadomości metrologicznej oraz techniczne ukierunkowywanie dalszego rozwoju edukacyjnego. Planowana jest również współorganizacja konkursów wiedzy o metrologii METROLIGA w szczególnie wiedzy o „metrologii na zielono”.

Podsumowując, wymienione powyżej pięć głównych działań, które zostaną zrealizowane w obecnej edycji Zadania są ambitnymi pomysłami, których realizacja gwarantuje zaistnienie metrologii w świadomości społeczeństwa oraz zapewni lepszą integrację środowiska metrologicznego i ułatwi mu codzienną współpracę.

Referencje

https://pum.pollub.pl/

ENSURING TRACEABILITY IN THE CERTIFICATION OF ISOTOPIC REFERENCE MATERIALS

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Knowledge of the isotopic composition is important for the understanding of many physical and chemical processes occurring in nature. Subtle changes in stable isotope ratios result from the phenomenon of natural isotope fractionation, which is a division of different isotopes of a an element between coexisting phases.

The main problem in measuring isotope composition by multicollector mass spectrometry (MC-ICP-MS) is the necessity to correct for mass discrimination effect and effectively correct matrix effects. Commonly used calibration methods that correct the effect of mass discrimination, such as Sample Standard Bracketing, Optimized Regression Model, and Internal Standard, require a standard of known isotopic compositions. Therefore, the availability of certified isotopic reference materials is crucial for ensuring measurement traceability, comparability of the results, research and development, forensic and legal applications, and the certification of other reference materials.

Ensuring traceability in the certification process of isotopic reference materials is critical for maintaining the integrity and comparability of isotopic measurements across diverse scientific disciplines, including environmental monitoring, nuclear forensics, and geochemical research. This presentation will outline a comprehensive approach to achieving traceability in the certification process, focusing on key elements such as the selection of primary standards, gravimetric isotope mixture preparation, and the implementation of appropriate calibration strategies. These challenges constitute new trends in chemical metrology.

Acknowledgements

The presentation was prepared within MultiBio CRM (Multifunctional Biological Reference Material) and Multifunctional Polish Natural Waters as part of the Polish Metrology project, financed by Ministry of Science and Higher Education.

IDENTIFICATION OF LONG-TERM NEEDS AND DIRECTIONS OF STRATEGIC ACTIVITIES FOR THE DEVELOPMENT OF POLISH METROLOGY

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Keywords: metrology, Polish Metrology, diagnosis of the state of metrology, strategic directions of the development of metrology.

The paper presents a summary of the implementation of the project entitled „Identification of long-term needs and directions of strategic activities for the development of Polish metrology" under the Polish Metrology program. In the face of global trends, it is necessary to develop a coherent strategy that will allow Poland to maintain competitiveness and credibility in the international metrology arena. This action will support the national metrology policy. The lack of such approach may result in marginalization and underinvestment of metrology, translating into the risk of increasing the distance to highly developed countries.

Introduction

Metrology plays a key role in the development of society and economy. Its importance is manifested both in the precise determination of the quantity values and also in ensuring the reliability and repeatability of measurements, which are the foundation of innovation, international trade and health protection. The challenges of the modern world pose new tasks for Polish metrology.

Currently, a long-term and nationwide model forecasting the directions of metrology development does not exist in Poland. There are only local and scattered partial strategies formulated, among others, in short-term action plans of selected institutions.

Project

The identification of long-term needs and directions of strategic activities for the development of Polish metrology was based on the opinion of Experts (scientists), known both in Poland and around the world. Their authority is unquestionable and knowledge related to a given area of metrology – unquestionable. The metrology analysis was carried out for the following fields of metrology:

- chemical metrology – Professor Ewa Bulska, PhD, DSc – University of Warsaw,

- electrical metrology – Professor Janusz Gajda, PhD, DSc (Eng.) – AGH University of Science and Technology in Cracow,
- physical metrology – Professor Grzegorz Budzik, PhD, DSc (Eng.) – Rzeszow University of Technology,
- medical metrology – Professor Gerard Cybulski, PhD, DSc (Eng.) – Warsaw University of Technology,
- optical metrology – Professor Małgorzata Kujawińska, PhD, DSc (Eng.) – Warsaw University of Technology,
- industrial metrology – Professor Michał Wieczorowski, PhD, DSc (Eng.) – Poznan University of Technology,
- geometric quantities metrology – Professor Adam Woźniak, PhD, DSc (Eng.) – Warsaw University of Technology,
- coordinate metrology – Professor Jerzy A. Sładek, PhD, DSc (Eng.) – Cracow University of Technology,
- legal metrology – Paulina Olszewska – Central Office of Measures.

An important contribution to this research was made by the Central Office of Measures. The Polish Metrological Union has also significant role. This unit was represented by Jerzy Józwik, PhD, DSc (Eng.), Associate Professor.

The result of the project is a scientific monograph entitled „Identification of long-term needs and directions of strategic activities for the development of Polish metrology" published by the Lublin University of Technology Publishing House

Conclusions

Metrology should be treated as a strategic element of development policy, supporting the country's prosperity. A nationwide strategy for its development is necessary to ensure the effectiveness and competitiveness of Poland on the international stage and to support innovation in key sectors of the economy. However, it should be emphasized that due to the complexity and wide range of metrology applications, it is impossible to develop a strategy covering all areas. Therefore, the first, pioneering attempt to conduct such analysis was done in this project. Well, it can serve as a starting point for further, more detailed actions, which will lead to the full development and implementation of metrology strategy.

Acknowledgements

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ON THE CHARACTERIZATION OF FREEFORM SURFACES CREATED BY SELECTIVE LASER MELTING – A RE-ENTRANT STORY

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Keywords: additive manufacturing, SLM, re-entrant, freeform, microCT

The purpose of this research is to demonstrate the method which allows the detection and characterization of re-entrant surfaces which are the result of not fully melted particles in laser powder bed fusion technology. The method involves the analysis of freeform surfaces as measured by X-ray micro-computed tomography. The significant presence of re-entrant features makes it questionable to characterize the surface through standard ISO 25178 areal parameters as their definitions do not reflect the freeform nature of analyzed surfaces. This research discusses the effects of technological parameters on the intensity of re-entrant occurrence and on the areal characterizations trying to determine their more convenient definitions.

Introduction

Metal additive manufacturing enables the fabrication of complex surfaces, called freeform [1]. By definition, a freeform is a complex invariant surface where the surface shape has no continuous translational or rotational symmetry about its axes (ISO 17450-1 2011). The geometry of freeform surfaces, which cannot be described by a single universal mathematical formula, strongly influences the functional their performance [2,3]. Conventional surface texture characterizations are only possible if a datum can be established. The measured surface must be locally approximated with a plane or simple form (i.e., cylinder, sphere, ellipsoid, etc.) or observed at a sufficiently larger scale and if the surface texture can be represented as a function, only one height (z) at each location (x,y). Re-entrant features typically have three heights at one location. Conventional characterizations, developed largely for surface textures made by machining and abrasive processes, do not perform well on complex, additively manufactured (AM) surfaces with re-entrant features on these complex surfaces.

Re-entrant features cannot be measured with conventional optical and stylus methods.

Materials and methods

The subjects of this study were 20 laser melted parts made of titanium-based powder – 6AL-4V ELI-A GRADE 23 which particle size varied between 15 µm and 45 µm. The geometry of the part was a quarter cylinder of radius equal to 5 mm and height 25 mm. To achieve high-resolution measurements by X-ray computed tomography (microCT), the thickness of the parts was relatively low to achieve good penetration of radiation and low noise. The 3D printer used for this study was EOS M290 (EOS GmbH Electro Optical Systems, Krailling, Germany). Two process parameters, laser power and scanning speed, were modified to achieve a high variety of surface topographies. The laser power was set between 107 and 267 W, with an increase of 40 W, and the scanning speed varied between 250 mm/s and 1000 mm/s (an increment of 250 mm/s). In total, 20 groups of individual parameters were considered. All other process parameters were set to default following the software recommendation for the given geometry and materials. The surface topography of parts created with laser powder-bed fusion was measured with microCT scanner (General Electric v|tome|x s240). We achieved voxel size of 5.5 µm. The scanned geometries were then cut into smaller regions of approx. 0.75×0.7 mm and subjected the developed algorithm which detected the re-entrant features based on the projection area of individual triangles on the form. Surfaces with large portion of re-entrant features were then characterized with standard and non-standard areal parameters.

Results

Exemplary results indicating the detected regions with re-entrant features is shown in figure 1. It was noted that for analyzed surfaces the intensity of re-entrants occurrence is high and usually above 10%. Laser power strongly contributed to the intensity of this phenomenon. The surfaces were characterized with ISO 25178 parameters including their newly proposed freeform definitions. Significant differences between the calculated values were noted. The correlations between analyzed parameters were different depending on the parameter definition. This is briefly summarized in correlation matrix (fig. 2).

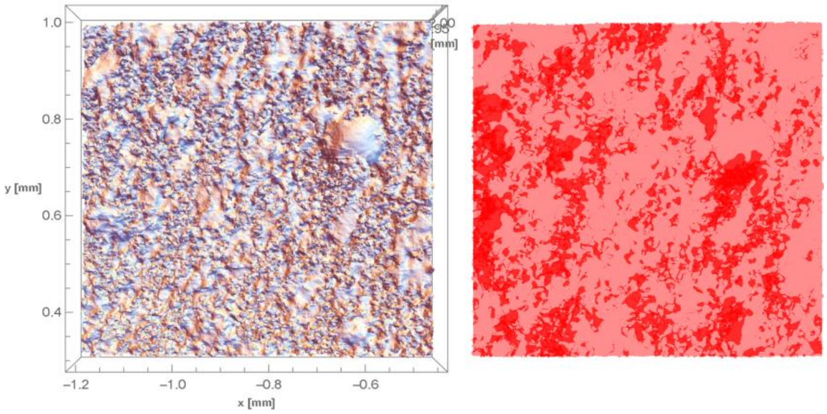
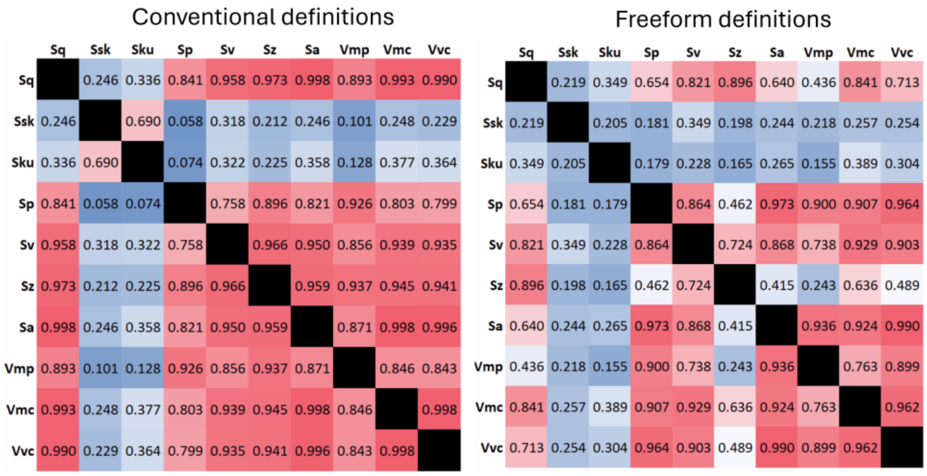


Fig. 1. *The exemplary geometry (left) and detected regions with re-entrant features colored with intensive red (right)*



Conventional definitions

	Sq	Ssk	Sku	Sp	Sv	Sz	Sa	Vmp	Vmc	Vvc
Sq		0.246	0.336	0.841	0.958	0.973	0.998	0.893	0.993	0.990
Ssk	0.246		0.690	0.058	0.318	0.212	0.246	0.101	0.248	0.229
Sku	0.336	0.690		0.074	0.322	0.225	0.358	0.128	0.377	0.364
Sp	0.841	0.058	0.074		0.758	0.896	0.821	0.926	0.803	0.799
Sv	0.958	0.318	0.322	0.758		0.966	0.950	0.856	0.939	0.935
Sz	0.973	0.212	0.225	0.896	0.966		0.959	0.937	0.945	0.941
Sa	0.998	0.246	0.358	0.821	0.950	0.959		0.871	0.998	0.996
Vmp	0.893	0.101	0.128	0.926	0.856	0.937	0.871		0.846	0.843
Vmc	0.993	0.248	0.377	0.803	0.939	0.945	0.998	0.846		0.998
Vvc	0.990	0.229	0.364	0.799	0.935	0.941	0.996	0.843	0.998	

Freeform definitions

	Sq	Ssk	Sku	Sp	Sv	Sz	Sa	Vmp	Vmc	Vvc
Sq		0.219	0.349	0.654	0.821	0.896	0.640	0.436	0.841	0.713
Ssk	0.219		0.205	0.181	0.349	0.198	0.244	0.218	0.257	0.254
Sku	0.349	0.205		0.179	0.228	0.165	0.265	0.155	0.389	0.304
Sp	0.654	0.181	0.179		0.864	0.462	0.973	0.900	0.907	0.964
Sv	0.821	0.349	0.228	0.864		0.724	0.868	0.738	0.929	0.903
Sz	0.896	0.198	0.165	0.462	0.724		0.415	0.243	0.636	0.489
Sa	0.640	0.244	0.265	0.973	0.868	0.415		0.936	0.924	0.990
Vmp	0.436	0.218	0.155	0.900	0.738	0.243	0.936		0.763	0.899
Vmc	0.841	0.257	0.389	0.907	0.929	0.636	0.924	0.763		0.962
Vvc	0.713	0.254	0.304	0.964	0.903	0.489	0.990	0.899	0.962	

Fig. 2. *Correlation matrix between analyzed parameters for their conventional (left) versus freeform (right) definitions*

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FABRICATION AND CHARACTERIZATION OF NANOSTRUCTURES FOR CALIBRATION OF SCANNING PROBE MICROSCOPES – COMPENDIUM

Janusz D. Fidelus[1]

[1] Zakład Czasu i Długości, GUM, w imieniu realizatorów projektu NANO/STM/AFM (numer rej. PM-II/SP/0044/2024/02)

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Słowa kluczowe: mikroskopia z sondą skanującą, SPM, AFM, STM, nanotechnologia, niepewność pomiarowa, kalibracja, wzorzec kalibracyjny.

W Polsce rośnie liczba laboratoriów używających nowoczesnych mikroskopów z sondą skanującą do badań przemysłowych, jednak większość tych urządzeń nie jest kalibrowana. Projekt ma na celu wytworzenie nanostruktur do kalibracji mikroskopów AFM/STM oraz opracowanie procedur kalibracji. W projekcie wykorzystane zostaną zaawansowane technologie do produkcji nanostruktur oraz specjalistyczna aparatura naukowa do pomiarów i kalibracji mikroskopów z sondą skanującą.

Wprowadzenie

Obecnie w Polsce coraz więcej laboratoriów badawczo-rozwojowych wyposażonych jest w nowoczesne mikroskopy z sondą skanującą i wykonują badania dla przemysłu. W kolejnych latach spodziewany jest dalszy wzrost liczby tego typu urządzeń ze względu na szybki rozwój nanotechnologii. Nieliczne z nich są poddawane rygorystycznym procedurom kalibracyjnym, co może wynikać z kosztów wzorców kalibracyjnych, braku odpowiednich procedur dotyczących kalibracji oraz skomplikowaniem pomiarów wykonywanych z wykorzystaniem mikroskopów ze skanującą sondą.

Celem projektu jest wytworzenie nanostruktur do kalibracji mikroskopów z sondą skanującą oraz opracowanie procedur kalibracji mikroskopów AFM i STM z wykorzystaniem dostępnych wzorców (w tym naturalnych), oraz wytworzonych w projekcie.

Projekt realizowany jest przez konsorcjum w którego skład wchodzą: Instytut Fizyki UJK w Kielcach jako koordynator projektu, Łukasiewicz IMIF oraz Instytut Nauk Chemicznych UMCS.

Zadania projektowe obejmują m.in. badania nano i sub-nanometrowych struktur, opracowanie nanostruktur do kalibracji mikroskopów z niepewnością mniejszą niż 0,5 nm oraz charakterystykę wytworzonych nanostruktur. Łukasiewicz-IMIF wytworzy nanostruktury, a instytuty naukowe użyją zaawansowanej aparatury naukowej do ich zbadania.

Realizacja projektu przyczyni się do uzyskania kompetencji w wytwarzaniu wzorców kalibracyjnych i wykonywaniu precyzyjnych pomiarów STM/AFM. Projekt uwzględnia współpracę z Zakładem Czasu i Długości GUM, który uzyska doświadczenie w optymalizacji stanowisk pomiarowych w nanoskali.

W ramach projektu powstanie specjalne stanowisko do weryfikacji nowych wzorców oraz innych, co przyczyni się do rozwoju metrologii w Polsce. Ostatecznie, projekt ma na celu zwiększenie zdolności pomiarowej kraju i komercjalizację opracowanych procedur i wzorców.

Podziękowania

Projekt dofinansowany ze środków budżetu państwa, przyznanych przez Ministra Edukacji i Nauki w ramach programu Polska Metrologia II (numer rej. PM-II/SP/0044/2024/02).

CHALLENGES IN FAST DYNAMIC LABORATORY TESTING

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The main goal of this presentation is to present the main challenges and difficulties that arise while testing materials and structures subjected to dynamic loads. The presentation will consider various tests and configurations used to test both the dynamic behavior of materials and the dynamic behavior of larger structures or structural elements. The examples will show which parameters are crucial for achieving high deformation rates during testing.

Acknowledgments

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UKRAINIAN ACADEMY OF METROLOGY STRUCTURE AND ACTIVITIES

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The metrology community of Ukraine includes research and academic staff of technical universities, representatives of the National Metrology Service, and employees of metrology departments of enterprises and organizations. Interaction and cooperation between them are the basis for developing metrology in Ukraine. Therefore, in 2016, the metrological community established the public organization Ukrainian Academy of Metrology (UAM) [1]. The goals of UAM are:

- supporting the creative, economic, scientific, and cultural interests of metrology scientists,
- promoting the development of metrology in Ukraine,
- forming scientific and technical programs and promoting the development of the latest technologies in the field of metrology.

The main tasks of UAM:

- expanding cooperation in the field of metrology and standardization with state authorities, local governments, public organizations, enterprises, organizations and higher education institutions;
- support for the free exchange of experience, knowledge and information between specialists in the field of metrology;
- improving the professional skills of UAM members.

UAM operates in the following main areas:

- analysis of the state, trends and prospects of metrology development;
- implementation of fundamental and applied metrology research;
- effective application of metrology achievements in various fields of science, production and economy, in accordance with the state policy of Ukraine;
- protecting society from unreliable measurement results;
- creation of information banks of scientific data on metrology;
- conducting public discussions and nominating outstanding works in the field of metrology for the State Prizes;
- participation in competitions for talented specialists and teams to solve important research and production, sectoral and inter-sectoral tasks;
- holding scientific conferences in the field of metrology;

- international cooperation relations with scientific and other institutions abroad in the field of metrology, participation in international scientific conferences;
- assessing the competence of laboratories at the request of enterprises.

Today, 68 persons are members of UAM - research and academic staff of technical universities, representatives of the Ukrainian Academy of Metrology, and employees of metrology departments of enterprises and organizations. Among them are 12% of young scientists, and UAM correspondent members. The President of UAM is Professor, Doctor of Technical Sciences Yevhen Volodarski (National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, Department of Information and Measurement Technologies). The Vice-Presidents are Yuriy Kuzmenko (State Enterprise "Ukrmetrteststandard", Deputy General Director for metrology, assessment of conformity of measuring equipment and scientific activity) and prof. Nataliya Hots (Lviv Polytechnic National University, Department of Information and Measurement Technologies). The highest governing body of the Organization is the General Meeting of its members. The UAM's organizational structure includes the following structural units:

- Department of legal metrology;
- Department of Metrology in Medicine and Pharmacology;
- Youth section;
- Department of qualimetry;
- Institutes of the Ukrainian Academy of Metrology - Institute for Advanced Training and Retraining of Metrology Specialists and Educational and Research Institute “Education in the field of measurement and instrumentation”.

Since 2016, UAM together with the Kharkiv National University of Radio Electronics, All-Ukrainian State Scientific and Production Center for Standardization, Metrology, Certification, and Consumer Protection "SE Ukrmetrteststandard" LLC Production and Commercial Firm "FAVOR, LTD” publishes the scientific journal "Metrology and Instruments" The journal is included in the "List of scientific professional publications of Ukraine, and in the international scientometric database Index Copernicus ISSN 2307-2180. The magazine is published in the field of technical sciences, specialty – 152 "Metrology and information and measuring equipment". Since 2020, UAM together with "Ukrmetrteststandard" and the National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute" are co-founders of the scientific and technical journal "Measurement Infrastructure". Topics of the magazine:

- methods and means of metrological support of production;
- accreditation, verification, calibration;
- metrological certification and expertise;

- development of new and improvement of existing measuring instruments;
- practical recommendations for the operation and repair of devices;
- the reference base;
- ensuring the unity, reliability and required accuracy of measurements;
- state and control tests;
- register of measuring instruments and standard samples;
- metrological centers and services;
- experience in improving the efficiency of calibration work;
- legislative and regulatory frameworks;
- current state, trends and prospects for the development of metrology.

Starting from 2016, UAM annually holds the Conference of Young Scientists in the field of metrology "Technical use of measurement".

Fig. 1. *Conference of Young Scientists in the field of metrology "Technical use of measurement" (2020)*

UAM represents Ukraine in the international organization IMEKO. IMEKO is a non-governmental confederation established in 1958, which today unites national organizations, and scientific and engineering communities from more than 40 countries of the world whose activities are aimed at developing technologies and ensuring the uniformity of measurements. Members of the Academy of Metrology participate in the following IMEKO Technical Committees:

TC1 - Education and Training in Measurement and Instrumentation;
TC3 - Measurement of Force, Mass and Torque;
TC4 - Measurement of Electrical Quantities;
TC7 - Measurement Science;
TC8 - Traceability in Metrology;
TC9 - Flow Measurement;
TC10 - Technical Diagnostics;
TC12 - Temperature and Thermal Measurements;

TC13 - Measurements in Biology and Medicine;
TC20 - Measurements of Energy and Related Quantities;
TC22 - Vibration Measurement;
TC24 - Chemical Measurements.

The interaction and cooperation of members of the Ukrainian Academy of Metrology community is the basis for the development of metrology in Ukraine.

Reference

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THE INFLUENCE OF THE OBJECT MATTING PROCESS AT VARIOUS AIR COMPRESSION VALUES ON THE ACCURACY OF COORDINATE OPTICAL MEASUREMENT

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Keywords: optical coordinate measurement, matting process, spray, measurement accuracy, point cloud.

Several tests were carried out in the Laboratory of Coordinate Metrology aimed at finding the relationship between the matting method of the measured object and the accuracy of the optical coordinate measurement. This article presents the results of measurements with the Zeiss O-Inspect multi-sensor coordinate machine of a matted object using an AESUB Yellow Airbrush at various air compression values. The research confirmed that the method of whitening objects is not completely neutral in the context of the obtained measurement results. It is necessary to continue considerations to provide the operator with practical tips in this area.

Introduction

Coordinate optical measurement of transparent or highly reflective elements is problematic without proper object preparation. Therefore, various works are being carried out to counter these difficulties [1,2,3]. To enable the measurement of such objects, it is necessary to cover the surface of the measured object with a matting layer. In the context of the work carried out so far in the Laboratory od Coordinate Metrology [4,5], the results of which confirmed the positive effect of the use of preparations, it was shown that the accuracy of coordinate optical measurement is, to some extent, dependent on the selected preparation for 3D scanning and the adopted matting strategy, as they affect the thickness and uniformity of the resulting coating.

Researches

The tests used AESUB Yellow a self-volatilizing scanning spray liquid, which was applied at various air compression values in the range of 1-8 bar. Layer thicknesses were measured on a ZEISS O-Inspect multi-sensor coordinate measuring system with Calypso software. This research was funded by the National Science Centre, Poland, grant number 2023/07/X/ST8/00845.

Fig. 1. *Non-contact measurement with a white light sensor, Airbrush and matted gauge blocks*

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METROLOGICAL CHALLENGES OF MEASURING THERMOMECHANICAL EFFECTS ON THE SURFACE LAYER CONDITION IN THE MACHINING OF LIGHT AIRCRAFT ALLOYS

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Keywords: metrologia warstwy wierzchniej, topografia powierzchni, mikrostruktura, stopy lotnicze, obróbka skrawaniem.

The production of parts used in aviation is associated with the need to manufacture them with appropriate design requirements. The requirements of the technological surface layer are subject to internal quality standards established by the recipients of the parts. The subject of the research was the analysis of measurements of the condition of the surface layer of elements after mechanical processing for the purpose of conducting experimental studies in the field of determining the influence of thermo-mechanical interactions in the processes of turning and milling of aluminium, magnesium, and titanium alloys. The subject was analyzed and the main challenges in the field of metrology of the surface layer were identified.

Introduction

Advanced material measurements in the field of tool wear and the condition of the surface layer formed in the subtractive machining process should strictly take into account the knowledge of thermomechanical interactions resulting from the properties of the cut material, the cutting tool, cutting parameters, and cutting conditions (e.g. dry machining, cutting in MQL conditions or HPC cooling) [1-3].

The standard approach to the analysis of the cutting process is to determine the effect of cutting parameters and other technological variables (cutting tool geometry, cutting conditions, machined material, blade material, etc.) on machinability indicators. In the case of aircraft parts, and especially critical elements responsible for flight safety, in addition to meeting the design requirements in terms of dimensional and shape accuracy and machined surface quality, it is also necessary to determine the impact of the cutting process on unmachined zones. Such a comprehensive view of research requires a systematic approach to measurements along with the construction of procedures facilitating the comparison of results. The aim of the research was to analyze the main metrological challenges in the field of measuring thermo-mechanical effects on the condition of the surface layer in the machining of light aircraft alloys in terms of the possibility of developing appropriate measurement procedures.

Materials and methods

The research analysed measurements of thermomechanical interactions in the scope of advanced measurements of cutting force components with multipoint and multiaxis vibration measurements in order to optimise cutting parameters in relation to the dynamic system machine-holder-workpiece-tool and temperature measurements in the cutting zone using a natural thermocouple (material pair tool-workpiece) and thermovision measurements - particularly important in the case of machining of materials susceptible to self-ignition (magnesium and titanium alloys). In relation to the metrology of the surface layer, measurements of roughness parameters and surface topography were analyzed taking into account advanced material measurements including changes in the morphology of the microstructure of the surface layer, strengthening in the surface layer and residual stresses after machining.

Analysis of metrological challenges

Aircraft parts, responsible for flight safety, must meet requirements both in terms of geometry and dimensional accuracy, but also in terms of the technological condition of the surface layer (Fig. 1). This layer is defined by the external surface that determines the shape of the workpiece after machining and the depth of impact of mechanical processing on unprocessed zones [4, 5]. The technological surface layer of the object is characterised by a specific surface topography and zones of thermo-mechanical interactions that result from the cutting process [6]:

- near-surface zone – adjacent to the surface of the object, which is characterised by the presence of chemical compounds in its microstructure resulting from cutting under specific conditions (cutting tool, parameters, cooling method, etc.),
- orientation zone as a result of plastic deformation, a plastically deformed part of the technological surface layer, characterised by the orientation of the grains of the processed material; thermal impact zone, where microstructural changes occur as a result of thermal processes (e.g. recrystallisation and grain growth, phase transformation, chemical reactions). This creates metrological challenges in terms of surface layer measurements.

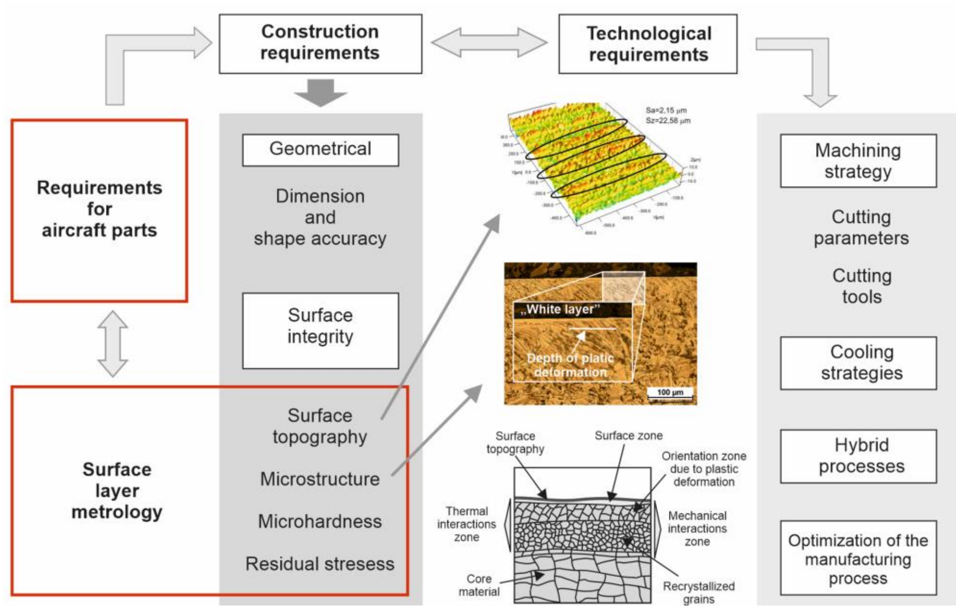

Fig. 1. *The structure and relationships occurring in the metrology of the surface layer of aircraft alloys after machining*

Conclusions

Among the main metrological challenges in the area of technological measurements of the surface layer after processing of light aircraft alloys are appropriate metrological procedures for establishing a conventional measure in the field of material tests (e.g. changes in the morphology of the microstructure of the surface layer), identifying the size of thermomechanical interactions. This will allow for the development of tools for comparing the condition of the surface layer and quantification of selected assessment indicators.

Acknowledgments

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MULTISTATE MENISCUS-REMOVAL ALGORITHMS FOR BROADBAND MICROWAVE DIELECTRIC-PERMITTIVITY MEASUREMENT OF LIQUIDS

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Keywords: accurate microwave measurements, dielectric spectroscopy, complex dielectric permittivity, liquid characterization, meniscus, scattering parameters, vector network analyzer.

In this paper, we report on new algorithms and fixtures for broadband dielectric-permittivity measurement of liquids developed at the Institute of Electronic Systems (ISE), Warsaw University of Technology. Liquid under test is measured in semi-open vertically oriented test fixtures in a frequency band from 0.1 GHz to 50 GHz. A significant part of this work has been done in the framework of a project with the Central Office of Measures, Poland, under the "Polish Metrology" program, involving the delivery of a setup for permittivity measurements.

Introduction

Knowledge of the complex dielectric permittivity of liquids is required in many fields of science, industry, and technology [1] such as: civil engineering, biology, chemistry, agriculture, geophysics, medicine, radio communications, remote sensing, etc. At microwave frequencies, the dielectric permittivity is typically extracted from the data acquired with the vector network analyzers (VNA) measuring scattering parameters of liquid samples put into a special test fixture.

In the microwave band, the most useful and accurate methods can be divided into resonant and broadband [2]. Resonant methods have been proven to deliver excellent accuracy, especially for low-loss materials, but deliver the permittivity at discrete frequencies only. Broadband methods, which are the subject of our work, can be divided into one-port (reflection only) and transmission/reflection (T/R) methods. One of the most classic and widely used algorithms for T/R measurements is the Nicolson-Ross-Weir method [3] which was originally introduced for characterizing properties of isotropic, homogeneous solid-state materials.

The fixtures for T/R methods applied for liquid permittivity measurement can be either closed with two dielectric plugs or be semi-open with only one plug allowing for variable volumes of the liquid. Semi-open cells are more versatile, allowing for multistate measurements and adjusting the volume of a liquid sample according to its attenuation or phase shift introduced. However, the permittivity characterization requires knowledge of the sample height and may be deteriorated by errors if the upper surface of the liquid sample diverges from a flat and transversal plane due to the meniscus effect.

The meniscus causes the measured sample to be asymmetrical, making its accurate modeling very difficult. Studies on the influence of the meniscus on the accuracy of permittivity determination and measurement methods involving the removal of the meniscus have become our topic of interest at the Institute of Electronic Systems (ISE) since 2017. A significant part of the work in this field constituted a project with the Central Office of Measures, Poland, under the "Polish Metrology" program, involving the delivery of a setup for permittivity measurements.

In this report, we want to briefly introduce new algorithms and fixtures for broadband liquid permittivity measurements developed at the ISE. We also compare the results of the permittivity obtained with one of the meniscus-removal methods and the classic NRW algorithm for different liquids.

Novel measurement techniques

Novel algorithms for meniscus-removal methods are based on the multistate measurements of the liquid under test (LUT). We measure the two-port scattering (S) parameters of: the empty fixture (not required in some methods, Fig. 1a) and several volumes of the LUT (Fig. 1b). Under the assumption that the top shape of the liquid remains the same during the measurement, we can eliminate its impact with various mathematical methods, depending on the complexity of the measurement model.

As the volume of the liquid is variable, the heights of the liquid columns, required for permittivity calculation, should be determined. Advanced automatic methods can extract this information from electrical measurements, however, the model of such measurements is more complicated. Among the measurement methods, those that do not require VNA calibration are particularly valuable and have been the subject of our newest research. The summary of the developed methods is presented in Tab. 1.

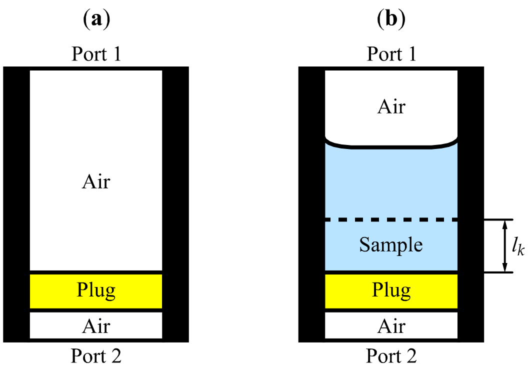

Fig. 1. *Sketch of the semi-open (waveguide) fixture. (a) The empty cell; (b) k-th measurement state of liquid under test (k = 0, 1, ...)*

Tab. 1. *Multistate methods for liquid permittivity measurement in semi-open fixtures with meniscus-removal developed at the ISE*

Publications/ status	**Need for VNA calibration**	**Mechanical sample-length determination**	**Measurement states**
[4–7]	Yes	No	Empty cell, two volumes of liquid
[8]	No	Yes	Three volumes of liquid
Under preparation	No	No	Five volumes of liquid

Measurement fixtures

We have developed several semi-open test fixtures for liquid permittivity measurement operating up to 50 GHz in coaxial and rectangular waveguide standards, as presented in Tab. 2. Each cell is equipped with one dielectric plug from polytetrafluoroethylene (PTFE) holding the liquid sample. The inlet at the bottom of the cell allows dosing of the liquid without disassembly of the cell, therefore eliminating the errors due to the nonrepeatability of contacts. Excess air flows out through a small hole at the top of the fixture. The influence of the inlets on permittivity errors was investigated with electromagnetic simulations, presented in [9], delivering valuable tips for manufacturing the fixtures [6], with an example presented in Fig. 2.

Fig. 2. *A semi-open rectangular waveguide fixture for liquid permittivity measurements in WR22 standard (Q-band, 33-50 GHz) with a liquid dosing appliance*

Tab. 2. *A list of different types of test fixtures developed at the ISE*

Type	Standard	Bandwidth	Publications/status
Coaxial	7 mm	Up to 18 GHz	[4, 5, 7, 8]
Coaxial	2.92 mm	Up to 40 GHz	Ready for tests
Waveguide	WR42	18-26.5 GHz	Ready for tests
Waveguide	WR28	26.5-40 GHz	Ready for tests
Waveguide	WR22	33-50 GHz	[6, 9]

Measurement results

In this section, we present the permittivity results in the 33-50 GHz frequency range (Q-band) for distilled water, propan-2-ol (IPA), and 50% aqueous solution of IPA. The methods used are: the calibration-dependent meniscus-removal method (MR) [6], which requires two volumes of liquid; and the NRW method [3], which uses only one volume and, therefore can deliver two permittivity results.

The results in Fig. 3 show that, depending on the type of liquid, the differences between the classical NRW method, which does not take the meniscus into account, and the method with meniscus removal (MR) can be very large. In the case of neglecting the meniscus effect during the liquid permittivity measurements in semi-open cells, its influence on the permittivity results depends: on the type of liquid – the higher the permittivity, the greater the errors; on the volume of the liquid – the smaller the volume, the greater the influence of the meniscus; on the measurement frequency – higher frequencies mean greater errors due to the shorter wavelength (the meniscus becomes a greater disturbance of the geometry). At higher frequencies, smaller dimensions of the test fixture should be used which also causes higher errors in the permittivity. In this case (Fig. 3), for high-permittivity water, the classic NRW method delivers severely disturbed data, while for low-permittivity IPA the meniscus effect seems to be negligible.

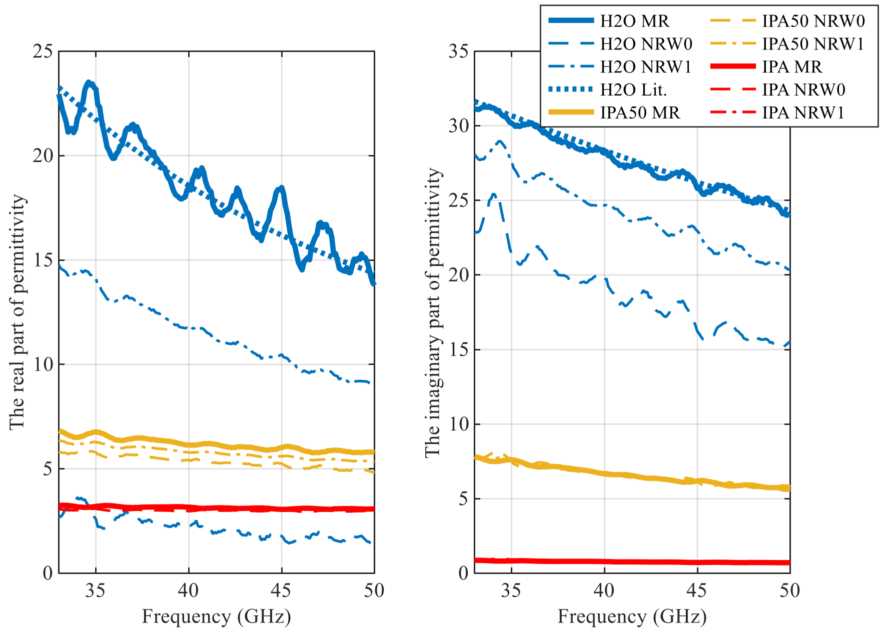

Fig. 3. *The relative complex permittivity at 24 ºC obtained for the meniscus-removal method (MR, solid lines) and Nicolson-Ross-Weir method (NRW0, dashed-dotted lines for lower; and NRW1, dashed lines, for higher level of the sample) for distilled water (blue lines), 50% aqueous solution of IPA (yellow lines) and IPA (red lines). Blue dotted lines represent literature data for water from* [10]

Conclusions

We have briefly presented the novel methods and fixtures for liquid permittivity measurements in microwave bands in semi-open test fixtures developed at the ISE. We showed the influence of the meniscus effect on permittivity occurring in such cell types in the measurements in the 33-50 GHz band.

The general conclusion is that the accuracy of the permittivity determination may heavily depend on methods applied to its extraction, test cell design and its size. Depending on the frequency range of measurements, liquid permittivity and volume of the sample, the errors resulting from the meniscus shaping the top surface of the LUT can be significant or negligible.

Acknowledgments

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MULTIWAVELENGTH APPROACH TO STEP HEIGHT STANDARDS

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Keywords: interferometry, variable wavelength interferometry, multiwavelength interferometer, retarder, waveplate, refractive index, Wollaston prism, thickness standard, step height standard, metrology.

The paper is focused at measuring the thickness of step height standards using a new variable wavelength interferometer (VAWI). The illumination system consists of a white LED with a monochromator, and it generates a light beam in the visible and near-infrared range. The fringe field is formed by combining two dedicated birefringent Wollaston prisms mounted in a classical microscope with the Köhler illumination system. The system constructed in this way is potentially suitable for measurements either in transmitted or reflected-light modes. Thanks to the sequential analysis of the distribution of fringes in the recorded images, the device allows the user to characterize optical or geometrical features of samples. The leading theme in this paper is the use of the system to measure the surface geometry of step height standards in reflected light mode.

Introduction and basic description

The metrology of small objects' geometries and their photonic properties is a challenging aim for interferometry. In this presentation we focus on the variable wavelength interferometry (VAWI) [1-4]. In this technique the illumination system forms the light beam, wavelength of which can be continuously scanned over the whole visible spectrum. The continuous characteristic of the source offers simultaneously high accuracy and long measurement range, which constitutes the most important feature of the instrument. The interferometer has the ability to measure directional refractive indexes and birefringence [5-7]. The new version of the system has been modified to measure nanometre step height standards. When the object under study is positioned in the empty fringe-field and the wavelength of the light source is modified, the interfringe distance changes accordingly. The measurement process can proceed in two directions: from the long waves to short or the other way round. Interestingly, the early systems could work without computer support [1-5]. The originator used to observe the coincidence and anticoincidence patterns in the fringe field in the object and surrounding media. When the fringes in the object and the empty fringe field created continuous lines the phase shift could be defined as equal to 2π. The time of measurements was long and therefore not suitable for more practical applications. In this paper, we present a computerized system, which is based on different concept though it continues the leading line of research, i.e. continuously altered wavelength. The instrument is suitable for both transmitted and reflected-light modes and allows the user to measure optical and geometrical parameters of phase or reflective structures. This paper focuses on the reflected-light mode set-up and measurement of waveplates [8-11] and step height standards. The low uncertainty of the optical path difference is obtained by the continuous character of the light source and constitutes a key element of the system. In contrast to some previous presentations on the VAWI this paper deals with a collection of more precise algorithms for the fringe image processing. The complementary description of the system can be found in the cited literature [12].

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MEASUREMENT OF THE PROPERTIES OF THE BLAST WAVE GENERATED BY VARIOUS EXPLOSIVE

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Keywords: explosive, blast wave, Heksoflen, Amonal, pressure, impulse, detonation velocity, high-speed camera.

Explosives are a group of special purpose materials, which are widely used in various branches of industry. Interest in this type of materials has increased recently, especially due to the current geopolitical situation. Explosives are often used against military staff, as well as against citizens or critical infrastructure. Therefore, there is a need to investigate the threat related to the detonation of various explosives. In the manuscript, a new experimental set-up, consisting of detonation velocity probes, pressure sensors and a high-speed camera, is presented. Characterization of the blast wave generated by Amonal and Heksoflen charges has also been presented. The conducted research has shown that the presented experimental set-up allows comprehensively measuring important characteristics related to the detonation of the explosive. Video recorded by the high-speed camera also allows analyzing the detonation and combustion of the explosive in detail.

Introduction

An explosive is a material which, when suitably triggered, releases a large amount of heat and pressure by way of a very rapid self-sustaining exothermic decomposition reaction [1]. Explosives are a group of special purpose materials, which are used in various branches of industry around the world [2-5]. Unfortunately, due to the properties of explosives, they are also used in improvised explosive device (IED) [6,7]. IEDs are a significant threat against critical infrastructure, military staff and civilians [8, 9]. On the market, a great variety of explosives exists, but new explosives are being constantly developed, exhibiting improved properties in comparison to currently used explosives [10-12]. Because of the threat related to the use of explosives, researchers are interested in the impact of detonation on the surrounding area [13-15]. Such research is a great challenge due to the need to ensure the safety of research staff, mitigate the possibility of damaging the measurement system and the technical requirements related to high sampling frequency and large measurement range of the used equipment. Therefore, the development of the new measurement equipment is sometimes required to perform tests and obtain high-quality research data [16].

In the manuscript, we propose an experimental setup for investigating blast wave properties. The proposed setup was used to investigate the parameters of blast waves generated by various explosives.

Materials and methods

During research, two kinds of explosive charges were investigated. First type of the used explosive is Amonal mixed with addition of Al powder. Second type of the used explosive is Heksoflen. Both types of prepared charges were initiated by the A-IX-1 booster placed at the end of the each prepared charge. Moreover, four probes dedicated to the detonation velocity measurement were placed inside of each charge. Prepared charges were suspended vertically, 1m above ground level.

Prepared charges were detonated at the experimental setup, equipped with three pressure sensors placed 2 m, 2,5 m and 3 m from the charge. Detonation of each charge was also recorded with speed of 2600 FPS by Phantom v9.1 high-speed camera placed ca. 50m from the charge.

Results

Performed research indicates big differences between the tested explosive charges. The combustion area of the Amonal charges is rather small. The gases, mixed with solid combustion residues and Al powder, start to be released from the combustion area a short time after the detonation. Released gases cover the combustion area and the area close to the tested charge in a very short time. Released gases with solid residues remain in the detonation area for a long time after detonation. Detonation of Heksoflen charges is noticeably different in comparison to the Amonal charges. The combustion area after the detonation is much larger and remain around the charge in longer time. After some time, the combustion area starts to decrease and float higher and higher above the ground level. Exemplary images of the Amonal and Heksoflen charges explosion recorded with use on high-speed camera are presented in Figure 1.

a) b)

Fig. 1. *Explosion of the tested charges: a) Amonal, b) Heksoflen*

The average velocity detonation measured by probes, placed inside of each charge, is ca. 2.5 times higher in case of the Heksoflen charges in comparison to the Amonal charges. Both the maximum pressure measured by the pressure sensor located 2 m from the detonated charges are ca. 2 times higher in the case of Heksoflen charges than in the case of Amonal charges. In the case of all tested charges, both the maximum pressure and impulse decrease with increasing distance from the detonated charge.

Conclusions

Conducted research indicates that the presented experimental setup provides a wide range of research data about the energetic performance of explosive charges. Data such as detonation velocity, pressure and impulse can be used to characterize the blast wave generated by various explosives. Additionally, the explosion and combustion process of the explosive could be described step by step because of the videos recorded by high-speed camera. Approach based on the use of various sensors with connection to the high-speed camera allows obtaining much more data from a single experiment.

Conducted research indicate that, the properties of the blast wave and the combustion process highly depends from the used explosive. Measured detonation velocity, maximum pressure and impulse are higher in case of the Heksoflen charges in compare to the Amonal charges. The maximum pressure and impulse decrease with increasing distance from the detonated charge in all analyzed cases.

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CONSTRUCTION OF BLIND SIGNAL PROCESSING ALGORITHMS BASED ON THE GEOMETRIC STRUCTURE OF INFORMATION

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Keywords: blind source separation, independent component analysis, convolutional neural networks, fault diagnosis.

Scientific aim of the project

The aim of the research is to create of algorithms for blind signal processing based on geometric information structures, optimal from the point of view of technical diagnostics. Achieving this aim will enable the construction of expert system diagnosing the condition of technical devices based on the analysis of vibroacoustic signal generated by the operating device. Each mechanical device is the source of vibroacoustic signal referred to as a complex diagnostic signal which is the composition of signals coming from a number of individual sources. Component signals can be identified with particular components of the devices or the processes occurring in the device which are their sources. Each mechanical process (both correct and incorrect) is the source of a single component signal in a complex diagnostic signal. In the device, in which one element is not working properly, an appropriate component should appear referred to as a failure signal. Extraction and identification of the component coming from the source of a failure in a complex diagnostic signal can be used to diagnose the failure.

The aim of the research is the identification of failure signals in diagnostic signal using the methods based on geometric structure of information, in particular BSP (Blind Signal Processing).

Research hypotheses

1. In a complex diagnostic signal there are the components coming from the source of the failure of mechanical device.
2. It is possible to separate and extract the failure signals from a complex diagnostic signal using the optimized BSP techniques.
3. The identification of failure signals in a complex diagnostic signal will enable effective diagnostics of the technical condition of the device.

The significance of the project

Current state of knowledge

The idea that statistical models can be treated as mathematical differentiable manifolds and analyzed using differential geometry comes from C.R. Rao's work published in 1945 [19]. Rao was the first to prove that Fischer information can be treated as Riemannian manifold in the space created by a family of probability distributions. Since that moment the concept has developed in many fields of science and technology [9,10,11,12,13,16,18]. Nevertheless, the techniques based on this concept have not been used in technical diagnostics so far.

Blind Signal Processing BSP is one of the most interesting and developing areas of signal processing. It is based on solid theoretical foundations and has many potential applications. BSP has become the subject of researches in many fields of science, especially biomedical engineering, medical imaging, speech recognition, remote detection, communication systems, geophysics, economics and audio-visual systems. BSP techniques basically do not use learning data or a priori knowledge of the parameters of researched systems. Blind Signal Processing is divided into three areas: Blind Signal Separation (BSS), Independent Component Analysis (ICA) and blind deconvolution and filtration [14].

Blind Signal Processing BSP [14,15,17] is a technique relatively little used in the technique. The applications of these methods are limited to such fields of science as neurology, neuroscience, audiovisual techniques and economics. In Poland the use of BSP has been so far limited to audio signals and simple applications, mainly in the context of electroencephalographic signals EEG and removal of artefacts from electrocardiographic signals (ECG). In Polish scientific literature there are no theoretical bases for the use of BSP algorithms. Geometrization of information is not used in a conscious way.

In spite of having been used in so many aspects, these techniques have not been applied so far in the context of technical diagnostics, neither in Poland, nor abroad.

Reasons for the research

The possibility of extracting useful information from the studied object is very significant from a diagnostic point of view. The methods under research are universal both in the context of the type of signal and the type of analyzed object. It can be technical devices but also living creatures, especially human beings. Recorded signals are the composition of many single source signals and various types of interference. The analysis of such complex signals is very difficult and in many cases impossible. The useful information in this case is hidden in a complex signal. It makes it impossible to conduct effective technical or medical diagnostics. The separation of signals coming from analyzed sources enables the study of the whole object divided into compound elements which increases the diagnostic possibilities. In order to effectively separate source signals, it is necessary to create new BSP algorithms adapted to a specific type of diagnostic signal.

Innovatory character of the project

The separation and extraction of failure signals from a complex diagnostic signal using BSP techniques and their identification by comparison with their models with the use of e.g. Artificial Neural Networks ANN is the main idea of the project. Figure 1 presents the scheme of the operation of expert system. Complex diagnostic system (x_1, x_2,...,x_n) is being subjected to BSP analysis. Source signals extracted by BSP (s_1, s_2,...,s_m) are then identified by comparison with model signals. The identification process will be carried out using, for example, artificial neural networks, which will return information on the occurrence of a given type of damage when a signal similar to the pattern appears. At the identification stage, we plan to use alternative methods, such as various types of data clustering techniques.

Creating a specific BSP algorithm depends on the type of signal and the expected effects of the analysis. Project implementation will require the creation of new BSP algorithms adapted to technical diagnostics applications. In addition, it will be necessary to develop a way of cooperation between them in order to create a diagnostic expert system enabling automation of the process of assessing the technical condition of technical devices.

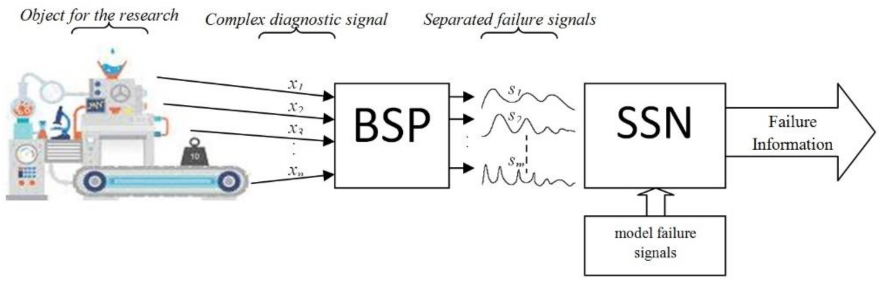

Fig. 1. *Block diagram showing the operation of a diagnostic expert system based on BSP and ANN techniques*

Creating a specific BSP algorithm depends on the type of signal and the expected effects of the analysis. Project implementation will require the creation of new BSP algorithms adapted to technical diagnostics applications. In addition, it will be necessary to develop a way of cooperation between them in order to create a diagnostic expert system enabling automation of the process of assessing the technical condition of technical devices.

The theoretical part of the project will allow for the synthesis of knowledge on this universal test method and the development of the procedures for the selection and optimization of algorithms in the context of a specific type of signal. It will enable the conscious use of the existing BSP and ANN algorithms and the creation of new ones. The experimental part will contribute to the creation of new BSP algorithms.

The methodology of the creation, selection and optimization of BSP algorithms in the context of a particular type of diagnostic signal and the expert system connecting these algorithms are the basis of the innovative nature of the project.

The influence of the project on the development of scientific discipline

The realization of the project will contribute to the development in the use of BSP in technical diagnostics and medicine. The creation and optimization of BSP models depend, to a large extent, on the analyzed diagnostic signals and required effects of diagnostic process. Different models will be used in the context of diagnostic signals in techniques and neurological or biomedical issues. The data and information collected during the realization of the project will contribute to the creation of the methodology of selection and optimization of BSP models in the context of a particular type of diagnostic signal. It will allow for faster and responsible use of these methods in different types of diagnostics.

The data and information from the research will be a completely new and important source of information for the future researchers interested in the use of geometrization of information in other fields of science.

The conception and plan of the research

The research on BSP methods will be conducted in the Laboratory of Environmental Research in the Engineering Studies Centre of The University College of Applied Sciences in Chełm. The place has a professionally equipped laboratory for the researches on noise and vibrations. The equipment of the laboratory consists of very modern devices for measurement and analysis of vibroacoustic signals, such as, 56-channel signal analyzer Siemens LMS Scadas Mobile, the matrix for acoustic holography, the analyzer of environmental noise Norsonic NOR140, seismic data recorder TEAC WX7016, piezoelectric vibration sensors, measurement microphones, specialized software LMS TestLab and LMS HD Acustics.

The project will involve theoretical and experimental researches. They will concentrate on the creation of optimum BSP algorithms in the context of the separation, extraction and identification of failure signals. The materials will be used to create the expert system combining the process of blind separation of signals with the process of identification of failure signals which will allow for automatic diagnosis of the technical condition of the researched device. The research will be conducted with the use of accessible, specialized laboratory equipment and will enable the analysis of the possibilities of using BSP methods in practice.

General plan of the research

1. Theoretical analysis of blind signal processing and artificial neural networks algorithms.
2. Selection of mechanical devices for the experiment.
3. Creation, selection and optimization of BSP algorithms in the context of the established aim of the research.
4. Conducting the measurement experiment.
5. Application of selected BSP algorithms with regard to the measured diagnostic signals.
6. Optimization of BSP algorithms on the basis of measurement data.
7. Creating diagnostic expert system on the basis of optimized BSP algorithms and its verification.
8. Formalization of the methodology of the creation of optimized diagnostic models.

Specific aims of the research

1. Analysis of the functioning of existing BSP algorithms and identification methods.
2. Analysis of the methods of the creation of BSP algorithms, including the analysis of mathematical mechanisms which form the base for their functioning.
3. Verification of separation possibilities of the studied BSP algorithms.
4. Selection of the objects for the research in order to obtain differentiated complex diagnostic signals.
5. Measurement of complex diagnostic signals on the selected objects.
6. Application of the selected BSP algorithms to the measured diagnostic signals.
7. Verification of separation possibilities of the selected BSP algorithms.
8. Conducting the experiment in order to collect model failure signals.
9. Creation and optimization of BSP algorithms which are the most effective in terms of separation possibilities of the measured diagnostic signals.
10. Creation of identification system which are optimal in terms of the identification of failure signals.
11. Creation of diagnostic expert system on the basis of optimized BSP algorithms and its verification.

12. Formalization of the methodology of the creation of optimized diagnostic models.

The results of the preliminary research

Dariusz Mika has dealt with the issue of blind separation of signals in his doctoral thesis entitled 'The Separation of sounds coming from different sources from a complex acoustic signal. He is experienced in the theory of blind signal processing BSP, artificial neural networks ANN and programming in Matlab environment. The results of his research works prove that there are great possibilities of applied methodology in the context of the separation of vibroacoustic signals. The analysis conducted on signals, primarily acoustic, proved that BSP techniques (especially ICA) are effective in the process of the extraction of source signals, which was confirmed by the publications of the applicant [20,21] (ARCHIVES OF ACOUSTICS). The researches on the separation of complex signals were conducted mainly in acoustic domain. Moreover, the experiments were conducted connected with the identification of source signals by the method of clustering with different measurements of the distance between the bases of the signals [20]. Jerzy Józwik, Dariusz Mika and Grzegorz Budzik also have dealt with the issue of blind separation of signals in their scientific work regarding single channel source separation with ICA - based time-frequency decomposition and Lie Group Methods in Blind Signal Processing. The results of these works and analyzes were presented in publications [22, 23, 24], (SENSORS, MDPI, Mechanical System and Signal Processing).

The greatest threats and risks in the project include: the recurrence of the Covid-19 pandemic and the resulting effects, the loss of the project's research contractor, improper project management and the risk of increase in price of equipment, additional research apparatus and planned purchase of software. **The risk related to the disruption of project implementation** is due to the limitations resulting from the COVID-19 pandemic and other random events. The risk may affect the project's objectives, their timeline, and the final success of the project (likelihood of risk is unlikely, impact is moderate). Planned preventive measures are: the project will be managed by individuals with necessary skills and hands-on experience in project management, which will ensure that project implementation, will be carried out accordingly to the situation. In situ and online meetings with the project team members will be held in order to discuss problems arising in project implementation and how to solve them. **The risk related to losing project participants** is largely random and thus difficult to predict and avoid (illness, pandemic, lack of availability, etc.). This risk may have a negative impact on achieving partial objectives of the project assumed under given project implementation stages (likelihood of risk is very unlikely, impact is minimal). The planned preventive measures include:

involving people with a wide range of skills in order to ensure substitution in the event of a loss of a team member; offering attractive remuneration for project participants; ensuring transparency of the objectives set for scientific teams; providing project participants with the possibility of communicating their own ideas and improvements; ensuring open communication and comfortable conditions for cooperation. **The next risk is related to incorrect determination of the scope of works in the project.** Due to inadequate management of the project, the scope of the planned works may differ from the assumed objectives of the project (likelihood of risk is very unlikely, impact is minimal). Planned preventive measures are: on-going monitoring of the achieved project objectives. Participants in the project will have required skills and hand-on experience in project management. Cooperation with LUT's Project Office to assess the correctness of project implementation. Planned preventive measures in this area are on-going monitoring of the achieved project objectives. As countermeasures against price changes, the following measures were planned: diversification of activities related to the search for and selection of contractors supplying scientific research equipment (negotiations, optimization of equipment parameters, selection of a cheaper contractor, etc.), relatively quick signing of contracts for the supply of equipment and ensuring the stability of the costs of supplied equipment (guaranteed by contractors at the time of entering tenders). **All actions planned to counteract potential threats are to lead to an undisturbed course of project implementation.**

Methodology of the research

Giving geometric structure to the studied models creates many new research possibilities which allow the researcher to achieve significant cognitive, scientific and utilitarian goals. Although there were attempts at using geometric information in many scientific researches, it is still in the initial stage of development and, at the same time, creates wider perspectives for its use in different fields of science [1-10].

Information geometry stems from the application of non-Euclidean geometry to probability theory. It was created on the basis of the studies on natural, geometric (differential) structure of the family of probability distributions. It examines a set (family) of probability distributions creating a statistical model as a differentiable manifold and allows for the analysis of the relation between geometric structure of this manifold and statistical estimation on a given model.

A special role in statistical modelling is played by statistical spaces for which Riemann curvature tensor vanishes (zeroes) for all S manifold (a manifold with zero internal curvature). Such spaces are called affine flat. On such manifold we can introduce affine coordinate system for which all connection coefficients are identically equal zero Γ_{ij}^{k} which means that covariant derivatives of basis vectors ∂_i vanishes. It is the result of the definition of the covariant derivative of basis vectors (1) (Einstein summation convention was applied) [10]:

$$\nabla_{\partial_i} \partial_j = \Gamma_{ij}^{k} \partial_k = 0 \quad (1)$$

It means that all basis vectors ∂_i a parallel on the whole statistical manifold S. The examples of such spaces are well-known families of exponential and mixed distributions [10]. Flat models of that kind are very effective in terms of research properties.

From the point of view of widely understood diagnostics, the most interesting is the way in which we can use information geometry in the context of artificial neural networks ANN and signal processing, especially blind signal processing BSP.

The space of the parameters of multilayer artificial neural networks and separating matrices in BSP techniques has the Riemannian metric structure. The functioning of ANN and BSP algorithms is based on searching for the extremes, so called cost functions, defined in a set of parameters which are Riemannian manifolds. Searching for these extremes usually involves defining the gradient of cost function, which indicates the direction of its fastest change. A normal gradient of a function, however, indicates the direction of the fastest change in Euclidean spaces. In the case of Riemannian space the direction is indicated by, so called, natural gradient. In differential geometry it is a contravariant form of the gradient of a function. The researches have proved that optimization algorithms are less effective if based on a natural gradient [11].

From three above-mentioned areas of BSP the most noteworthy is Independent Component Analysis (ICA) technique. The block scheme of ICA method is presented in Figure 2.

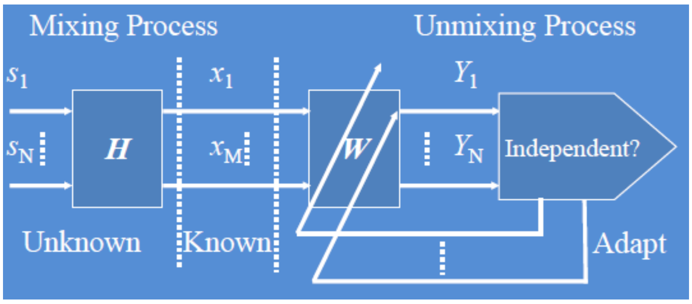

Fig. 2. *Block diagram of the Independent Component Analysis ICA*

ICA analysis through estimating separating matrix *W* (fig. 2) makes it possible to find independent components *S*. ICA analysis is conducted by means of formulating, so called, cost function, which is the measurement of independence of random variables and then its minimizing or maximizing with the use of classical optimization methods, such as gradient, iterative, Newton's method etc. [9].

ICA analysis is a statistical and computational technique which allows for the extraction of hidden components from the set of random variables, measurement data and signals. It is a very efficient and effective technique. In the context of technical diagnostics it can be used as one of BSS techniques to separate source signals. The identification of failure signals from the set of separated source signals can be conducted with the use of pattern recognition techniques, including artificial neural networks ANN.

The research on the use of BSP in technical diagnostics will be conducted in the Laboratory of Environmental Research in the Engineering Studies Centre of The University College of Applied Sciences in Chełm. Measurement data will be acquired by means of the measurement system consisting of signal analyzer Siemens LMS Scadas Mobile, signal recorder TEAC WX7016, a set of piezoelectric vibration sensors, measurement microphones and a matrix for acoustic holography. The analysis of the signal will be conducted on specialized software LMS TestLab and in Matlab system.

Acknowledgment

This work was prepared within the project PMII/SP/0093/2024/02 entitled "Building the algorithms of blind signal processing based on geometrical structure of information", financed by the Ministry of Education and Science (Poland) as a part of the Polish Metrology II Programme.

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APPLICATION OF BLIND SOURCE SEPARATION ALGORITHMS BASED ON GEOMETRIC INFORMATION STRUCTURE IN DIAGNOSTICS OF MECHANICAL SYSTEMS

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Keywords: blind source separation, independent component analysis, convolutional neural networks, fault diagnosis.

The article presents the concept of using a blind source separation algorithms based on geometric information structures in technical diagnostics. Achieving this goal will enable the construction of an expert system for diagnosing the condition of technical devices based on the analysis of the vibroacoustic signal generated by the operating device.

Introduction

Blind Signal Processing BSP is one of the most interesting and developing areas of signal processing. It is based on solid theoretical foundations and has many potential applications. BSP has become the subject of researches in many fields of science, especially biomedical engineering, medical imaging, speech recognition, remote detection, communication systems, geophysics, economics and audio-visual systems. BSP techniques basically do not use learning data or a priori knowledge of the parameters of researched systems. Blind Signal Processing is divided into three areas: Blind Source Separation (BSS), Independent Component Analysis (ICA) and blind deconvolution and filtration [1].

Independent component analysis (ICA) is a powerful tool for a wide variety of signal processing applications such as image and acoustic signal processing, brain imaging analysis, data analysis and communications applications [2]. Standard ICA involves the recovery of linearly mixed, statistically independent source component, without any information about the sources (e.g. time, spectral and statistical features) beyond their mutual independence. One of the main factor determining the effectiveness of ICA is the adopted optimization strategy, i.e. the method of finding the critical point of the cost function. The specific geometry of the standard ICA model has the geometric structure of a special orthogonal group SO (n), i.e. the search space is a group of orthogonal square matrices satisfying the condition $W^T W = I$. Apart from the geometric properties of the $SO(n)$ group, the ICA model also has its differential structure. It is known that the SO (n) group has the structure of a smooth differential manifold, which is why it is called the Lie group. The use of this convenient structure in general ICA models can be found in [3, 4, 5, 6]. Optimization methods using the Lie group structure are often known as geodesic optimization methods because during the optimization movement they ensure 'locking' to the surface of orthogonal matrices (post geodetic movement). The idea of a standard optimization procedure based on this concept is the optimization movement in the Lie algebra space followed by 'transition' to the Lie group through the exponential projection.

Proposed methodology

Each mechanical device is the source of vibroacoustic signal referred to as a complex diagnostic signal which is the composition of signals coming from a number of individual sources. Component signals can be identified with particular components of the devices or the processes occurring in the device which are their sources. Each mechanical process is the source of a single component signal in a complex diagnostic signal. In the device, in which one element is not working properly, an appropriate component should appear referred to as a failure signal. Extraction and identification of the component coming from the source of a failure in a complex diagnostic signal can be used to diagnose the failure.

The aim of the research is the identification of failure signals in diagnostic signal using the methods based on geometric structure of information, in particular BSS and ANN (Artificial Neural Network).

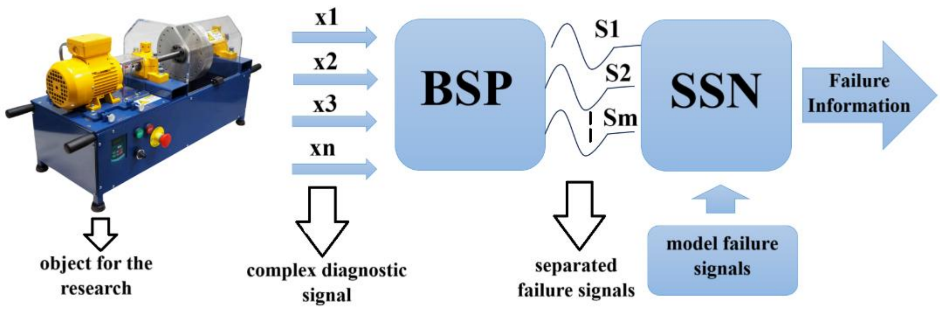

Fig. 1. *Block diagram showing the operation of a diagnostic expert system based on BSS and ANN techniques*

In the conducted research the methods of separation and identification of failure signals based on geometric structures of information will be applied.The separation and extraction of failure signals from a complex diagnostic signal using BSP techniques and their identification by comparison with their models with the use of artificial neural networks ANN is the main idea of the project. Figure 1. presents the scheme of the operation of expert system based on the above-mentioned methods

The data and information collected during the realization of the project will contribute to the creation of the methodology of selection and optimization of BSP and ANN models in the context of a particular type of diagnostic signal. It will allow for faster and responsible use of these methods in different types of diagnostics.

The data and information from the research will be a completely new and important source of information for the future researchers interested in the use of geometrization of information for technical use. The theoretical part of the project will allow for the synthesis of knowledge on this universal test method and the development of the procedures for the selection and optimization of algorithms in the context of a specific type of signal.

Acknowledgment

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PREPARATION OF THE SWIETOKRZYSKIE LABORATORY CAMPUS STATIONS FOR CONDUCTING ACCREDITED ACTIVITIES

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Keywords: Świętokrzyski Kampus Laboratoryjny Głównego Urzędu Miar, akredytacja .

Świętokrzyski Kampus Laboratoryjny Głównego Urzędu Miar, który powstał w Kielcach w ramach Projektu nr RPSW.01.01.00-26-0001/20 pn. „Świętokrzyski Kampus Laboratoryjny Głównego Urzędu Miar – Etap I" współfinansowanego z Europejskiego Funduszu Rozwoju Regionalnego będzie prowadził zarówno działalność badawczo-rozwojową jak i komercyjną. Działalność gospodarcza ŚKLGUM będzie realizowana przez Politechnikę Świętokrzyską w Kielcach, w ramach której świadczone będą następujące usługi: badania na zlecenie, usługi badawcze, wynajem infrastruktury, edukacja poza publicznym systemem (studia podyplomowe, kursy, oraz szkolenia). W celu zwiększenia zaufania do wyników wzorcowań, pomiarów i badań wykonywanych w ramach działalności gospodarczej ŚKLGUM postanowiono utworzyć i akredytować w Politechnice Świętokrzyskiej dedykowane do tego celu laboratorium. W artykule przedstawiono stan realizacji prac przygotowujących laboratorium do prowadzenia działalności akredytowanej w oparciu o infrastrukturę pomiarową ŚKLGUM.

Wstęp

Świętokrzyski Kampus Laboratoryjny Głównego Urzędu Miar to projekt realizowany wspólnie przez Główny Urząd Miar w Warszawie i Politechnikę Świętokrzyską w Kielcach. Całkowita powierzchnia ośmiu budynków wynosi blisko 14 tys. m^2. 29 grudnia 2023 r. konsorcjum w składzie: Skarb Państwa – Główny Urząd Miar oraz Politechnika Świętokrzyska, otrzymało pozytywną decyzję Powiatowego Inspektora Nadzoru budowlanego dla Miasta Kielce, dopuszczającą do użytkowania zespół budynków kampusu. Znajduje się w nich m.in. 6 laboratoriów badawczo-pomiarowych. W kampusie będą prowadzone badania i eksperymentalne prace rozwojowe z zakresu: akustyki i drgań, czasu i częstotliwości, długości, masy, termometrii oraz metrologii interdyscyplinarnej.

Strategicznym celem działalności ŚKLGUM w Kielcach ma być wykorzystanie metrologii do podniesienia konkurencyjności polskich firm na rynku europejskim i światowym oraz utworzenie centrum polskiej metrologii –

miejsca, w którym spotykać się będą środowiska naukowe oraz związane z przemysłem. Działalność gospodarcza w kampusie będzie realizowana przez Politechnikę Świętokrzyską w Kielcach. W ramach tej działalności mają być realizowane badania na zlecenie, pomiary i wzorcowania, wynajem infrastruktury oraz edukacja poza systemem (studia podyplomowe, kursy i szkolenia). Dla realizacji części tych zadań postanowiono utworzyć w Politechnice Świętokrzyskiej laboratorium działające w oparciu o infrastrukturę badawczą kampusu a następnie doprowadzić do jego akredytacji.

Założenia projektu

Na początku 2024 r. w Politechnice Świętokrzyskiej rozpoczęto prace związane z realizacją projektu nr PM/SP/0107/2024 pt. „Przygotowanie stanowisk ŚKLGUM w Kielcach do prowadzenia działalności akredytowanej" w ramach programu pod nazwą Polska Metrologia II. Celem projektu pt. „Przygotowanie stanowisk ŚKLGUM w Kielcach do prowadzenia działalności akredytowanej" jest uzyskanie akredytacji Polskiego Centrum Akredytacji dla utworzonego w Politechnice Świętokrzyskiej laboratorium do prowadzenia akredytowanej działalności laboratoryjnej zgodnie z normą PN-EN ISO 17025:2018-2 [1] w oparciu o wyposażenie stanowisk w ŚKLGUM. Będzie on dotyczył wykonywania wzorcowań i badań w obszarze pomiarów wielkości geometrycznych, pomiarów geodezyjnych, pomiarów momentu siły, badań przewodności cieplnej i dyfuzyjności oraz badań paliw.

Projekt polegający na prowadzeniu akredytowanej działalności w oparciu o normę PN-EN ISO 17025:2018-2 [1] laboratorium utworzonego w Politechnice Świętokrzyskiej umożliwi zdecydowanie pełniejsze wykorzystanie zasobów aparaturowych ŚKLGUM ze względu na spełnienie wymagań, które umożliwiają wykazanie, że laboratorium działa w sposób kompetentny, jest w stanie uzyskiwać ważne wyniki [1] oraz zapewnić spójność pomiarową [2], co spowoduje zwiększenie zaufania do jego działalności. Powinno się to w konsekwencji przełożyć na wzrost liczby potencjalnych klientów korzystających z usług ŚKLGUM, wywodzących się z obszaru laboratoriów akredytowanych jak również podmiotów gospodarczych, które mają wdrożony system zarządzania jakością.

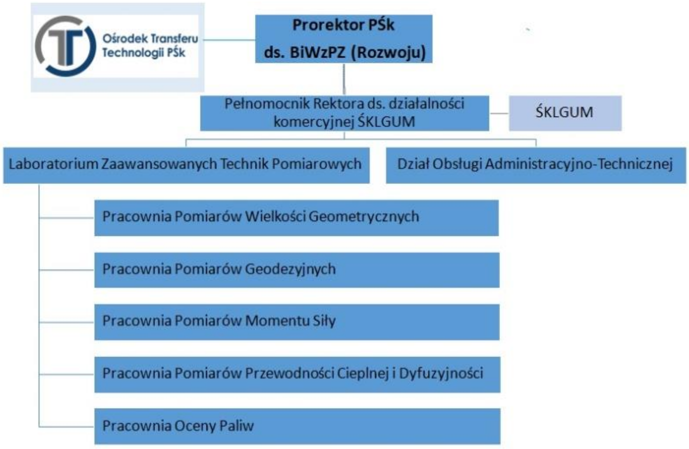
W pierwszym etapie zakłada się przeprowadzenie szkoleń personelu laboratorium z zakresu systemów zarządzania według normy PN-EN ISO 17025:2018-2 [1] oraz szacowania niepewności pomiaru. Kolejnym krokiem będzie ustanowienie i udokumentowanie systemu zarządzania laboratorium zgodnego z wymaganiami normy odniesienia oraz dokumentami Polskiego Centrum Akredytacji [3,4]. W oparciu o wyposażenie pomiarowe, wzorce, którym będzie dysponowało laboratorium w ŚKLGUM zostanie ustalony zakres badań, pomiarów i wzorcowań, które znajdą się w zakresie akredytacji laboratorium. Dla wytypowanego zakresu zostaną opracowane niezbędne procedury badawcze i instrukcje wzorcowania.

W drugim etapie zakłada się wdrożenie systemu zarządzania laboratorium. Zostanie przeprowadzona analiza możliwości wykonania wzorcowania wyposażenia pomiarowego w oparciu o posiadane wzorce, wytypowanie wzorców niezbędnych do zakupu oraz możliwości przeprowadzenia wzorcowań w oparciu o możliwości posiadane przez GUM lub laboratoria akredytowane w kraju lub zagranicą. W tym etapie zostanie przeprowadzony audyt wewnętrzny laboratorium, którego celem będzie ocena spełnienia wymagań normy odniesienia [1], skuteczności wdrożenia ustanowionego systemu zarządzania oraz potwierdzenia kompetencji laboratorium w planowanym obszarze jego działalności.

W trzecim etapie zakłada się przeprowadzenie działań korygujących w odniesieniu do stwierdzonych podczas audytu wewnętrznego niezgodności. Dla planowanego zakresu akredytacji badań i wzorcowań przewiduje się przeprowadzenie porównań dwustronnych, w celu potwierdzenia ważności wyników. W pierwszej kolejności zostaną wykonane porównania z laboratoriami Głównego Urzędu Miar, a w przypadku braku możliwości technicznych z laboratoriami akredytowanymi o możliwie najmniejszych deklarowanych wartościach CMC (Calibration and MeasurementCapabilities). Głównym elementem tego etapu będzie złożenie wniosku do Polskiego Centrum Akredytacji o akredytację laboratorium. Efektem końcowym będzie uzyskanie certyfikatu akredytacji na zaplanowane badania i wzorcowania oraz rozpoczęcie działalności jako laboratorium akredytowanego.

Realizacja projektu

Podstawowym warunkiem umożliwiającym realizację projektu było powołanie w strukturze Politechniki Świętokrzyskiej Laboratorium Zawansowanych Technik Pomiarowych, które ma funkcjonować w oparciu o infrastrukturę badawczą ŚKLGUM. Umiejscowienie nowoutworzonego Laboratorium w strukturze Politechniki Świętokrzyskiej przedstawiono na rys. 1. Laboratorium Zawansowanych Technik Pomiarowych składa się z pięciu pracowni: pomiarów wielkości geometrycznych, pomiarów geodezyjnych, pomiaru momentu siły, pomiarów przewodności cieplnej i dyfuzyjności oraz oceny paliw. Laboratorium podlega bezpośrednio pełnomocnikowi Rektora Politechniki Świętokrzyskiej ds. działalności komercyjnej ŚKLGUM. Za obsługę zleceń zewnętrznych odpowiedzialny jest Ośrodek Transferu Technologii PŚk, który zajmuje się przyjmowaniem zamówień, współpracą z Klientem w obszarze formalnym oraz rozliczaniem wykonanych prac.



Rys. 1. *Umiejscowienie nowoutworzonego Laboratorium w strukturze Politechniki Świętokrzyskiej w Kielcach*

Na początkowym etapie realizacji projektu zostało przeprowadzone szereg szkoleń pracowników, którzy będą zaangażowani do pracy w laboratorium przez personel akredytowanego Laboratorium Komputerowych Pomiarów Wielkości Geometrycznych (AP 188) funkcjonującego w Politechnice Świętokrzyskiej z wymagań normy PN-EN ISO 17025:2018-2 [1].

Pracownicy brali udział w instalowaniu, uruchomieniu systemów pomiarowych oraz realizowali wstępne pomiary mające na celu zdobycie wymaganych kwalifikacji i kompetencji do obsługi przyrządów pomiarowych.

Dla pracowników Laboratorium zostało przeprowadzone szkolenie pt. „Ogólne wymagania dotyczące kompetencji laboratoriów badawczych i wzorcujących" przez Instytut Kształcenia Menadżerów Jakości oraz szkolenie pt. „Praktyka obliczania niepewności pomiaru" zrealizowane przez Główny Urząd Miar [5, 6].

Wyposażenie aparaturowe poszczególnych pracowni i przewidywany zakres prowadzonych pomiarów, wzorcowań i badań został przedstawiony w tabeli 1.

Tab. 1. *Wyposażenie i zakres prowadzonych prac przez poszczególne pracownie Laboratorium Zaawansowanych Technik Pomiarowych*

Laboratorium Zaawansowanych Technik Pomiarowych		
Pracownia	**Wyposażenie**	**Zakres prac**
P1 Pomiarów wielkości geometrycznych	• Nanomaszyna NMM-1 wyposażona w cztery wymienne głowice pomiarowe	Pomiary: • struktury geometrycznej powierzchni w skali nano, • stykowe struktury

	• profilometr stykowy, • przyrząd do pomiarów odchyłek kształtu, • wielkogabarytowa współrzędnościowa maszyna pomiarowa, • laser tracker API, • skaner światła strukturalnego, • ściana referencyjna	geometrycznej powierzchni (kształt, falistość i chropowatość), • odchyłek kształtu elementów obrotowych (okrągłość, walcowość, prostoliniowość, płaskość), • optyczne elementów wielkogabarytowych za pomocą skanera światła strukturalnego, • stykowe elementów wielkogabarytowych za pomocą współrzędnościowej maszyny pomiarowej, • elementów wielkogabarytowych za pomocą laser trackera, • z wykorzystaniem ściany referencyjnej. Wzorowanie: • wzorców chropowatości powierzchni, wzorców okrągłości w postaci wałka ze ścięciem (tzw. flick standard), • wzorców w postaci półkuli szklanej • wzorca prostoliniowości w postaci walca.
P2 Pomiarów geodezyjnych	Stanowisko do wzorcowania przyrządów geodezyjnych wyposażone w interferometr laserowy	Wzorcowanie przyrządów geodezyjnych : • skanerów laserowych, • teodolitów, • tachimetrów , • niwelatorów • łat niwelacyjnych • dalmierzy laserowych.
P3 Pomiarów momentu siły	Stanowisko do wzorcowania czujników siły w zakresie	Wzorcowanieczujników momentu siły
P4 Pomiarów przewodności cieplnej i dyfuzyjności	• Przyrząd do pomiaru dyfuzyjności metodą laserową LFA 427, • przyrząd do pomiaru przewodności cieplnejHFM-446M, • kalorymetr różnicowy	Pomiary związane z: • przewodnictwem cieplnym, • dyfuzyjnością cieplną, • wyznaczeniem ciepła właściwego materiałów, • rozszerzalnością cieplną ciał

	DSC 214 Polyma, • dylatometr DIL 402.	stałych, proszków i lepkich cieczy
P5 Oceny paliw	• System dynamicznej kalorymetrii skaningowej DSC, • spektrometr masowy , • analizator elementarny CHNS , • wielofazowy analizator węgla i wodoru/wilgoci , • analizator termograwimetryczny TGA, • kalorymetr pracujący metodą izoperibolową.	Przeprowadzanie badań: • ilościowych grup związków chemicznych w próbkach, organicznych i nieorganicznych • identyfikacji związków chemicznych w różnego rodzaju matrycach, • izolacyjności materiałów, • właściwości energetycznych paliw stałych, ciekłych i gazowych.

Podziękowania

Projekt dofinansowany ze środków budżetu państwa w ramach programu Ministra Nauki i Szkolnictwa Wyższego pn. Polska Metrologia II pt. „Przygotowanie stanowisk ŚKLGUM w Kielcach do prowadzenia działalności akredytowanej". Nr projektu: PM-II/SP/0107/2024/02.

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[3] DAP-04 Akredytacja laboratoriów wzorcujących
[4] DAB-07 Akredytacja laboratoriów badawczych
[5] EA-4/02 Ocena niepewności pomiaru przy wzorcowaniu
[6] JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement

VALIDATION OF THE GEODETIC INSTRUMENT TESTING STATION AT THE SWIETOKRZYSKIE LABORATORY CAMPUS

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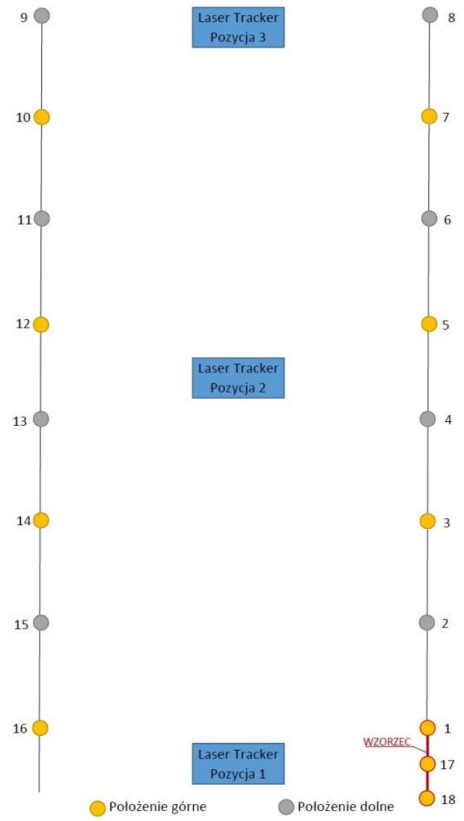
Słowa kluczowe: walidacja, tachimetr, laser tracker

W Świętokrzyskim Kampusie Laboratoryjnym Głównego Urzędu Miar w Kielcach będzie funkcjonowało stanowisko do sprawdzania przyrządów geodezyjnych zamontowane na stabilnej ścianie referencyjnej o długości 12 m zlokalizowanej w podziemnym laboratorim. Wadą takiego rozwiązania jest ograniczony zakres pomiarowy. Powstał pomysł zbudowania dodatkowego stanowiska i wykorzystania do tego celu istniejącego w ŚKLGUM pomieszczenia laboratoryjnego o długości 76 m. W artykule przedstawiono wstępne wyniki walidacji zbudowanego stanowiska.

Wstęp

Prototypowe stanowisko do sprawdzania przyrządów geodezyjnych składa się z piętnastu punktów pomiarowych rozmieszczonych na dwóch równoległych ścianach pomieszczenia laboratorium na długości około 47 m oraz prętowego elementu wzorca długości z trzema dodatkowymi punktami pomiarowymi (rys. 1). Każdy z punktów pomiarowych to podstawa do SMR-a (Spherically Mounted Retroreflector) umieszczona na kątowniku umożliwiającym zamocowanie jej do ściany. Punkty pomiarowe rozmieszczone są naprzemiennie na dwóch wysokościach oddalonych od siebie o około 2 m. Wzorzec długości posiadający świadectwo wzorcowania składa się z profilu wykonanego z włókna węglowego z zamontowanymi trzema podstawkami do SMR-ów rozmieszczonymi co 1500 mm. Schemat rozmieszczenia punktów pomiarowych oraz wzorca długości oraz trzech położeń laser trackera podczas pomiarów walidacyjnych [1] przedstawiono na rys. 1., a na rys. 2 fotografie prototypowego stanowiska. Celem prowadzonych badań jest również identyfikacja potencjalnych źródeł błędów, które będą decydowały kształcie budżetu niepewności wzorcowania przyrządów geodezyjnych z wykorzystaniem stanowiska [2, 3, 4].



Rys. 1. *Schemat rozmieszczenia punktów pomiarowych*

a) b)

Rys. 2. *Stanowisko do sprawdzania przyrządów geodezyjnych a) położenie laser trackera podczas pomiarów wykonywanych z pozycji 1 b) pomiar wzorca długości*

Wyniki

Walidacja [1] stanowiska polegała na wykonaniu kolejno trzech serii pomiarów współrzędnych poszczególnych punktów pomiarowych za pomocą laser trackera API Radian Pro zlokalizowanego na początku, w środkowej części oraz na końcu stanowiska (rys.1). W oparciu o zmierzone współrzędne z wykorzystaniem oprogramowania CMM Menager wyznaczono 122 odległości przestrzenne pomiędzy wszystkimi punktami oraz 11 wybranych kątów pomiędzy odcinkami łączącymi punkty pomiarowe.

W tablicy 1 przedstawiono przyporządkowany poszczególnym odległościom numer porządkowy, na rys. 3 średnie odległości pomiędzy poszczególnymi punktami a na rys. 4 rozstęp wyników dla pomiarów wykonanych z trzech różnych położeń laser trackera.

Wyniki pomiarów odległości punktów pomiarowych na wzorcu (punkty 1;17;18) przedstawiono w tablicy 2. Wzorcowanie wzorca długości zostało przeprowadzone z niepewnością rozszerzoną (k = 2) U=2,5 μm + 2,5 · 10^{-6} ·l (gdzie l jest długością wzorca).

W tablicy 3 przedstawiono przyporządkowany wybranym do analizy kątom numer porządkowy. Zostały zdefiniowane po trzy kąty pionowe na każdej ze ścian oraz pięć kątów poziomych.

Uzyskane wartości średnie poszczególnych zdefiniowanych kątów zostały przedstawione na rys. 5 a rozstęp wyników dla pomiarów wykonanych z trzech różnych położeń laser trackera na rys. 6.

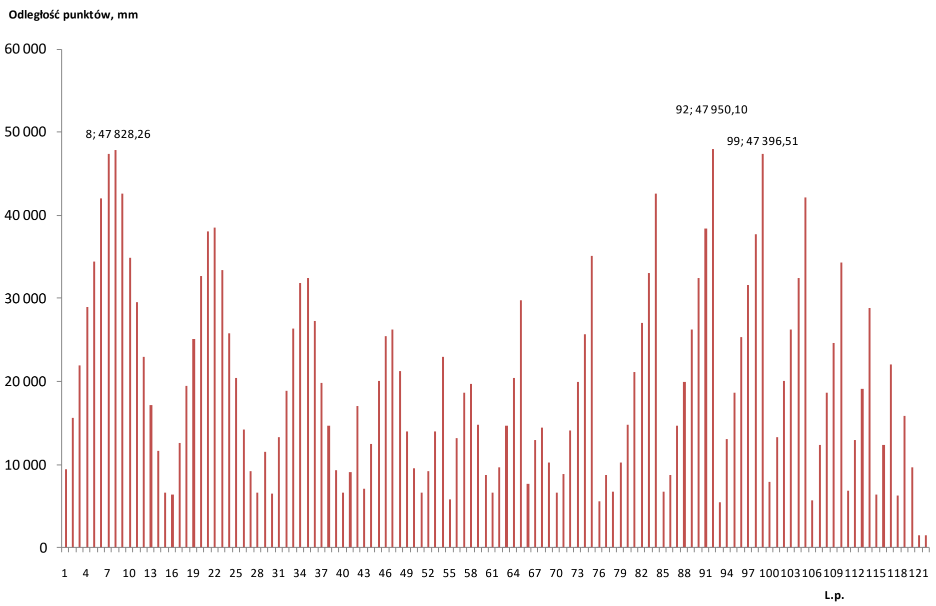
Podsumowanie

Przeprowadzone wstępne pomiary współrzędnych poszczególnych punktów, w oparciu o które zostały obliczone zdefiniowane odległości i kąty oraz ich analiza prowadzi do następujących spostrzeżeń i wniosków:

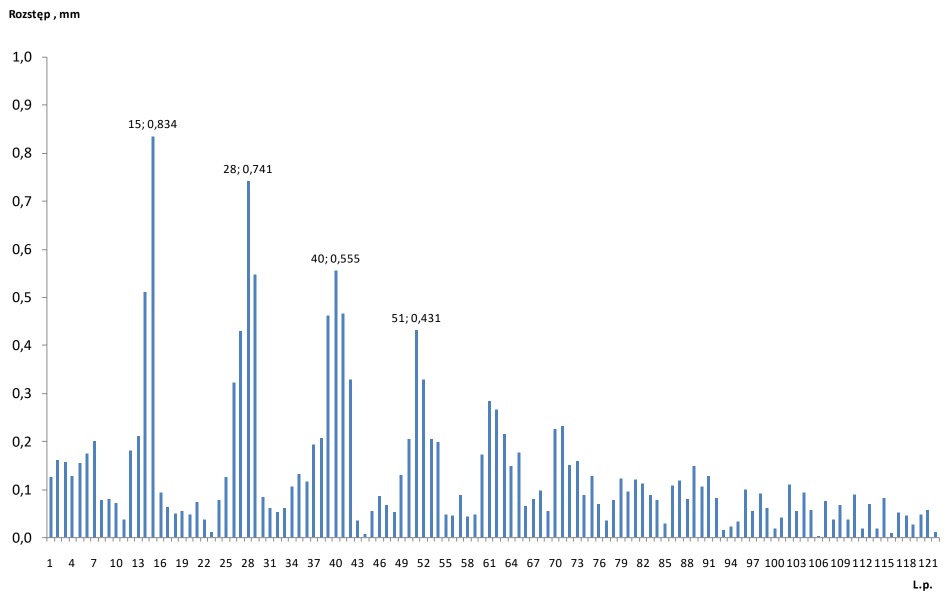
- wykonane pomiary wzorca długości za pomocą laser trackera potwierdzają jego przydatność do wzorcowania stanowiska,
- największy rozstęp wyników dla odległości poszczególnych punktów pomiarowych zanotowano dla punktów leżących na przeciwległych ścianach w początkowej części stanowiska,
- największy rozstęp wyników zanotowano dla kąta poziomego o numerze porządkowym 10,
- dalsze badania powinny polegać na sprawdzeniu stabilności poszczególnych punktów pomiarowych w dłuższym okresie czasu oraz pomiarów powtarzalności mocowania SMR-a do podstawki,
- przeprowadzone badania powinny umożliwić sporządzenie budżetu niepewności wzorcowania stanowiska.

Tab. 1. *Przyporządkowanie poszczególnym odległościom numeru porządkowego*

L.p.	**Numery punktów pomiarowych**	**L.p.**	**Numery punktów pomiarowych**	**L.p.**	**Numery punktów pomiarowych**	**L.p.**	**Numery punktów pomiarowych**
1	1-2	32	3-6	63	5-14	94	9-11
2	1-3	33	3-7	64	5-15	95	9-12
3	1-4	34	3-8	65	5-16	96	9-13
4	1-5	35	3-9	66	6-7	97	9-14
5	1-6	36	3-10	67	6-8	98	9-15
6	1-7	37	3-11	68	6-9	99	9-16
7	1-8	38	3-12	69	6-10	100	10-11
8	1-9	39	3-13	70	6-11	101	10-12
9	1-10	40	3-14	71	6-12	102	10-13
10	1-11	41	3-15	72	6-13	103	10-14
11	1-12	42	3-16	73	6-14	104	10-15
12	1-13	43	4-5	74	6-15	105	10-16
13	1-14	44	4-6	75	6-16	106	11-12
14	1-15	45	4-7	76	7-8	107	11-13
15	1-16	46	4-8	77	7-9	108	11-14
16	2-3	47	4-9	78	7-10	109	11-15
17	2-4	48	4-10	79	7-11	110	11-16
18	2-5	49	4-11	80	7-12	111	12-13
19	2-6	50	4-12	81	7-13	112	12-14
20	2-7	51	4-13	82	7-14	113	12-15
21	2-8	52	4-14	83	7-15	114	12-16
22	2-9	53	4-15	84	7-16	115	13-14
23	2-10	54	4-16	85	8-9	116	13-15
24	2-11	55	5-6	86	8-10	117	13-16
25	2-12	56	5-7	87	8-11	118	14-15
26	2-13	57	5-8	88	8-12	119	14-16
27	2-14	58	5-9	89	8-13	120	15-16
28	2-15	59	5-10	90	8-14	121	1-17
29	2-16	60	5-11	91	8-15	122	17-18
30	3-4	61	5-12	92	8-16		
31	3-5	62	5-13	93	9-10		



Rys. 1. *Średnie odległości pomiędzy punktami pomiarowymi*



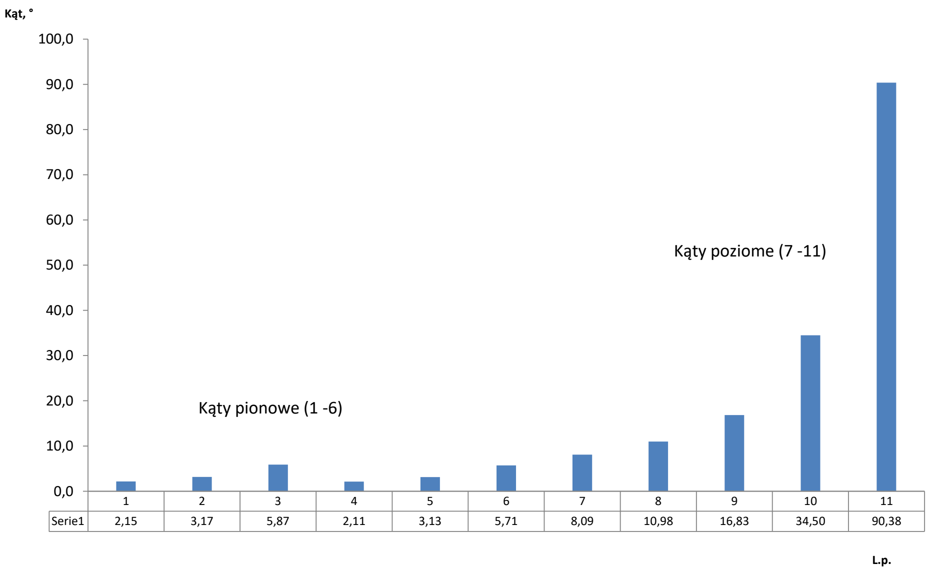
Rys. 2. *Rozstęp wyników pomiarów średnich odległości punków pomiarowych*

Tab.2. *Wyniki pomiarów wzorca*

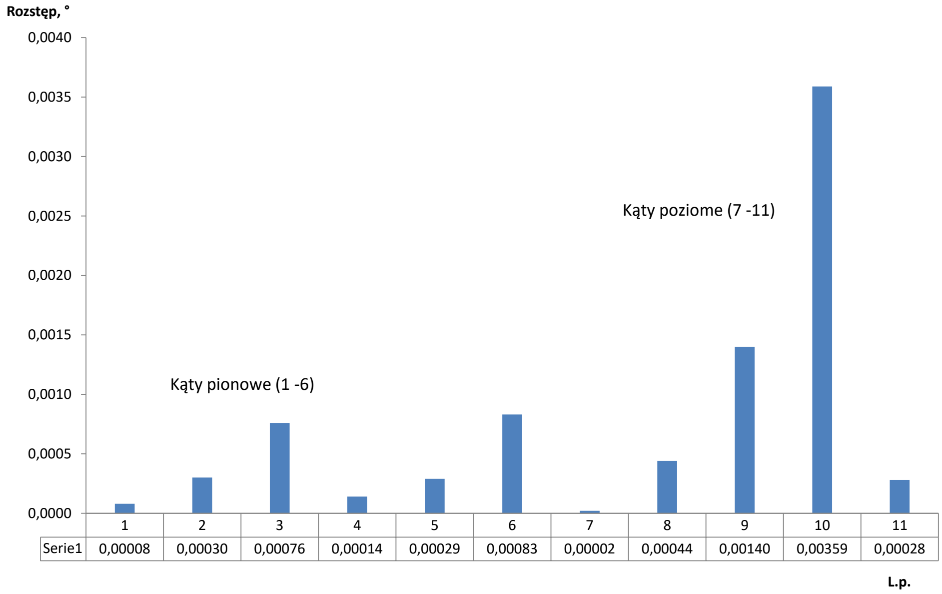
L.p.	Numery punktów pomiarowych	Odległość ze świadectwa wzorcowania, mm	Odległość zmierzona, mm	Odchylenie, mm
1	1-17	1 500,2429	1 500,2410	0,0019
2	17-18	1 499,6435	1 499,6427	0,0008

Tab.3. *Przyporządkowanie poszczególnym kątom numeru porządkowego*

L.p.	Kąt pomiędzy odcinkami	Ściana	Kąt
1	L1(1-8) - L2(1-7)	1	Pionowy
2	L1(1-8) - L3(1-5)	1	Pionowy
3	L1(1-8) - L4(1-3)	1	Pionowy
4	L5(16-9) - L6(16-10)	2	Pionowy
5	L5(16-9) - L7(16-12)	2	Pionowy
6	L5(16-9) - L8(16-14)	2	Pionowy
7	L1(1-8) - L9(1-9)	1;2	Poziomy
8	L1(1-8) - L10(1-11)	1;2	Poziomy
9	L1(1-8) - L11(1-13)	1;2	Poziomy
10	L1(1-8) - L12(1-15)	1;2	Poziomy
11	L1(1-8) - L13(1-16)	1;2	Poziomy



Rys. 5. *Średnie wartości zdefiniowanych kątów*



Rys. 6. *Rozstęp wyników pomiarów zdefiniowanych kątów*

Referencje

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[4] JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement.

IMPORTANCE OF COLOR INFORMATION CAPTURED BY OPTICAL MEASUREMENT SYSTEMS (3D SCANNERS) FOR QUALITY CONTROL AND MAINTENANCE PLANNING

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Słowa kluczowe: 3D scanner, optical metrology, quality control, color measurement, wear assessment.

Optical measurement systems, particularly 3D scanners, play a crucial role in industrial quality control and wear assessment. These devices are valued for their ability to accurately capture surface points, achieving micrometer-level precision and rapid data acquisition, which accelerates inspections compared to traditional methods like CMMs. Although development has focused on matching contact method precision, non-contact techniques offer unique benefits. Color-detecting 3D scanners further enhance inspections by identifying wear indicators like discolorations and micro-cracks, enabling early damage detection and reducing the need for manual inspections and expensive repairs. This paper explores the integration of texture data with geometric measurements and discusses the necessary diagnostic software functions.

COMPARATIVE ANALYSIS OF THE MEASUREMENT UNCERTAINTY BUDGET OF HIGH-PERFORMANCE AND HIGH-QUALITY LASER SCANNERS USED ON CMMs

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Comparative analysis of the measurement uncertainty budget of high-performance and high-quality laser scanners used in quality control and reverse engineering on CMMs and identification of the most important metrological characteristics of these devices. Consideration of key aspects in the context of various industrial applications.

Introduction

Among the many scanners offered on the market by companies producing measuring devices, especially coordinate measuring machines (CMM), there are different customs of providing parameters of laser scanners. This leads to arbitrary interpretation and sometimes unconscious choices. An informed choice should take into account the following characteristics.

- High Precision: Offers accurate 3D scanning with high resolution, making it suitable for capturing fine details.
- Lightweight or Heavy: The "Lite" version suggests a more portable and easy-to-handle model compared to heavier, bulkier scanners.
- Versatility: It can be used with various types of coordinate measuring machines (CMMs), portable arms, or other compatible platforms.
- User-Friendly: Designed for ease of use, allowing operators to quickly set up and start scanning with minimal training. II.

Illustrations

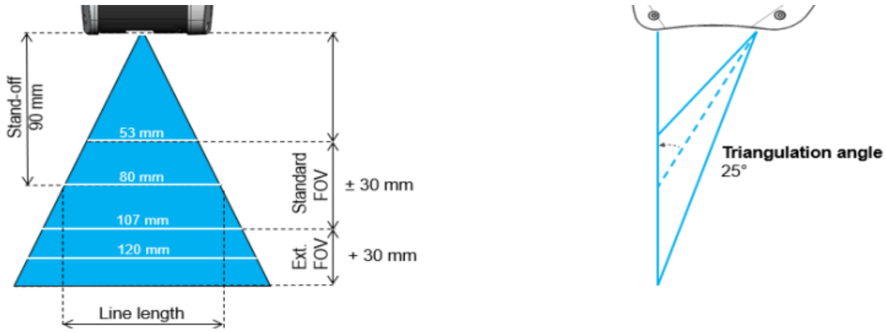

Fig. 1. *FOV as one of the main characteristics influencing other parameters*

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ISO10360-9:2013
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ISO14405-1:2016
ISO14253-1
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Zeiss
Kreon
Nikon/LK
Hexagon
Metrology

NEW KILOGRAM, MASS NANOMETROLOGY AND CHALLENGES FOR POLAND

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Keywords: SI redefinition, Kibble balance, mass nano comparator

The main goal of the lecture is to motivate the Polish metrological community to establish the project of a new mass standard for our country in the context of SI redefinition. A review of the numerous countries' achievements in this field has been done. Additionally, the great success of the Polish industry in the domain of mass nanometrology has been discussed.

Introduction

Over the century the mass difference between the superior standard and the reference copies occurred to be greater than 50 micrograms. This was the motivation for the SI redefinition and the invention of Kibble balance as a non-artefact new mass standard. Unfortunately, Poland lags behind many countries in this aspect, despite the great potential of the Polish metrological industry.

Review and research

The presentation explores the ancient origins of metrology, the inception of the SI, and the recent revolution in the system of units. It explains the principle of the Watt-Kibble balance and quantum standards of electrical quantities. Additionally, it provides a global overview of Watt-Kibble balance projects and highlights the contribution of Polish industry to modern mass metrology. The situation in mass metrology after several years from the SI redefinition is also discussed as well as future trends in mass metrology in the world. Alternative projects with respect to Watt-Kibble balance are mentioned as well as Kibble balance–based standards of other than mass mechanical quantities. The crucial point of the presentation is a discussion on the most appropriate tasks for Poland in the domain of mass metrology. In this context, both mass nanometrology and Watt-Kibble balances for small mass standards are proposed [1,2]. In Fig. 1 the first in the world achieved nanogram precision of the new Polish RADWAG AK-4 automatic mass comparator [1] is demonstrated.

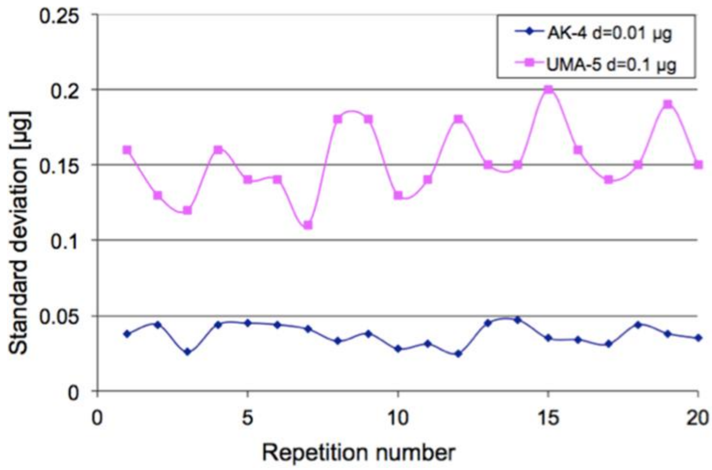

Fig. 1. *Comparison of the standard deviation of innovative RADWAG AK-4 mass nano comparator [1] with that of previous generation UMA-5 device*

Conclusions

There has been a real revolution in the International System of Units (SI), thanks to the abandoning of the artefact-based standard of the kilogram. The new system of units is based on fundamental constants and physical phenomena – not on the artefacts. The Watt-Kibble balance provided a practical implementation of the new mass standard. There is no coordinated, national strategy in Poland after SI redefintion concerning new mass standards. The present analysis points to the small mass Watt-Kibble balances as the most reasonable, innovative solution for Poland (common projects with NIST/USA, LNE/France, UME/Turkey or even NIS/Egipt). Polish industry is actively involved in the development of innovative mass metrology (including mass nanometrology).

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EQUIVALENT SOUND LEVEL SENSITIVITY FACTOR ANALYSIS

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Keywords: sensitivity coefficient, equivalent sound level.

The metrology of environmental noise pollution and interpretation of the obtained results are carried out in the decibel state space. These analyses are related to the Weber-Fechner law, which determines humans' perception of acoustic pressure disturbances. The equivalent sound level is the most commonly used parameter to describe these disturbances. Environmental noise analyses are concentrated in the ranges from 80 dB to 130 dB, considered harmful, and from 45 dB to 80 dB, considered burdensome. Increasingly, in environmental analyses, attention is paid to the range of sound pressure levels from 8 dB to 45 dB, which is associated with the analysis of acoustic comfort. An essential element of the decibel scale analysis are also values from 0 dB to 10 dB, which can be associated with the interpretations of the results: the uncertainty of environmental noise measurements, the effectiveness of improving the acoustic climate, or exceedances of permissible noise levels occurring in the environment, which are most often determined by the Euclidean difference of the noise levels considered.

The question that arises is the interpretation of measurement results in the given ranges of the decibel scale. The authors seek answers to such a question in the analysis of the proposed model of the sensitivity coefficient of the equivalent sound level expressed in the decibel scale, which refers to the logarithm value of the relative energy of acoustic disturbances to the relative energy of acoustic pressure disturbances. The paper analyzed the problem of whether the representation of acoustic disturbances in the decibel scale has a constant value in the entire range of analyzed noise levels.

The results of the simulations showed that for noise levels greater than 30 dB, it can be assumed that the value of the sensitivity coefficient of the equivalent sound level does not change and has a constant and linear course. However, this coefficient does not have this property in the range from 0 dB to 30 dB. In this range of analysis in the decibel scale, the representation of changes in input-to-output quantities of the measurement path occurs nonlinearly.

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ASSESSMENT OF THE STRUCTURAL CONDITION OF COMPOSITE MATERIALS BASED ON FERROMAGNETIC MATERIALS USING A MAGNETIC FIELD CAMERA AND ATHERMAL IMAGING CAMERA

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Keywords: promieniowanie podczerwone, pole magnetyczne, metodyka badań, kompozyty, termografia aktywna.

W pracy przeanalizowano metodę wykorzystującą promieniowanie podczerwone rejestrowane przy pomocy kamery termowizyjnej oraz pole magnetyczne, którego rozkład jest badany przez kamerę pola magnetycznego. Dokonano bezpośredniego porównania obu metod wskazując ich mocne i słabe strony. W pracy zaprezentowano również postępy w realizacji projektu PM-II/SP/0003/2024/02 „Standaryzacja procedury wymiarowania defektów metodą aktywnej termografii w podczerwieni”.

Wprowadzenie

Coraz to powszechniejsze stosowanie materiałów kompozytowych [1] powoduje konieczność opracowywania i wykorzystywania różnego rodzaju badań stanu materiału, a w szczególności badań nieniszczących. Istnieje kilka różnych metod tego typu badań, gdzie każda z nich wykorzystuje inne zjawiska fizyczne występujące w przyrodzie. Istotnym jest dobór właściwej metody do badanego materiału.

O projekcie

Materiały kompozytowe są poddawane badaniom jakościowym już na etapie produkcji. Termografia aktywna jest podstawową techniką diagnostyczną kompozytów. Termografia w podczerwieni została uznana za pełnoprawną metodę nieniszczących:

- **PN-ISO 18434-1:2023-10** (Monitorowanie stanu i diagnostyka maszyn – Termografia -- Część 1: Procedury ogólne).
- **PN-EN 16714:2016** (Badania nieniszczące – Badania termograficzne, Część 1: Zasady ogólne, Część 2: Wyposażenie, Część 3: Terminologia).
- **PN-EN ISO 9712:2022-09** Certyfikacja personelu do badań nieniszczących.

Celem projektu badawczego „Standaryzacja procedury wymiarowania defektów metodą aktywnej termografii w podczerwieni” o numerze PM-II/SP/0003/2024/02 jest zaproponowanie skutecznej i usystematyzowanej procedury pomiarowej do badań nieniszczących wybranych materiałów i obiektów, głównie stosowanych w branży lotniczej i transporcie. Procedura pomiarowa służyć będzie wykrywaniu defektów w strukturze badanego materiału oraz określenie ich lokalizacji i liczby na podstawie analizy sekwencji termogramów.

Zadaniem B+R jest określenie warunków pomiarów, dobór aparatury, sposób automatycznej analizy, interpretacji i raportowania danych pomiarowych tak, aby metodę tę można było stosować w warunkach laboratoryjnych, jak i przemysłowych.

Realizacja projektu została podzielona na poszczególne zadania:

1. Opracowanie metodyki badań właściwości procedury pomiarowej i doposażenie stanowiska w niezbędne akcesoria, w tym optykę zbliżeniową do kamery FLIR T1020 – zakończone. Na fig. 1 przedstawiono doposażone stanowisko badawcze.

Fig. 1. *Stanowisko badawcze*

2. Opracowanie i wytworzenie typoszeregu wzorcowych materiałów odniesienia oraz przykładowych próbek testowych materiałów z defektami – w toku. Na fig. 2 zaprezentowano przykładową próbkę testową z defektami.
3. Optymalizacja procedury pomiarowej dla każdego z typoszeregów wzorcowych materiałów odniesienia – badania modelowe, eksperymentalne – w toku. W tym zadaniu określono dla każdego z typoszeregów wzorcowych materiałów określenie zagadnienia, równania, sprowadzenie do wielkości bezwymiarowych, a następnie rozwiązanie dla impulsu nagrzewania oraz stygnięcia. Na końcu przedstawiono wyniki modelowe i eksperymentalne.

4. Walidacja procedury pomiarowej na przykładowych próbkach testowych o znanych parametrach i rozmiarach; opracowanie rekomendacji procedury pomiarowej.

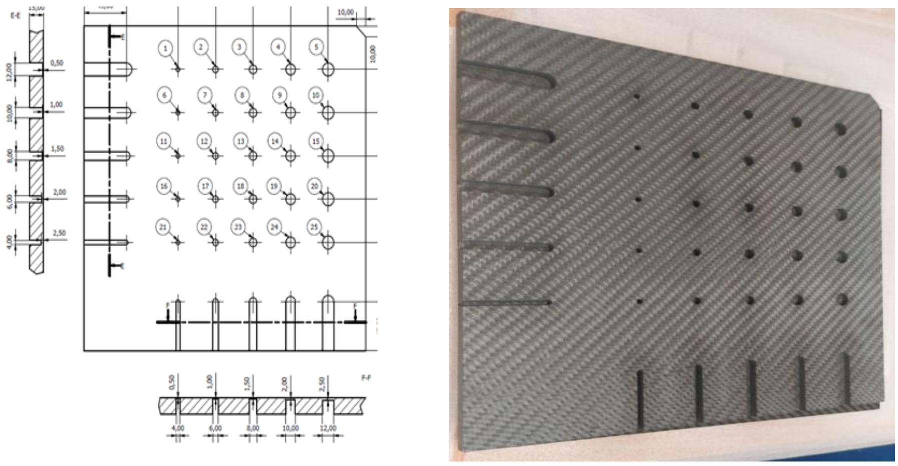

Fig. 2. *Próbka testowa CFRP z defektami – schemat oraz próbka rzeczywiska*

5. Opracowanie sposobu szacowania niepewności wymiarowania defektów ma podstawie analizy sekwencji termogramów uzyskanych metodą aktywnej termografii.
6. Opracowanie końcowego raportu z badań, przykładowego otwartego oprogramowania i skryptu z pseudokodem zawierającego algorytm analizy danych, materiałów promocyjnych.

Spodziewane rezultaty projektu to:

- Opracowanie typoszeregu wzorcowych materiałów odniesienia o właściwościach i geometrii typowych rzeczywistych materiałów i defektów badanych metodą aktywnej termografii; materiały odniesienia będą służyć do wzorcowania i adiustacji stanowiska pomiarowego do wykrywania niejednorodności w strukturze materiałów jednorodnych oraz materiałów złożonych z wielu warstw lub o niejednorodnej strukturze wewnętrznej.
- Opracowanie i sformalizowanie procedury pomiarowej, w tym sposobu analizy i interpretacji danych pomiarowych, szacowania niepewności.
- Zbudowanie prototypu stanowiska pomiarowego do wykrywania i charakteryzacji parametrów defektów metodą aktywnej termografii z zaimplementowaną opracowaną procedurą pomiarową.
- Określenie ograniczeń zaproponowanej procedury pomiarowej i zakresu jej stosowalności w warunkach laboratoryjnych i przemysłowych.

- Opracowanie rekomendacji procedury pomiarowej, tj.: warunków prowadzenia takich pomiarów, doboru aparatury, sposobu analizy danych i wnioskowania pod kątem jest upowszechnienia i potencjalnej komercjalizacji.
- Opracowanie demonstracyjnego oprogramowania użytkowego do analizy i interpretacji sekwencji termogramów.

Badania

Badania przeprowadzane w ramach projektu pozwoliły na wykonanie kolejnych eksperymentów związanych z badaniami nieniszczącymi. Wykonano serie badań próbek kompozytowych opartych o materiały ferromagnetyczne wykorzystując kamerę termowizyjną oraz kamerę pola magnetycznego. Dzięki tym dwóm urządzeniom uzyskano efekt synergii.

Badania eksperymentalne przeprowadzono na stanowisku wyposażonym w kamerę pola magnetycznego MagCam 3D, zainstalowaną na manipulatorze trójosiowym, oraz kamerę termowizyjną IRS336-NDT. System MagCam, wyposażony w matrycę 2D czujników Halla, umożliwia mapowanie pól magnetycznych 3D z dokładnością pomiaru 0,1 mT. Matryca ma rozdzielczość 128x128 punktów pomiarowych, a każdy czujnik Halla ma aktywny obszar 40 μm x 40 μm, co pozwala na precyzyjny rozkład wektora gęstości strumienia magnetycznego (Bx, By, Bz). Badania termograficzne wykonano przy pomocy kamery termowizyjnej IRS336-NDT firmy Technology Automation o rozdzielczości 336x256 pikseli i czułości termicznej <30 mK, w zakresie pomiarowym temperatury od -10°C do 140°C.

Eksperymenty podzielono na dwa etapy. Pierwszy etap dotyczył pomiaru natężenia pola magnetycznego, natomiast podczas drugiego etapu próbkę zbadano przy pomocy kamery termowizyjnej. Lokalizację wtrąceń oraz nieciągłości materiałowych w magnetykach można wykonać metodą upływu strumienia magnetycznego. Możliwe jest również zarejestrowanie temperatur na powierzchni badanej próbki w postaci termogramów dla różnych faz procesu wymiany ciepła. Na fig. 3 przedstawiono wyniki badań próbki referencyjnej (bez wtrąceń) wykonanej z proszku żelaza wymieszanego (75%) z polichlorkiem winylu (25%). Zaprezentowano obraz pola magnetycznego próbki oraz jego rozkład równolegle do osi X (dla Y = 17,5 mm) próbki przy wymuszeniu pola magnetycznego umiejscowionego po środku. W celu efektywniejszego porównywania otrzymywanych wyników wszelkie wartości indukcji zostały przedstawione w wartościach względnych w zakresie od -0,2 do 1. Maksymalna zmierzona indukcja składowej Z wynosiła 0,0654 T i taka też wartość została przyjęta do określenia względnej indukcji dla pozostałych pomiarów.

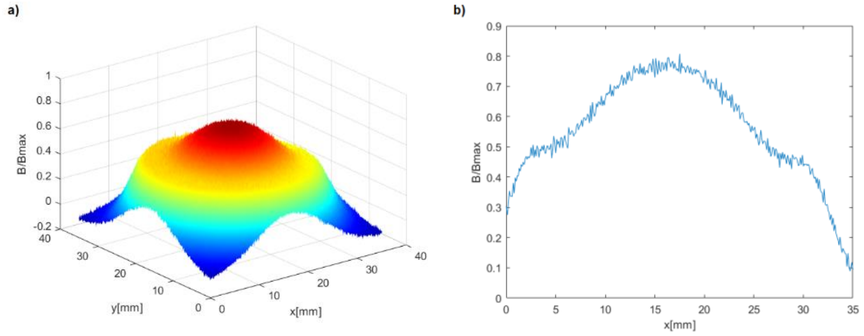

Fig. 3. *Po lewej: a) obraz pola magnetycznego nad powierzchnią badanej próbki referencyjnej: wymuszenie magnetyczne po środku. Po prawej: b) rozkład indukcji magnetycznej nad powierzchnią badanej próbki referencyjnej równolegle do osi X, dla Y = 17,5 mm, wymuszenie magnetyczne po środku*

Fig. 4 przedstawia termogram próbki referencyjnej w 2 sekundzie nagrzewania oraz rozkład temperatury powierzchni badanej próbki wzdłuż osi X (na poziomie 30 piksela osi Y).

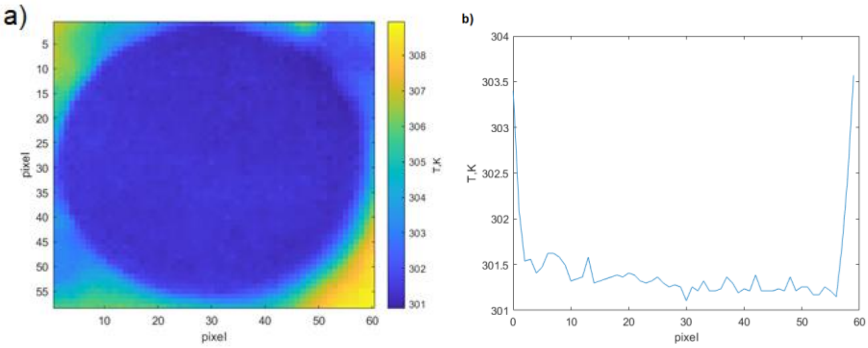

Fig. 4. *Rozkład temperatury a) na powierzchni próbki referencyjnej, b)równolegle do osi X (Y = 30 px)*

Wykonano również próbki z wtrąceniami ferromagnetycznymi, które przebadano w analogiczny sposób. Dla przykładu zaprezentowano próbkę wykonaną z proszku żelaza wymieszanego (75%) z polichlorkiem winylu (25%) z dodatkowym wtrąceniem. Wtrącenie w postaci krążka blachy elektrotechnicznej dodano do środka próbki w czasie jej przygotowywania w laboratorium. Na fig. 5-6 przedstawiono uzyskane wyniki dla ww. próbki.

Wykorzystując metodę progowania lokalnego doprecyzowano dokładne rozmieszczenie wtrącenia ferromagnetycznego w próbce. Wykorzystano metodę median [7], a efekt analizy przedstawiono na fig. 7.

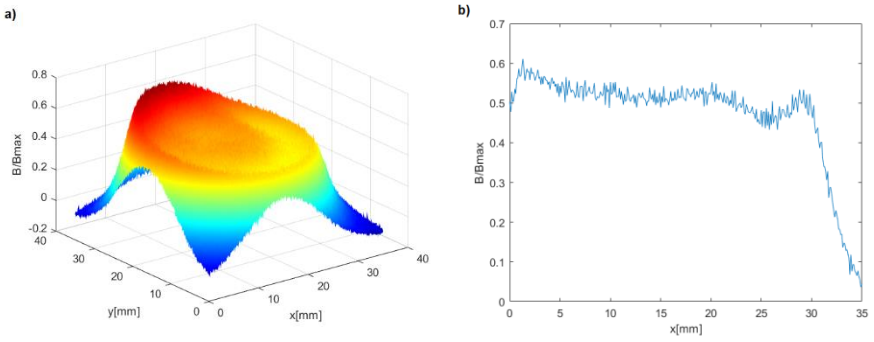

Fig. 5. *Po lewej: a) obraz pola magnetycznego nad powierzchnią badanej próbki z wtrąceniem: wymuszenie magnetyczne po środku. Po prawej: b) rozkład indukcji magnetycznej nad powierzchnią badanej próbki z wtrąceniem równolegle do osi X, dla Y = 17,5 mm, wymuszenie magnetyczne po środku*

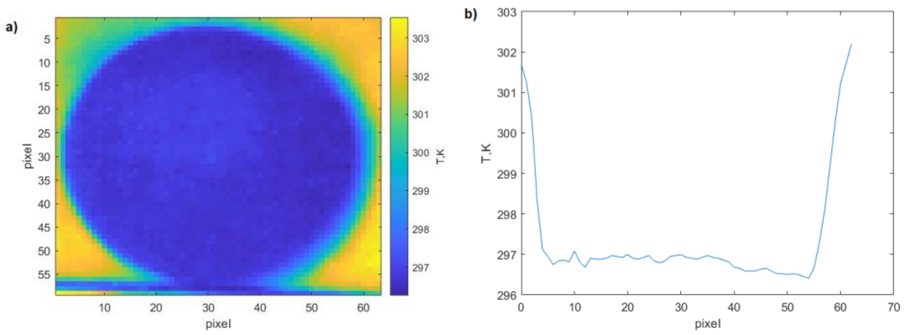

Fig. 6. *Rozkład temperatury a) na powierzchni próbki z wtrąceniem, b)równolegle do osi X (Y = 30 px)*

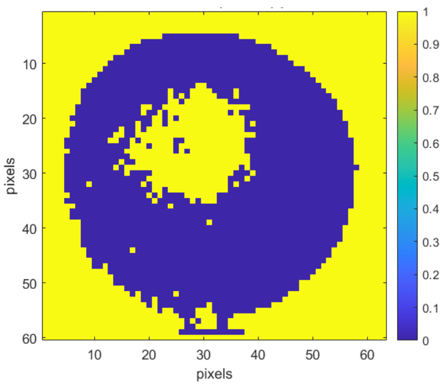

Fig. 7. *Wynik binaryzacji termogramu próbki z wtrąceniem ferromagnetycznym przy wykorzystaniu metody progowania lokalnego (Tau = 2 s, metoda median, s = 0,5, nbsize = 51x51 pikseli)*

Wnioski

Analizując dane, można zauważyć wpływ wtrąceń na pole magnetyczne. Materiał bazowy próbki i wtrącenia są ferromagnetyczne. To znacznie utrudnia analizę pola magnetycznego. Mimo to, w odległości 1 mm od próbki można wykryć wtrącenie. Lokalizacja wtrącenia nie jest jednak precyzyjna. Kamera termowizyjna pozwala na dokładniejsze badania. Dzięki technikom przetwarzania obrazów można jednoznacznie określić obecność wtrącenia. Można także precyzyjnie określić jego lokalizację w próbce.

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3D PERIPHERAL OBJECT SCANNING METHOD FOR X-RAY TOMOGRAPH

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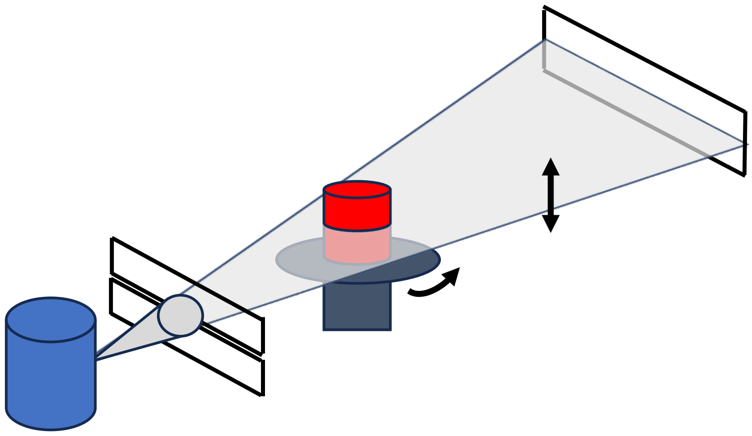
Słowa kluczowe: Skaner X-Ray, Tomografia 3D, metoda skanowania, rekonstrukcja obrazu.

W pracy przedstawiono nowy sposób skanowania obiektów na potrzeby rekonstrukcji 3D. Opisano zasadę działania skanera Rentgenowskiego opartego na nowej metodzie skanowanie. Porównano zaproponowane rozwiązanie z dotychczas stosowanymi oraz zwrócono na wady i zalety zaproponowanego rozwiązania.

Wstęp

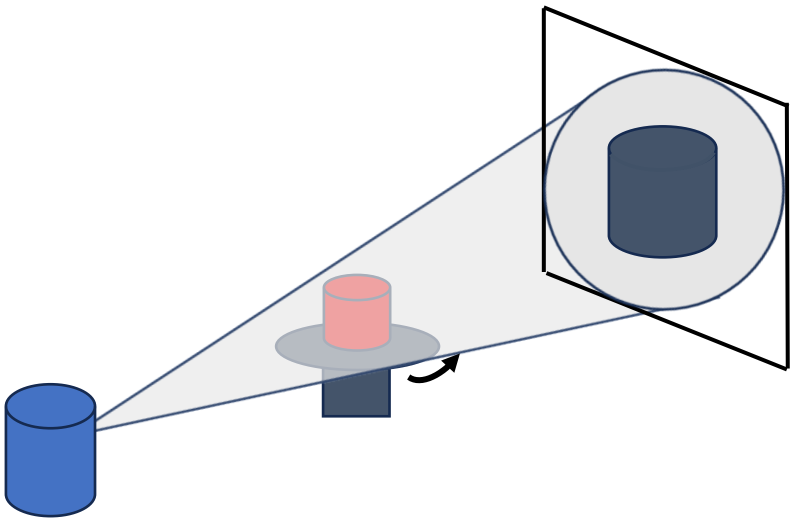
Skanowanie i tworzenie cyfrowych obrazów 3D niejednokrotnie realizowane jest w oparciu o tomografy Rentgenowskie [1]. Są to urządzenia stosunkowo kosztowne, gdzie najdroższym urządzeniem jest detektor. W rozwiązaniach niskobudżetowych stosuje się detektory liniowe (rys. 1).



Rys. 1. *Skanowanie płaską wiązką*

Zasada działania polega na prześwietlaniu obiektu w stosunkowo wąskim przekroju poprzecznym. Detektor liniowy rejestruje rozkład absorpcji promieniowania występujący wzdłuż linii prześwietlania obiektu. Po zaaresztowaniu tego rozkładu następuje obrót przedmiotu o niewielki kąt i ponowne zarejestrowanie rozkładu absorpcji promieniowania. W ten sposób otrzymuje się szereg pomiarów dla różnych kątów prześwietlenia obiektu. Pomiary te stanowią podstawę do zrekonstruowania obraz 2D przekroju obiektu w wybranym obszarze. W kolejnych krokach następuje przesunięcie układu źródło detektor (w górę lub w dół) do kolejnego przekroju i ponowne zrekonstruowanie obrazu 2D dla kolejnego przekroju. Po złożeniu wszystkich obrazów otrzymuje się warstwowy trójwymiarowy obraz przedmiotu.

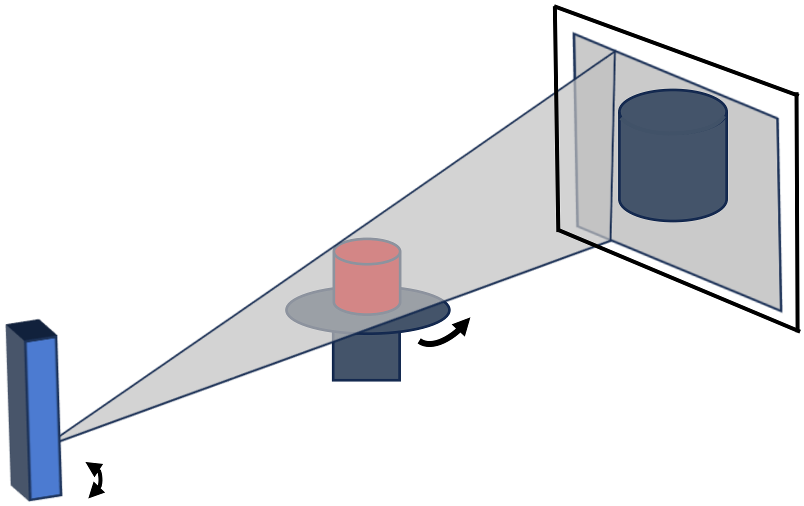
Rozwiązanie to umożliwiające uzyskanie dużych rozdzielczości, a zastosowanie detektora liniowego znacząco obniża koszt tomografu. Jednak czas skanowania jest stosunkowo długi zwykle wynosi on kilkadziesiąt minut.



Rys. 2. *Skanowanie wiązką promieniowania Rentgenowskiego o przekroju kołowym*

Znacznie szybszą metodą skanowania jest zastosowanie rozproszonego źródła promieniowania Rentgenowskiego o kołowym przekroju wiązki promieniowania (rys. 2) [2]. Rozwiązanie to polega na prześwietleniu całego obiektu wiązanką promieniowania Rentgenowskiego bez potrzeby przemieszczenia układu źródło detektor wzdłuż obiektu badanego. Wykonuj się jedynie sekwencję pomiarów dla różnych kątów obrotu przedmiotu. Wymaga to jednak zastosowania detektora powierzchniowego, który jest znacznie droższy od detektora liniowego. Rekonstrukcja obrazu podobnie jak w skanowaniu z detektorem liniowym polega na wyznaczeniu kolejnych obrazów przekroju poprzecznego przedmiotu dla kolejnych poziomych linii obrazy z detektora powierzchniowego. Następnie po złożeniu wszystkich obrazów otrzymuje się warstwowy trójwymiarowy obraz przedmiotu.

Skanowanie z wykorzystaniem rozproszonej wiązki promieniowania o przekroju kołowym jest znacznie szybsze od skanowania za pomocą detektora liniowego, gdyż nie wymaga wielokrotnego obrócenia przedmiotu, lecz wystarczy wykonać jedynie jeden pełły obrót w celu wykonania kompletnej rekonstrukcji. Zastosowanie wiązki o przekroju kołowym powoduje, że promienie promieniowania nie są względem siebie równoległe, co wymaga wprowadzenie odpowiedniej korekty w procesie rekonstrukcji, a przypadku wysokich przedmiotów prowadzi do zniekształcenia trójwymiarowego obrazu przedmiotu.

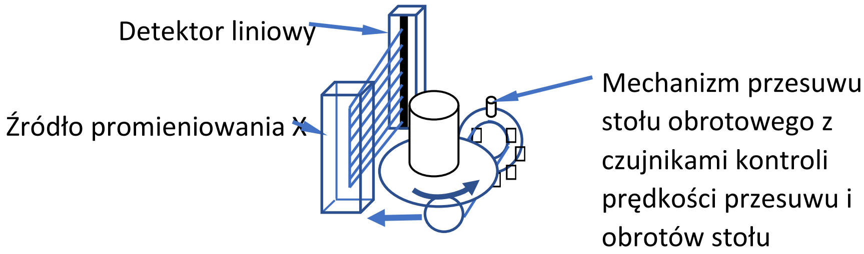


Rys. 3. *Skanowanie wiązką promieniowania Rentgenowskiego o przekroju kołowym*

Trzecim rozwiązaniem jest zastosowanie liniowego źródła promieniowania Rentgenowskiego i detektora powierzchniowego (rys. 3). W tym celu stosuje się liniowe źródło promieniowania rentgenowskiego emitujące równoległe względem siebie promienie promieniowania Rentgenowskiego. W celu prześwietlenia całego przedmiotu źródło promieniowania wykonuje ruch obrotowo zwrotny skanując w ten sposób cała powierzchnię przedmiotu. Ponieważ tego rodzaju ruch wiązki promieniowani można uzyskać poprzez odbicie wiązanki od zwierciadła obrotowego szybkość skanowania jest wielokrotnie wyższa niż w układzie z mechanicznym przemieszczaniem przedmiotu jakie miało miejsce w skanerze z detektorem liniowym. Jest jednak nieco wolniejsze od skanowania z wiązką rozproszona o przekroju kołowym. Ponadto również wymaga zastosowania drogiego detektora powierzchniowego.

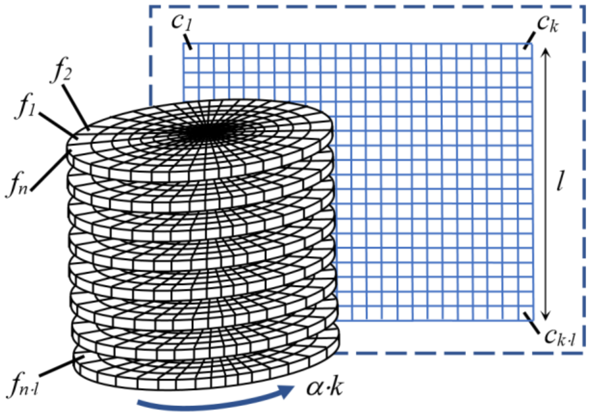
Zaproponowane rozwiązanie

Rozwiązanie autorskie stanowi alternatywę umożliwiającą zastosowanie detektora liniowego przy jednoczesnym ograniczeniu liczby obrotów obiektu i skrócenia czasu skanowania. Budowę tomografu przedstawiono na rysunku 4. W zaproponowanym rozwiązaniu układ detektor źródło promieniowania X jest zamontowane pionowo, względem mechanizmu przesuwającego obiekt, który wykonuje ruch obrotowy. Mechanizm jest tak zsynchronizowany, że na jeden obrót przedmiotu przypada jednostkowy skok przesuwu obiektu. W ten sposób uzyskuje się obraz przedmiotu prześwietlany dla różnych promieni.



Rys. 4. *Skanowanie obiektu dla rozwiązania autorskiego*

Trójwymiarowy obraz jest tworzony na podstawie siatki promieniowej (rys. 5). W rozwiązaniu zaproponowanym przez autora w procesie rekonstrukcji obrazu 3D przestrzeń rekonstruowana składa się ze skończonej liczby vokseli o kształcie wycinków walca. Objętości vokseli nie są równe, lecz zmniejszają się wraz z promieniem. Przy czym liczba vokseli na obwodzie walca jest niezmienna. Tego rodzaju rozłożenie vokseli sprawia, że w środkowej części przestrzeni rekonstruowanej uzyskuje się większa rozdzielczość. Jest to korzystne w przypadku skanowania zarówno dużych obiektów jak i małych, gdyż rozdzielczość będzie proporcjonalna do wielkości obiektu. W porównaniu z klasycznymi metodami wykonuje się o połowę mniej pomiarów, a następnie w procesie rekonstrukcji tyle samo mniej operacji matematycznych. Jest to korzystne ze względu na czas pomiaru i rekonstrukcji. Mniejsza liczba pomiarów prowadzi do gorszej jakości obrazu zrekonstruowanego, jednak wielu zastosowaniach do kontroli np. bagażu duża jakość nie jest wymagana natomiast skrócony czas rekonstrukcji znacznie usprawnia pracę.



Rys. 5. *Siatka rekonstrukcji*

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INTiBS IN PROJECT "DISSEMINATION OF THE REDEFINED KELVIN" OF THE EUROPEAN METROLOGY PARTNERSHIP'S

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The Institute of Low Temperature and Structural Research is the owner of the national temperature standard for the low-temperature range and, as such, holds the status of a Designated Institute within the European Association of National Metrology Institutes (EURAMET) and the International Bureau of Weights and Measures (BIPM). This status provides access to knowledge and the latest trends in global metrology, with a particular focus on temperature metrology. It also enables participation in international projects under the Horizon Europe program within The European Metrology Partnership.

The paper will present the latest project in which the INTiBS is a key partner: the Partnership research project 'Dissemination of the redefined kelvin' (DireK-T), which began in September 2023 and will last for three years. This project is a response to and a continuation of work related to the change in the temperature unit that took place in 2019.The project's goal is to leverage the redefinition of the kelvin to validate primary thermometry methods for direct dissemination of thermodynamic temperature.

Building on the previous Real-K project, which started moving away from ITS-90/PLTS-2000 scales, DireK-T addresses high-level metrology needs by establishing capabilities to measure the difference between thermodynamic temperature (T) and its approximation (T90) above 400 K, aiming for dissemination up to 700 K. The project will demonstrate kelvin dissemination from 4 K to 300 K with defined scale-level uncertainties and develop a framework for traceability through primary thermometry.

DireK-T's outcomes will significantly advance the long-term objective of realizing and disseminating thermodynamic temperatures, ultimately establishing a robust European temperature metrology infrastructure for the measurement supply chain, CIPM, EURAMET, and key industry and academic interested parties.

RESEARCH ON THE POSSIBILITY OF USING THE M1 CALIBRATION BASE FOR CHECKING TOTAL STATIONS IN THE LABORATORY OF NEW TECHNOLOGIES OF TIME AND LENGTH OF THE ŚKLGUM

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Keywords: calibration of geodetic instruments, total station measurements, 3D vectors, master base.

The implemented 3D calibration base called M1 is a measurement pattern for geodetic instruments such as electronic total stations in the Laboratory of New Time and Length Technologies of the ŚKLGUM. On the basis of total station measurements, surveyors measure horizontal and vertical angles and distances to measurement points in the field. Then, in connection with the geodetic control network, they calculate the coordinates of the measured points, which are entered on the master map or many engineering tasks are used. Among other things, to determine structural axes in the construction of single-family, multi-storey and hall buildings, or to monitor, for example, landslides in order to determine hazards. The correctness and compliance with the accuracy criteria of the measurements performed for this type of tasks is a key element. Therefore, it is advisable to create a database that will give the possibility of checking total stations by comparing 1-3D vectors between the points of the base, determined from the coordinates obtained from total stations and the reference vectors. Reference vectors between the base points are obtained by measuring with the Laser Tracker RADIAN PRO (50m) on the basis of measuring the coordinates of the points. The maximum permissible error of the length measurement made with the Laser Tracker (declared by the manufacturer) is 0.7 μm/m. The base reference points are installed on the wall in a room 60 m long and 6 m wide. Measurements with the use of the Laser Tracker and those made with a total station are carried out after placing SMR (Spherically Mounted Retroreflector) prisms on 16 points of the reference base. Vector values are derived from points arranged in the basis sequence.

On the basis of the developed reference base, the geodetic instrument was checked in terms of the determined coordinates of points by measuring the values of angles and distance measurements, as well as testing the repeatability of placing prisms on the measurement points of the reference base. At the same time, the reference database will be the basis for further research and, above all, it will give the opportunity to determine the errors of indications when performing measurements with geodetic total stations.

AN LED-BASED CIE-A ILLUMINANT FOR PHOTOMETRIC APPLICATIONS

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Keywords: LED, CIE-A illuminant, design, photometry.

In the scientific literature, proposals for constructing laboratory standards and sources for various applications based on electroluminescent sources are increasingly encountered. This manuscript describes the research on designing and developing the multichannel LED source to replace the incandescent CIE-A illuminant for photometric applications, for example, in the luminance meter calibration stand.

Introduction

Accelerating metrological infrastructure in photometry towards digital transformation is one of the main goals of the CIE research strategy. Therefore, LED-based illuminant systems are designed for various applications, such as solar energy [1] or biomedical research [2]. Most up-to-date solutions were based on a random selection of LED components and inadequate quality criteria [3]. Recently [4], Japanese NMI presented their construction of an LED-based A-illuminant dedicated to illuminance meter calibration. This work presents the proposed design methodology and the construction of the developed standard source system.

Design and development of the standard source

We proposed a reliable methodology for designing the LED engine for the standard CIE-A illuminant. Two versions of the LED-based CIE-A illuminant were constructed for the tests (Fig. 1). We also designed and developed the stand's mechanical construction and electronics (Fig. 2), which allows testing the performance of illuminance and luminance meters, also for the uniform chromatic light.

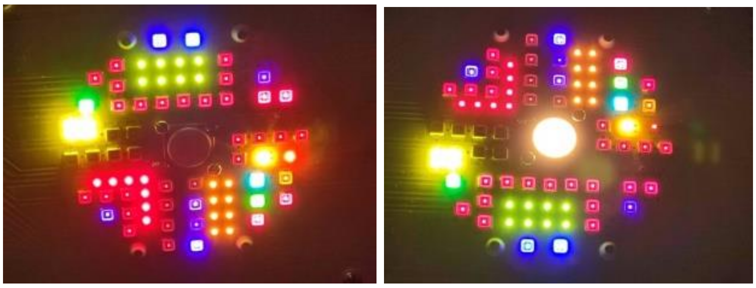

Fig. 1. *Images of the 2 versions of the CIE-A LED illuminant at their maximum luminous flux*

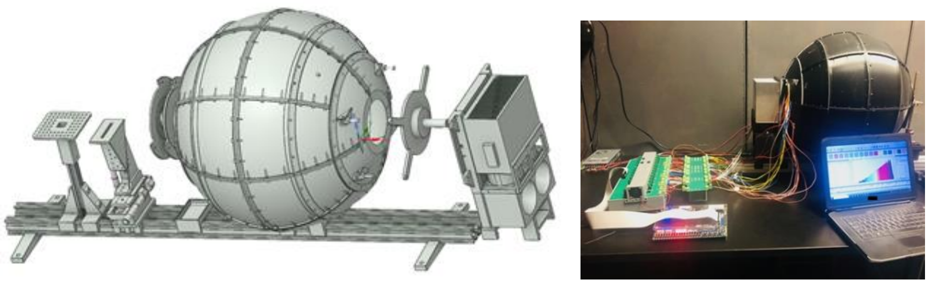

Fig. 2. *Visualization of the laboratory stand and then image of the working system*

Results

The tests performed prove the accordance of the parameters of the system with the assumptions and their stability. The tests were performed for 2 illuminance values at the sphere's exit port (16,57 klx and 26 klx), which allowed obtaining luminances of 4600 cd/m^2 and 7320 cd/m^2, respectively.

Acknowledgements

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FIT OF NONLINEAR CURVES TO MEASUREMENT POINTS USING THE TOTAL WEIGHTED LEAST SQUARES METHOD IN AN APPROXIMATE LINEAR MODEL

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Keywords: Weighted Total Least Squares method, covariance matrix, nonlinear curve fitting.

The paper presents an approximate method of fitting measurement points to parameterized arbitrary nonlinear curves described by complex equations, even implicit ones, the most commonly used method of least squares in general WTLS. An approximation of a linear model is used here, in which the laws of propagation of error and propagation of uncertainty are true, so that only the first derivative of the transforming function is relevant. The effectiveness of the method has been demonstrated in several numerical examples.

Introduction

The In many issues related to the calibration of measuring instruments, we perform measurements at single measurement points, most often defined by two measured coordinates in the Cartesian system, associated with measurement uncertainties. Measurement points do not always fit into a straight line describing the characteristics, but in many cases the characteristics create nonlinear relationships. To determine this type of characteristic, we use the least squares method. Fitting the parameters of a nonlinear curve using the general method of least squares e.g. Weighted Total Least Squares (WTLS) [1-4] method to many measurement points is quite a challenge, and determining the uncertainty corridor around this curve is, despite the enormous computing power of modern computers, a time-consuming task that requires multiple solutions of nonlinear equations.

In order to minimize the computation time, it is proposed to solve the WTLS least squares problem in a linear approximation when the error propagation laws and uncertainty propagation laws are satisfied using the first derivatives of the transformation functions. The approximation used leads to a straight line fit in the new coordinates using the inverse effective covariance matrix.

Examples of fitting to a nonlinear curve with a cut-off change will be presented – a chain curve representing the shape of the overhang of a high-voltage power line, as well as a function involved in the measurement of current and voltage: in a system of a series-connected diode and resistance, as well as to matching the parameters of a complex capacitor model consisting of three resistances and two capacitances.

Verification of the proposed method will be performed by comparison with the Levenberg-Marguardt gradient method, as well as for fitting to a parabolic curve, with the Monte Carlo method applied iteratively.

The presented results of calculations lead to the conclusion that the proposed method allows to obtain almost identical results as the methods used so far, assuming small errors of deviations of the measurement points from the ideal characteristics.

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A NEW DEFINITION OF MEASUREMENT UNCERTAINTY IN THE CONTEXT OF THE GUM APPROACH FOR EVALUATION OF MEASUREMENT DATA

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Keywords: measurement uncertainty, evaluation of measurement data, measurand, propagation of distributions, GUM approach.

The GUM approach, which derives its acronym from the words Guide to Uncertainty of Measurement, has been developed for years by the JCGM (Joint Committee for Guides in Metrology) associated with BIPM (International Bureau of Weights and Measures). This approach concerns the evaluation of measurement data. It is based on the development of an adequate measurement model defined the measurand. For univariate measurement model the measurement result is presented as standard uncertainty, expanded uncertainty or coverage interval with the associated probability distribution as distribution function or probability density function. This distribution is obtained by the method for propagation of distributions through the measurement model. For multivariate measurement model the measurement result is presented as coverage region. The GUM approach is presented in documents published by the JCGM [1-4]. According to this approach the JCGM presents new definition of measurement uncertainty.

Introduction

Joint Committee for Guides in Metrology presents a new definition of measurement uncertainty. The current definition of measurement uncertainty is a parameter associated with the result of a measurement, that characterizes the dispersion of the values that could responsibly be attributed to the measurand, presented in document [1]. This definition is quantitative. The proposition of the new definition is qualitative as a doubt about the value of the measurand that remains after making a measurement. The new definition takes into account the approaches presented in the documents [2] and [3] associated with the numerical method for propagation of distributions. This approach applies to both univariate and multivariate measurement models that described in document [4].

Univariate models

Evaluation of measurement uncertainty for univariate models is presented in document [2]. The evaluation consist of three main stages: formulation, propagation and summarizing. In formulation stage the output quantity Y is defined as the measurand. In this stage the input quantities $\boldsymbol{X} = (X_1, \ldots, X_N)^T$ upon which Y depends are determined and also the model relating Y and $\boldsymbol{X}$ is developed. On the basis of available knowledge a normal or a rectangular distributions are attributed to any $X_1, \ldots, X_N$ input quantities. In propagation stage the probability distribution for an output quantity Y, from the probability distributions assigned to the input quantities $X_1, \ldots, X_N$ through the model, is propagated. In summarizing stage the expectation of Y, taken as an estimate y of the quantity, the standard deviation of Y, taken as the standard uncertainty $u(y)$ associated with y and coverage interval containing Y with specified probability, in general 95 %, are calculated.

Multivariate models

Evaluation of measurement uncertainty for multivariate models is presented in document [3]. The evaluation also consist of three main stages: formulation, propagation and summarizing. In formulation stage the vector output quantity $\boldsymbol{Y} = (Y_1, \ldots, Y_m)^T$ is defined as the vector measurand. In this stage the input quantity $\boldsymbol{X} = (X_1, \ldots, X_N)^T$ upon which $\boldsymbol{Y}$ depends are determined and also the model or measurement function $\boldsymbol{f}$ relating $\boldsymbol{Y}$ and $\boldsymbol{X}$ is developed. On the basis of available knowledge a normal or a rectangular distributions are attributed to the components of input quantity $\boldsymbol{X}$. In propagation stage the probability distributions for components of $\boldsymbol{X}$ through the model are propagated. In summarizing stage the expectation of $\boldsymbol{Y}$, taken as an estimate $\boldsymbol{y}$ of the output quantity, the covariances matrix of $\boldsymbol{Y}$, taken as the covariance matrix $\boldsymbol{U_y}$ associated with $\boldsymbol{y}$ and coverage region containing $\boldsymbol{Y}$ with specified probability, in general 95 %, are calculated.

For explicit multivariate measurement model specifies a relationship between an output quantity and input quantity takes a form $\boldsymbol{Y} = \boldsymbol{f}(\boldsymbol{X})$, where $\boldsymbol{f} = (f_1, \ldots, f_m)^T$. The suitable covariance matrixes for input and output quantities are defined as:

$$\boldsymbol{U_x} = \begin{bmatrix} u^2(x_1) & \ldots & u(x_1, x_N) \\ \vdots & \ddots & \vdots \\ u(x_N, x_1) & \ldots & u^2(x_N) \end{bmatrix} \quad \boldsymbol{U_y} = \begin{bmatrix} u^2(y_1) & \ldots & u(y_1, y_m) \\ \vdots & \ddots & \vdots \\ u(y_m, y_1) & \ldots & u^2(y_m) \end{bmatrix}$$

where $u^2(x_i)$ and $u^2(y_j)$ are a variances but $u(x_i, x_j)$ and $u(y_i, y_j)$ are a covariances.

The covariance matrix is calculated from $\boldsymbol{U_y} = \boldsymbol{C_x} \boldsymbol{U_x} \boldsymbol{C_x}^T$ where $\boldsymbol{C_x}$ is a sensitivity matrix defined as:

$$C_x = \begin{bmatrix} \frac{\partial f_1}{\partial X_1} & \cdots & \frac{\partial f_1}{\partial X_N} \\ \vdots & \ddots & \vdots \\ \frac{\partial f_m}{\partial X_1} & \cdots & \frac{\partial f_m}{\partial X_N} \end{bmatrix}$$

In case of bivariate measurement model the coverage region may be calculated from as the ellipse centered at $\boldsymbol{y}$:

$$(\boldsymbol{\eta} - \boldsymbol{y})^{\mathrm{T}} \boldsymbol{U}_{\boldsymbol{y}}^{-1} (\boldsymbol{\eta} - \boldsymbol{y}) = k_p^2$$

where $\boldsymbol{\eta}$ is a variable describing possible values of output quantity $\boldsymbol{Y}$ and k_p is a coverage factor for a coverage region in the form of ellipsoid corresponding to coverage probability p.

Conclusion

New definition of measurement uncertainty is a qualitative, because it refers to any measurement model. Any quantity can be described fully and quantitatively by a probability distribution on the set of possible values of the measurand. For scalar measurands, measurement uncertainty can be expressed by a standard uncertainty, a coverage interval with specified coverage probability or by selected quantiles of the probability distribution. For multivariate measurands, measurement uncertainty can be described by the covariance matrix or by a coverage region, with specified coverage probability.

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THE IMPORTANCE OF RELIABLE TIME AND FREQUENCY SIGNAL DISTRIBUTION SERVICES IN THE MODERN DIGITAL INDUSTRY: A CASE STUDY OF THE E-CZASPL PROJECT

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Keywords: official time, time and frequency distribution, signal phase modulation.

Sectors of the economy such as transport, energy, telecommunications, banking, and financial markets rely on reliable and trustworthy ICT solutions for time synchronization. In Poland, the authority responsible for generating, maintaining, and distributing official time signals, used to support the growing economy and digital society, is the President of the Central Office of Measures (GUM). To meet the challenges of the modern world, the services provided by GUM in the area of Polish official time distribution must align with the pace of IT development in the various sectors of the economy. Therefore, one of the Office's goals is to reach as many recipients as possible and provide them with services that meet their real needs. To achieve this, it is also necessary to educate the public and raise awareness of the importance of issues addressed by institutions such as the National Metrology Institutes (which in the case of Poland is GUM).

The Central Office of Measures has launched, among other official time related services, a service for broadcasting encoded digital time signals on long waves, using the 225 kHz carrier wave of the First Polish Radio Program, from a transmitter located in the territory of Poland. It is a technique similar to the DCF77 system but based on signal phase modulation. As a result, it is possible to synchronize timekeeping devices in Poland and a large part of Europe with the official time using cheap, energy-efficient, and uncomplicated receiving devices. This technique makes it possible to synchronize many timekeeping devices with an accuracy of a few or several milliseconds to the official time in the territory of the Republic of Poland. The system is an additional (redundant) source of time information for users, which can complement standard techniques such as GNSS or NTP protocol. The above is particularly important in the context of intentional and accidental disruptions and falsifications of time information.

Using digitally coded time signals involves adding an appropriate device (modulator) to the infrastructure for emitting radio waves at RCN Solec Kujawski (PCSK-225) and implementing receivers. The receiver performs its tasks automatically (i.e., determines the official time based on the emitted time signals) after correctly receiving the received signal.

MEASUREMENTS USING PIEZOELECTRIC PRESSURE TRANSDUCERS IN THE ANALYSIS OF CONTACT STRESS DISTRIBUTIONS IN EXTRUSION PROCESSES

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Keywords: piezoresistive transducers, calibration, extrusion, contact stresses, pressure distribution.

The experimental method based on piezoresistive transducers has been presented in this paper.

A high-sensitivity piezoresistive silicon chip is used for pressure sensing. The chip is protected against ambient influences by a stainless steel housing sealed with a concentrically corrugated diaphragm. The housing is filled with silicone oil so as to ensure the transfer of the pressure from the diaphragm to the sensing component. The results of pressure distribution have been shown on contact surface between ram, container and extruded material. The technique of measurement has been analysed as well. Experiments are made using plasticine as a substiute material. This kind of material is used to simulate extrusion process of aluminium alloys in elevated temperatures. The significant differences has been obtained in pressure distribution between symmetric and non - symmetric extrusion process.

Introduction

Piezoelectric measuring transducers use the phenomenon of surface charges in dielectrics under the influence of a specific stress state. It should be noted that the pressure acting on the crystal surface is numerically equal to the stress occurring in the crystal, which causes the induction of electric charges. Due to such properties of the piezoelectric effect, pressure transducers have been used in measuring fast-changing pressures [3].

In the presented research method, the basic element of the measuring system is a KELLER transducer type PA 10 with a measuring range from 0 to 1000 bar (Fig. 1), available in the commercial offer. Plasticine was used as a modelling material. Its suitability for modeling plastic forming processes is described in [2, 6].

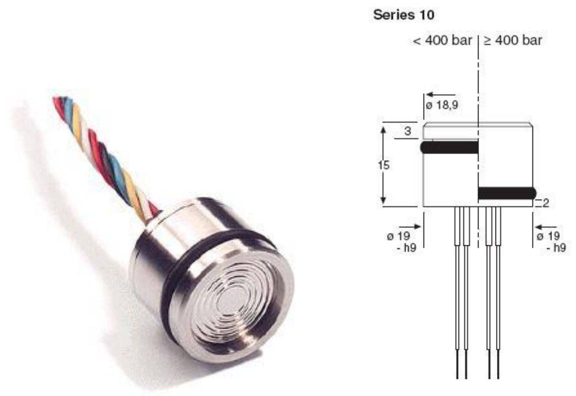

Fig. 1. *Piezoelectric pressure measuring transducer: general view and assembly diagram*

Calibration of measuring transducers

The calibration of the transducer measuring path was carried out on an INSTRON testing machine. Hydrostatic pressure in a closed container was used for this purpose, and plasticine was used as the compressed medium. Therefore, the tests were carried out on the same medium and using the same geometric parameters that were later used in the extrusion process. After applying a specific force on the punch, the transducer measurement signals were recorded. The test was repeated several times to eliminate the phenomenon of compressibility. Each time, pressure was applied in the increasing and then decreasing direction to capture the hysteresis loop. It is shown in Fig. 2.

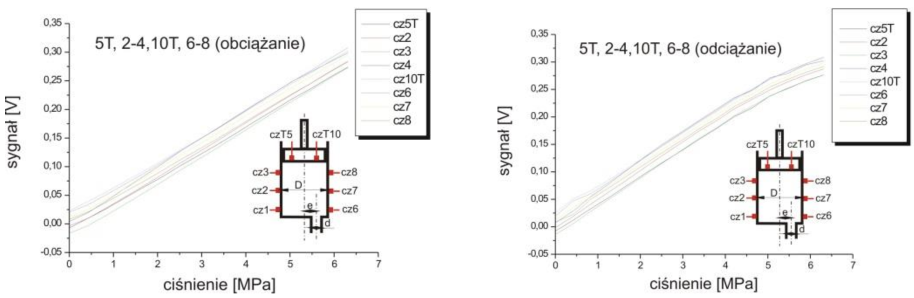

Fig. 2. *Calibration of transducers (loading and unloading tests)*

Measurements and equipment

The measurement signal in the form of voltage changes was transmitted to the MC 201 signal recorder. The signal recorder allowed for simultaneous recording of up to eight individual measurement signals. Two measuring transducers were placed in the piston, the remaining six in the side walls of the container. The measuring station also included a computer. Appropriate software allowed for saving the course of the recorded signals in the form of text files.

Results

The results can be divided into two groups depending on the nature of the modeled process. Plasticine samples were used for the tests. Two materials were prepared that differed primarily in the size of the yield point. The addition of rapeseed oil in the amount of about 10% of the volumetric composition also changed the friction conditions on the contact surface of the model material and the container [1, 4, 5]. Examples of pressure distribution changes during the extrusion process are presented in Fig. 3 and 4 (symmetrical extrusion process and non-symmetrical extrusion process).

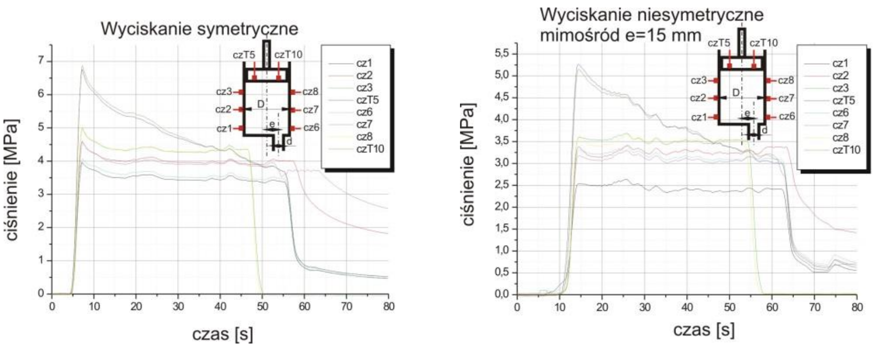

Fig. 3. *Samples of the pressure measurements during extrusion tests*

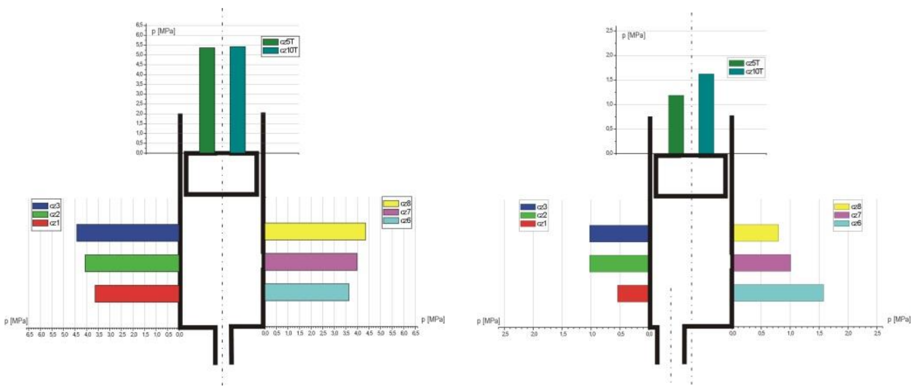

Fig. 4. *Samples of the pressure distribution during extrusion tests*

Conclusions

The method of measuring pressures on the piston and the walls of the container using piezoelectric measuring transducers is an accurate method. For the applied measuring system, it is quite easy to calibrate the measuring path of the transducers, i.e. standardization. The disadvantage of the method is, unfortunately, the relatively high cost of the measuring station, and especially the cost of the transducers themselves. Sometimes the obstacle is the overall dimensions of the transducers.

The experimental results show clear differences between the pressure distributions identified with local contact stresses in the symmetric and asymmetric extrusion process. A strong asymmetry of the contact stress distributions on the container walls and on the piston surface was found in the asymmetric extrusion process (Fig. 4). It is also interesting that this asymmetry is more visible when a die with a lower degree of reduction λ is used. In the case of a large reduction, the pressure distributions also show asymmetry, but it is more leveled by the greater flow resistance. Therefore, in this case we observe distributions somewhat similar to the pressure distributions obtained for the symmetric extrusion tests.

Apart from the high costs of building a test stand, the method of using piezoelectric pressure transducers for analyzing stresses in extrusion processes seems to be the most reasonable. The wide variety of measurement ranges allows the use of various substitute materials for experiments, and to a small extent also metals and their alloys. The main advantage of the presented research method is its high accuracy and sensitivity to changes in the measured values.

Acknowledgments

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DETERMINATION OF CUTTING FORCES IN THE PROCESS OF CONVENTIONAL AND TROCHOIDAL MILLING USING A STRAIN GAUGE MEASURING PLATFORM

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Keywords: milling, cutting forces, measuring platform, trochoidal milling.

The purpose of the work was determination and analysis of cutting forces in the process of conventional and trochoidal milling on the example of aluminum 2017 alloy. Next, a machining strategy, testing guidelines and the possibility of using a measuring platform based on resistance tensometry elements were developed. The paper also presents an analysis of the obtained results concerning the distribution of the cutting forces in the processes of conventional and trochoidal milling, carried out with the same cutting parameters and the same tools. The method of interpretation of the obtained results has been also proposed.

Introduction

Each cutting process, including milling, requires the use of force necessary to deform the cutting layer, separate it from the material in the form of a chip, deform the chip and overcome frictional resistance, occurring mainly between the tool and the processed material [1, 2]. Conventional milling is currently increasingly being replaced by high-performance varieties. This is possible due to the development of the machine tools themselves and the possibilities of programming the processing in CAD/CAM systems. Trochoidal milling, also referred to as TPC (Trochoidal Performance Cutting) and included in the HSM (High Speed Machining) strategy [6], can be distinguished here.

Understanding the nature and distribution of cutting forces during the process is essential for assessing the tool load. The research results can serve technologists and operators of numerically controlled machine tools as a different perspective on changing machining parameters in order to reduce machining times without a sudden increase in the acting forces [3, 4].

Samples and measuring equipment

The sample designed for machining is a 50x50 mm cube with a thickness of 20 mm. In the middle of the element there is an open pocket with a width of

16 mm and a depth of 6 mm, and on both sides there are grooves with a length of 44.5 mm, a width of 12 mm and a depth of 4 mm. The element is shown in Fig. 1. The selected material is the aluminum alloy PA6 (2017). It has a hardness of 101-110 HB.

a) b)

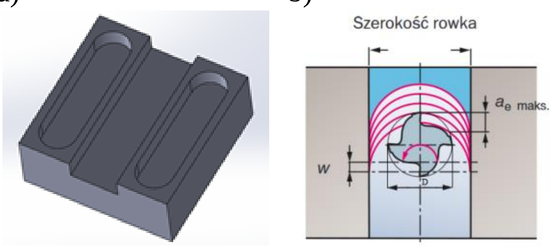

Fig. 1. *The sample being machined: a – visible open pocket and two grooves, b – diagram showing the parameters of trochoidal milling [7]*

The MC6 measuring platform is used to measure forces in perpendicular planes and components of the torque moment [5]. Its construction uses strain gauges mounted on a structure ensuring high stiffness, sensitivity and repeatability of measurements. The design of the transducers ensures stability and negligible mutual influence of the measured values. The solution is protected by a patent: U.S. Patent # 4493220. The housing is made in a waterproof and oil-tight version. The measuring platform is used where it is necessary to simultaneously record several values of forces and moments or to measure changes in their value and sense. The measuring platform used in the tests has 6 outputs corresponding to forces F_x, F_y, F_z and moments M_x, M_y, M_z [5]. The equipment of the station is shown in Fig. 2.

a) b)

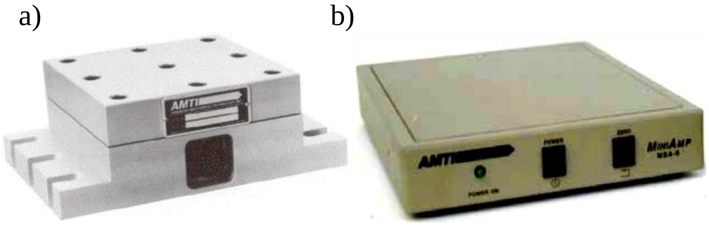

Fig. 2. *Measurement station equipment: a) AMTI MC6-6-4000 measurement platform, b) MiniAmp MSA-6 measuring amplifier*

Results

The obtained results in the form of text files were converted using an Excel spreadsheet into cutting force diagrams obtained for milling with both machining methods using the same tools and the same machining parameters.

Example results regarding the recorded cutting forces during slot milling with a Ø8 mm end mill using the conventional method are presented in Fig. 3 ÷ 5.

Fig. 3. *Graph of the measured force component F_x during slot milling using the conventional method*

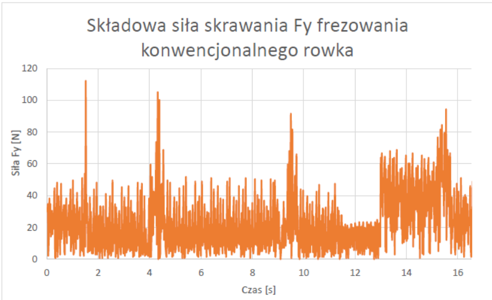

Fig. 4. *Graph of the measured force component F_y during slot milling using the conventional method*

Fig. 5. *Graph of the measured force component F_z during slot milling using the conventional method*

Cutting forces when milling slots with a Ø8 mm end mill using the trochoidal method are shown below (Fig. 6 ÷ 8):

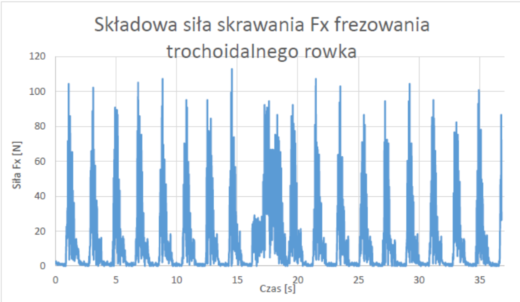

Fig. 6. *Graph of the measured force component F_x during slot milling using the trochoidal method*

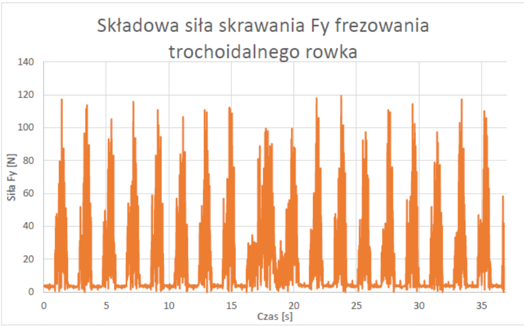

Fig. 7. *Graph of the measured force component F_y during slot milling using the trochoidal method*

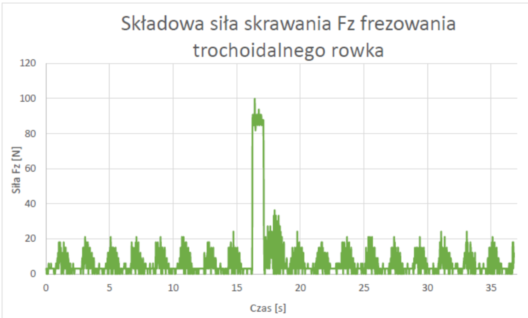

Fig. 8. *Graph of the measured force component F_z during slot milling using the trochoidal method*

Conclusions

The final conclusions are as follow:

- forces in the milling process are not as easy to measure as forces in the turning process, where the blade is in continuous contact with the material being processed,
- using the same machining parameters, the trochoidal milling time was 6 min 13 s and was significantly longer than the conventional machining time of 2 min 51 s, which is caused by the difference in the length of the tool path,
- it is possible to significantly shorten the trochoidal machining time by increasing the cutting depth a_p to a value of approx. 1.5 times the tool diameter, in this case, however, it would not be possible to compare the cutting resistance in both tested processes,
- the comparison of the two machining methods was carried out by analyzing the maximum forces, because averaging the force values, especially in trochoidal machining, is distorted by the moments when the tool is not working and the forces are close to zero,
- after machining using the two milling methods, significant differences in the appearance of the surface could be noticed,
- when machining with a cutter of a smaller diameter in both cases, the cutting forces decreased by half,
- the trochoidal milling machining program is several times longer than the conventional machining program, which indicates the complexity of the tool path.

Based on the presented results, it can be stated that the presented measurement method using a measuring platform, despite the need to use specialist equipment, gives good results, is fast and clear to the user. Additionally, its advantages include high functionality and the possibility of adapting to practically any type of machining procedure.

Acknowledgments

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CONTROLING TENSION AND WEAR DEVICE OF BELTS RUBBER IN THE CONVEYORS

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Keywords: controling device, tension, conveyors, rubber belts damage.

The article presents an innovative, prototype device for monitoring the condition/damage of conveyor belts based on strain gauge sensors placed directly on the idler roller.

The test bench consists of a drive conveyor belt model that allows to adjust the tension of the belt and set the feed rate. The measuring system tested consists of a set of three strain gauges mounted on a passive shaft and electronics communicating with computer via wireless Bluetooth means. Data processing is carried out by a specially prepared program which allows to display and store the received data. All the listed components are author's ideas and elaboration, and the new device for controlling tension and wear of rubber belts in the conveyors has been submitted to the Patent Office of the Republic of Poland.

Introduction

The existing design solutions and the need to ensure failure-free operation of belt conveyors define the main requirements for a system monitoring the condition of the belt during operation and detecting damage at an early stage of its occurrence. A CP152NS strain gauge sensor was used to build the prototype device. Three identical sensors were placed on the passive (return) shaft, which were marked T1, T2 and T3 (fig. 1).

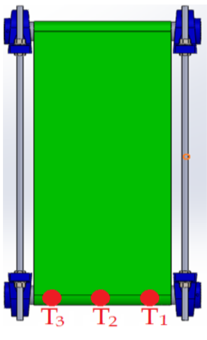

Fig. 1. *3 Indication tension on the shafr*

The test stand consists of a model of a belt conveyor with a drive, which allows for the regulation of the belt tension and setting of its feed speed. The tested measurement system consists of a set of three strain gauges placed on a passive shaft and electronics communicating with a computer via Bluetooth wireless. Data processing is carried out using a specially prepared program, which is intended to display and record the received data. All the listed components are original ideas and developments.

Before starting the tests, the tape was pre-tensioned. Sensor T2, due to its central position relative to the tape at the pre-tension, must be omitted, because its readings depend on the measured value of the tape tension by sensors placed closer to the edges of T1 and T3. The tests used a high-quality commercially available double-fabric tape EDV08PB-AS 2.0, coated with PVC on one side, transversely rigid, green. The technical parameters of the tape used are given in Table 1.

Table 1. *Belts parameter*

Thickness	2 [mm]
Min. working diameter d_{min}	30 [mm]
The force in the rod	F1%=8 [N/mm]
Temperature working range	-10÷80 [°C]

Currently, the initial belt tensioning in conveyors often depends on the knowledgeand experience of the operator or maintenance worker. The use of the new system allows for quick and precise adjustment of the belt tension. The area of research of the innovative device for monitoring the tension and wear of conveyor belts is the test of its damage. Analyses related to the destruction of the tested element are always undesirable due to the costs and the impossibility of performing repetitions, but in this case they were necessary due to the need to determine the actual response of the measuring system to physical damage to the belt. Due to the limitation of the tests to only one conveyor belt, only one test procedure can be carried out. Therefore, a three-stage test procedure was adopted with gradual damage to the belt on both sides, as shown in Fig. 2. The cuts on the right side of the belt are marked as R1, R2, R3, while those on the left as R4, R5, R6. The length of each cut is 5 cm. After each failure the conveyor will operate for about 10 minutes at a speed of f1 = 400 rpm (V1 = 0.5 m/s) taking 10 000 measurement samples. The results of dynamic measurements without load at the same values of operating parameters will be used to interpret the obtained results.

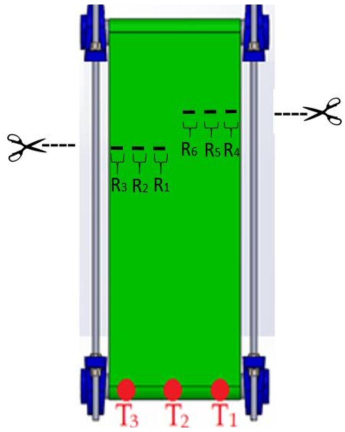

Fig. 2. *Damage place on the belt*

It is obvious that in the event of a complete belt tear, the sensors will send zero measurement signals, which clearly corresponds to the lack of pressure resulting from belt damage on the roller. The idea, however, that led to the construction of an innovative device for monitoring the tension and wear of conveyor belts, was to prevent such a state from occurring. Before starting the tests, the entire system was reset to stabilize the belt operation, the initial tension force is set at 35 N, set for sensors T1 and T3. Due to the predictable behavior of the sensors in the event of a cut on the edges of the belt, it was decided to start the tests by checking the sensor readings in the event of a cut appearing near the center of the belt. Therefore, the first damage was made in the central area at the point marked as R1. In order to provide an illustrative presentation of the correlation between individual cuts, each graph in Fig. 3-4 represents the collective course of the readings of a given sensor T1, T2 and T3 for a sequence of six cuts from R1 to R6. Due to the large amount of data (10 000 samples from each cycle), the graphs are limited to showing three shaft revolutions (approx. 500 samples). This makes the course of changes in the readings more visible.

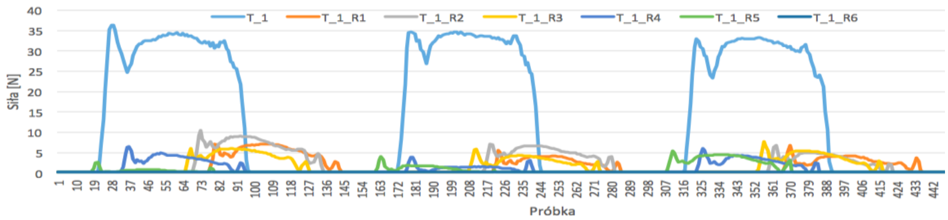

Fig. 3. *The tape pressure readings on the T1 sensor at six cuts, speed f1 = 400 rpm*

As can be seen from the graphs in Fig. 3, in the case of sensor T1, the reaction to belt damage is clearly noticeable. Comparing to the course of the graph during operation without load and without damage (curve marked T_1), one can clearly see a sharp drop in the belt pressure force with the appearance of the cut R1 (curve T_1_R1) and its further reduction due to subsequent cuts. A significant drop in the pressure force is visible after making the cut R4 (curve T_1_R3), which is located directly in the area of sensor T1. The last cut R6 (curve T_1_R6) brought the pressure force to zero: the sensor constantly indicated a value of 0.2 N, which did not change throughout the entire rotation of the shaft.

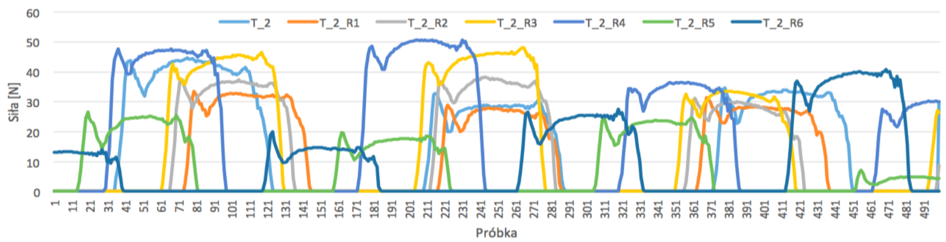

Fig. 4. *The tape pressure readings on the T2 sensor at six cuts, speed f1 = 400 rpm*

In the operation of the T2 sensor (Fig. 4), it is important to note significant differences between the pressure readings in one measurement cycle for both the undamaged tape and after each cut. For example, the T_2_R4 curve reached 50 N at the second rotation of the roller (sample 211), but only 36.5 N at the third (sample 361). Similarly, in the case of the T_2 curve, which corresponds to the operation of the undamaged tape, the pressure at the first rotation was 44.7 N (sample 81), and at the second 28.8 N. As mentioned above, this is a characteristic feature of the operation of the rubber tape. On the other hand, the course of the graphs for the T2 sensor may seem inconsistent with expectations and predictions, because with a greater number of cuts on the tape, the force measured by the sensor increases up to R4, and only the fifth cut R5 causes a decrease in the pressure force F on the T2 sensor. The increase in the pressure force on the T2 sensor is related to the narrowing of the belt area that transfers the load. In this situation, the distribution of pressure forces along the length of the roller changes. A sudden reduction in the pressure force in the damaged area causes it to increase on other sections of the roller length. The entire force tensioning the belt is not concentrated over its entire width but on a narrow strip, within which the T2 sensor is located. The maximum recorded value before complete damage is approx. 26 N (run T_2_R5). It can be noted that the pressures measured by the T2 sensor, located in the middle of the roller length, contain the most useful information, which, in combination with data from other sensors, allows for an adequate current assessment of the condition of the conveyor belt.

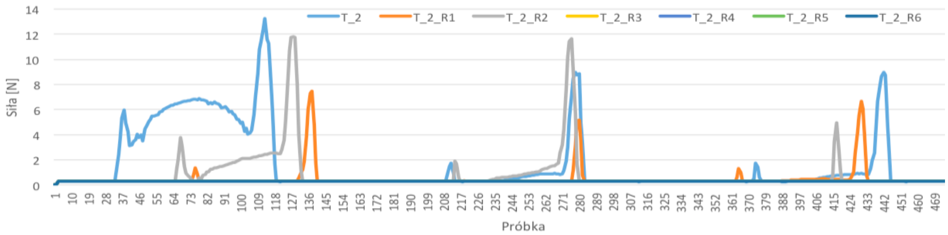

Fig. 5. *The tape pressure readings on the T3 sensor at six cuts, speed f1 = 400 rpm*

The T3 sensor readings are burdened with excessive errors. Apart from a few exceptions, the course of pressure changes is not smooth, but occurs in the form of single peaks, corresponding to the sensor leaving the belt under its operation. This applies to both the no-load and damage-free operating cycle (curve T_2) and the other experiments. Already at the R3 cut, the sensor stopped indicating any values. The probable cause of this is mechanical damage to the strain gauge sensor. Unfortunately, the damaged conveyor belt does not allow for repeating measurements for this sensor.

During no-load operation, the pressures on the middle sensor T2 are slightly higher, averaging 35.6 N compared to 33.9 N for T1. As expected, after the damage of the belt by the cut R1, a reduction in the pressures on both sensors was observed, with the pressure for sensor T1 decreasing by 84% from 33.9 to 5.2 N. The cut R2 increased the pressures on both sensors, but the readings of T1 remained significantly lower (approx. 7 N) than before, while the readings of T2 returned to the previous level of 35.1 N. The cutting of R3 and R4 resulted in a further reduction in the pressure on sensor T1, but an increase in the pressure on sensor T2. The middle part of the belt apparently took over the tension force, which was reduced in the areas closer to the edges due to the damage. The cut R5 caused a significant weakening of the tension of the entire belt, which was manifested by a 50% drop in the pressure force on the T2 sensor, from 44.8 to 22.3 N. Further damage to R6 caused the belt to loosen completely in the area of the T2 sensor, which only indicated the presence of the belt, registering a pressure close to zero F=0.23N. At the same time, the pressure force on the T2 sensor increased by 17%, which again indicates that the load was being taken over by the central part of the belt. The readings of the T3 sensor would certainly significantly broaden the picture of the distribution of the belt pressure force along the length of the shaft, providing adequate information about its damage, but during the experiments it was not possible to obtain correct results from it.

As a result of the obtained data, the correctness of the design and operational assumptions of the prototype device for monitoring damage to conveyor belts was confirmed, the principle of operation of which and the obtained data can be used to work in the 4.0 environment. Both static and dynamic tests proved that the new measurement system using strain gauges placed on the surface of the roller can monitor the condition of the belt during the operation of the conveyor. It is possible to check the correctness of the belt tension at the initial setting, detect the belt load and damage in real time. Already at this stage it is possible to indicate on the graph the areas of correct operation and the ranges of anomalies, indicating additional loads or damage.

Based on the results obtained, the project was expanded to include additional elements, including sensors placed around the entire circumference of the roller. The expansion of the issue is the area of the next doctoral thesis, which also includes the use of artificial intelligence to analyze data with already obtained positive effects.

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ANALYSIS OF FEED FORCE AND RECURRENCE QUANTIFICATIONS DURING DRILLING OF POLYMER COMPOSITES WITH GLASS, CARBON AND ARAMID FIBERS

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Keywords: polymer composites, drilling, feed force, recurrence analysis.

Composites after production are subjected to machining in order to achieve the expected surface quality. Holes, undercuts and surface leveling are made in these materials. One of the common machining methods after removing the composite from the mold is drilling. The article presents the results of feed force measurements during drilling of polymer composites with glass, carbon and aramid fibers. This machining was performed as drilling in the full composite material and secondary drilling. During the research, the measured feed force allowed to determine the relationship between the type of drilling and the size of the force. In addition, the novelty in the work is the use of measured forces for recurrence analysis. The analysis allowed to determine recurrence quantifications sensitive to the drilling method and the type of composite being machined.

Introduction

Machining methods such as drilling [1, 2], milling [3, 4] and turning [5, 6] are used to obtain accurate surfaces, shapes and dimensional tolerances. After removal from the mold, the material does not have a suitably accurate and smooth surface, which is why it requires further machining. Polymer composites are materials classified as difficult to machine due to the fact that they consist of several components with different properties. Composite materials require appropriate tools and machining conditions. Drilling is a very popular and widely used machining method aimed at producing holes with high accuracy. Drilling of polymer composites is most often performed using diamond-coated (PCD) tools and drills made of tungsten carbide coated with titanium nitride [7]. Selection of appropriate drilling parameters is important due to cutting forces, surface roughness and delamination. Increasing the feed causes an increase in the cutting

force, while increasing the cutting speed causes a decrease in the cutting force [8]. During drilling, a small feed rate causes an increase in the tool temperature.

Methodology

The drilling and secondary drilling were conducted under different feed per revolution and cutting speed for the each composite materials. The parameters are showed in Table 1.

Table 1. *Cutting speed and feed in drilling composite materials*

Lp.	1	2	3	4	5	6	7	8
feed per revolution [mm/rev]	0.1	0.15	0.2	0.3	0.15	0.15	0.15	0.15
cutting speed [m/min]	60	60	60	60	15	30	60	90

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STUDY OF THE EFFECT OF PRE-TREATMENT ON THE PROPERTIES OF THE SURFACE LAYER OF OBJECTS AFTER VIBRATORY SHOT PEENING

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Keywords: vibratory shot peening, surface roughness, surface topography, microhardness, residual stress, ANOVA analysis.

The study investigated the influence of the pre-treatment on the condition of the surface layer after vibratory shot peening. The pre-treatment was milling with variable feed, grinding and lapping. As a result of the pre-treatment, variable properties of the surface layer were obtained after the vibratory shot peening. The tested properties of the surface layer were: surface roughness, topography, microhardness and residual stresses. The obtained results were statistically processed. The one-way ANOVA analysis of variance confirmed the assumption that the type of pre-treatment affects the tested properties of the surface layer after vibratory shot peening.

Introduction

The technological process of production has a significant impact on the functional properties of the manufactured items, such as fatigue life, tribological wear resistance, and corrosion resistance [1-3]. The functional characteristics of objects are related to the state of the surface layer formed during their production process. A study of the correlation of surface layer properties, such as surface roughness, microhardness and residual stress, with the fatigue life of Ti6Al4V titanium alloy specimens subjected to burnishing with variable feed and variable force was conducted by the authors of [4]. In the work [5] it was shown that the condition of the surface layer also affects the friction coefficient, abrasive wear and corrosion resistance.

The methods of finishing machine elements, mainly used to shape the surface layer in a way that has a positive effect on the functional properties of these elements, include burnishing and shot peening [6, 7]. Changes in the properties of the surface layer in the burnishing process occur as a result of plastic deformation of this layer caused by the static impact of the tool with a specific force on the processed material [8-10].

The properties of the surface layer formed during burnishing and shot peening depend on many factors. The authors of many works present the results of research on the influence of technological process parameters on the condition of the surface layer [11, 12]. On the other hand, the works [13, 14] showed that the properties of the surface layer formed in the process of manufacturing objects depend not only on the finishing but also on the treatments to which these objects were previously subjected.

The aim of this study was to evaluate the influence of the pre-treatments, namely milling with variable feed, grinding and lapping, on the properties of the surface layer of the processed samples after vibratory shot peening.

Methodology

In the study, samples were used, made of C45 steel, which were preliminarily subjected to various pre-treatment methods, i.e. milling with variable feed, grinding and lapping. Table 1 presents the technological parameters of pre-treatments.

Tab. 1. *Technological parameters of pre-treatment*

Symbol of samples	**Technology**	**Paramters**
N	milling	f_z = 0.05 mm/tooth, n = 220 rev./min, a_p = 0.5 mm
L	milling	f_z = 0.15 mm/tooth, n = 220 rev./min, a_p = 0.5 mm
E	milling	f_z = 0.23 mm/tooth, n = 220 rev./min, a_p = 0.5 mm
Y	grinding	v_f = 3 mm/min, n = 3000 rev./min, a_p = 0.05 mm
S	lapping	hand lapping, electrocorundum lapping stone

In the next step, the rectangular samples were subjected to vibratory shot peening, which was carried out on a mechanical-kinematic vibrator using the parameters presented in Table 2.

Tab. 2. *Vibratory Shot Peening Technological Parameters*

No.	Ball diameter d_k, mm	Time t, min
1	3	7
2	14	
3	6	1
4		7
5		25

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MICROSCOPIC EXAMINATION OF SURFACE MORPHOLOGY AND GEOMETRIC FEATURES OF ALUMINUM-SILICON MULTILAYER STRUCTURES UNDER VARIOUS WATER JET CUTTING CONDITIONS

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Keywords: surface morphology, 3d geometry, water jet cutting, aluminum-silicon alloy, surface roughness.

This study investigates the 3D surface geometry and microscopic morphology of aluminum-silicon multilayer structures after water jet cutting. Using an Eckert hydro-abrasive cutter and Alicona microscope, the research analyzed surface roughness parameters (Sa, Sq, Ssk, Sku) under varying feed rates and abrasive flow rates. Measurements were taken for three areas: the aluminum surface, the silicone surface, and the interphase region. Results showed a consistent increase in roughness with changes in cutting conditions, modeled by a second-degree regression function. These findings provide insights into optimizing water jet cutting to improve surface quality and minimize delamination in aluminum-silicon structures.

Introduction

Hydro-abrasive processing is an innovative and unconventional method of material treatment increasingly utilized in industrial applications. This method employs high-pressure water jets to achieve the desired cutting effect, with velocities reaching up to 1000 m/s, made possible by high-pressure pumps operating at pressures of up to 400 MPa, or even 600 MPa in advanced systems. There are two main types of water jet cutting heads: one that uses only water (Water Jet - WJ) and another that incorporates abrasive material (Abrasive Water Jet - AWJ).

In water jet cutting, the relationship between feed rate and mass flow rate of the abrasive significantly affects the quality and characteristics of the cut. Lower feed rates combined with higher abrasive mass flow rates tend to increase delamination, particularly in multilayer structures like those involving AW-5754 aluminum alloy and silicone. This is attributed to an uneven distribution of kinetic energy and the presence of the Rebinder effect, which facilitates the delamination process.

Research

This study investigates the microscopic morphology and 3D surface geometry of multilayer structures, specifically aluminum-silicon type, subjected to water jet cutting under varying conditions. An Eckert hydro-abrasive cutter was employed to produce the samples, and surface analysis was conducted using an Alicona microscope. The study focused on 3D spatial roughness parameters such as Sa (arithmetical mean height), Sq (root mean square height), Ssk (skewness), and Sku (kurtosis).

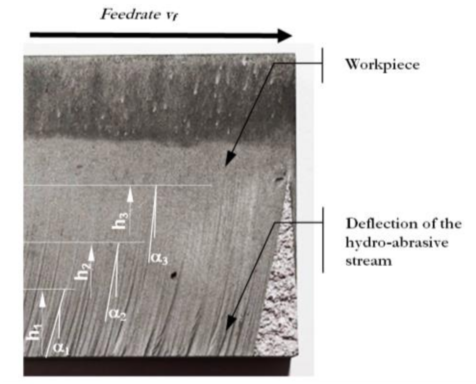

Fig. 1. *The surface after the hydroabrasive jet cutting process, the arrow marks the direction of cutting with the feed motion speed $v_{f.}$*

The experimental results were represented through a second-degree regression model, with relevant determination coefficients calculated to validate the model's accuracy. An upward trend was observed in the roughness characteristics as a function of the feed rate, indicating progressive changes across the entire range of tested input values. These findings provide valuable insights into optimizing water jet cutting processes for aluminum-silicon multilayer structures by adjusting feed rates and abrasive flow rates to achieve the desired surface quality and minimize delamination. Fig. 1 The surface after the hydroabrasive jet cutting process, the arrow marks the direction of cutting with the feed motion speed $v_{f.}$

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THE CONCEPT OF AN ELECTRONIC SEAT CONTROL SYSTEM

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Keywords: pressure sensors, rider's seat, load on the horse's back.

The rider's seat is considered the most important equestrian aid, and its effective influence allows full control of the horse and full use of its physical and mental capabilities. A technically correct and balanced seat allows for maximum harmony between the horse and the rider, which in turn translates into lightness and freedom of movement of the horse in full balance. The rider's seat should be balanced, straight but not stiff, which allows for even load on the horse's back. It has been proven many times that seat errors and loss of balance of the rider adversely affect the horse's back, which in turn leads to spine pain, disturbances in the functioning of the thoracic and pelvic limbs, loss of rhythm during movement and mental discomfort. The aim of the study was to determine the effectiveness of the sensors, determined on the basis of pressure changes in airbags of our own design, placed between the saddle and the horse's back, which would allow for the assessment of the flexibility and correctness of the rider's seat, as well as the strength of its influence on individual parts of the horse's back.

Introduction

The task of the rider's seat control system was to determine its correctness. For this purpose, airbags were used placed between the saddle and the horse's back. For research purposes, a Winderen corrective saddle pad was used, whose design properties allowed for easy placement of airbags inside.

The introduction of airbags between the inner layers of the pad means that the horse taking part in the study did not feel any difference between everyday work and work during the collection of measurement data. Four airbags were placed in the pad, two of which worked independently and two were connected in a pair (both airbags had the same pressure). A pair of pillows was placed under the front of the saddle, which enabled the analysis of changes in the impact of the rider's seat on the front pommel. Separated cushions were placed under the back of the saddle, which made it possible to test the impact of the rider's seat on the pommel with additional separation into the left and right sides, which enabled, for example, the detection of balance problems or asymmetries resulting from defects in the horse's structure. The arrangement of the pillows is shown in Figure 1.

In the process of preparing the system for testing, the pad was placed in a 20 mm high pocket, and then all pads were filled with air to obtain the same initial pressure (100 kPa), which ensured repeatability of measurements during the tests.

The consequence of the impact of the rider's seat were changes in the air pressure in the cushions. The air from the cushions was led outside the saddle using thin pneumatic tubes and then introduced to micromechanical, piezoresistive semiconductor pressure sensors type MPXHZ6400A from Freescale Semiconductor. The above pressure sensors were in the system a converter of a physical quantity, which was pressure, into an elec-trical value in the form of output voltage. Voltage signals from three pressure sensors (one for the front airbag and two for the rear airbags) were fed through wires to the measurement and transmission system, where they were converted into digital form and sent via radio link to the receiving system connected to the computer. The structure of the system is presented in Figure 1.

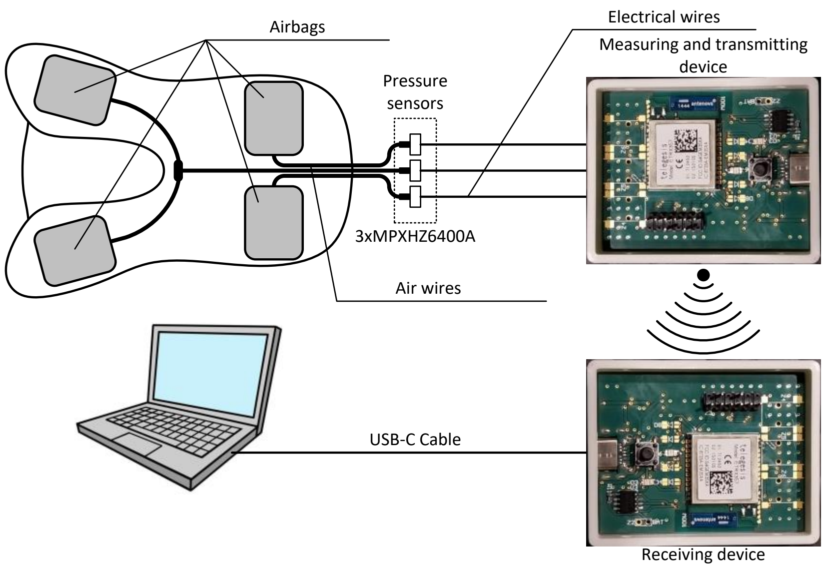

Fig. 1. *The structure of the electronic rider's seat control system*

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CHARACTERIZATION OF SURFACE NANOSTRUCTURES OF NATURAL SAMPLES FOR CALIBRATION MEASUREMENTS

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Keywords: scanning tunneling microscopy, crystal structure, atomic surface, Au(111), Matlab. Gwyddion, thermal drift, post-processing correction, piezoelectric actuator nonlinearities.

The dynamic technological progress of recent years is associated with the miniaturization of electronic devices. Research laboratories are increasingly equipped with scanning probe microscopes, which allow for the study of effects on an atomic scale, which is crucial for the development of new technologies. However, because of the relatively recent invention of this type of microscope, its widespread availability has only occurred in recent years, hence many laboratories do not yet have developed calibration procedures. Numerous effects at the atomic level and imperfections of research equipment affect the level of complexity of measurements, which means that operating microscopes requires a lot of user experience. In this work, we presented the results of measurements and post processing of the surface of Au(111) sample. The experiment was performed on the high purity single crystal, with the face centred cubic (FCC) structure produced by Czochralski method. We showed how the occurrence of artifacts resulting from the properties of the equipment components, affects the image deformation. We measured the distance between atoms and height of monoatomic steps allowing to determine calibration factors. We also used post-processing technique to correct the distortion due to thermal drift, hysteresis, and creep (DHCT) resulting from piezoelectric actuator nonlinearities [1]. Reduction of scan-line noise was performed using the linear-regression fitting method [2]. Processing of the obtained raw scans and distortion correction was performed using Matlab and Gwyddion [3] software. The surfaces were imaged using scanning tunneling microscope SPM Aarhus 150 (SPECS & University of Aarhus) operating under the pressure of 10-10 mbar in room temperature, at the Department of Atomic Physics and Nanophysics (Jan Kochanowski University, Kielce, Poland).

Acknowledgment

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DETERMINATION OF THE DIELECTRIC PERMITTIVITY SPECTRUM OF RAPESEEDS DEPENDING ON THEIR RIPENING STAGE

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Keywords: dielectric permittivity spectrum, rapeseed.

The paper presents an analysis of the dielectric permittivity spectrum in the frequency range of 20-500 MHz depending on the stage of rapeseed ripening stage. Measurements were performed 30 days before rapeseed harvest.

Introduction

Germination capacity is one of the key parameters of rapeseed. It is determined according to the methodology described in the Polish Standard [1]. Based on germination capacity, it is possible to assess the development stage of the plant before harvest. Unfortunately, although this method is very accurate, it has a major disadvantage - it is time-consuming. The aim of the work is to develop a new method for assessing the germination capacity of rapeseed.

Materials and methods

The vector network analyzer LibreVNA and 3 measuring probes were used for the research: antenna, open-ended, and a seven-rod probe. 30 days before harvest, seed samples were taken from the field and the dielectric permittivity spectrum was determined in the frequency range of 20-500 MHz. At the same time, moisture content of the collected seeds was measured because it has a large impact on the dielectric permittivity spectrum.

Acknowledgment

The research was supported by the projects: Miniatura 7, DEC-2023/07/X/ST2/00735

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HIGH-PRECISION SMALL-ANGLE MEASUREMENT INTERFEROMETER BASED SYSTEM

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An angle-measuring system based on an optical interferometer for high-resolution angle measurement is proposed. The system is based on high precission rotary table RT-300 and Renishaw interferometer XL-80. The principle of operation is based on sine rule, using concept "ratio of two lengths" and allow to measuring angle in the range ±5 degrees. In the system, angle measurement is obtained by measuring the separation of the retro-reflectors in the angular reflector and the optical path difference between two absolute optical path length. The RT-300 rotary table, in vertical direction is guided by a vacuum-air-bearing with a brake without lateral force. In radial direction the table has a stable air bearing. For the motion, 4 piezo motors are built on in each corner. As measuring-system a high precision encoder is used. The proposed system can be used for a variety of metrology applications such as: measurement of rotary axes, measurement of pitch or yaw errors in linear axes of motion with pitch table or measurement of guide-way straightness or table flatness by taking a sequence of angular measurements.

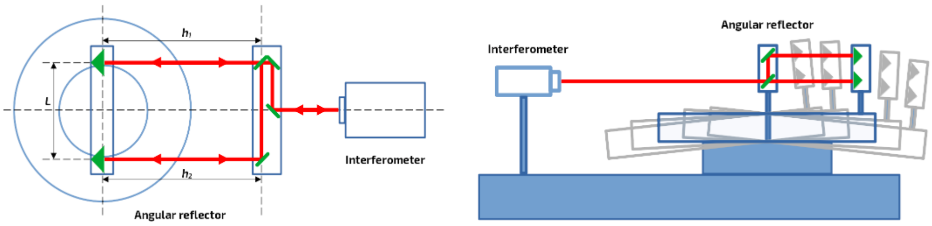

Fig. 1. *Sketch of the measuring system to small-angle measurement – top view (Left), and to pitch or yaw measurement – side view (Right)*

APPLICATION OF MACHINE LEARNING IN OPTIMIZATION OF COORDINATE MEASUREMENT STARTEGIES

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Keywords: coordinate measuring machine (CMM), machine learning, touch trigger probe, dimensional measurement, artificial intelligence.

Implementation of machine learning and AI in metrology is still a new and undiscovered area which in result of research may help in automatization of industrial measuring processes, reducing human error and optimize inspection processes. In current research conducted with Zeiss Contura coordinate machine, diameter of a hole was measured with various values of measuring speed and number of measurements points. Regression models were created to predict measurement deviation of the hole diameter.

Increasing the level of automation of the different tasks involved in the planning of activities in a production cycle, as well as maintain high accuracy quality control; this is a growing concern of production engineers. Some steps leading to decrease human error in the process were taken, such as generating the measurement plans and other activities, ex. automated inspection planning, probe calibration programs. In particular, in measurement planning, there are only few guidelines regarding setting parameters. Before an operator defines measuring speed or number of measurements points. These parameters have values suggested by manufacturer of coordinate measuring machine (CMM), but they are only recommended and setting the optimal values is the responsibility of the operator himself. Consequently, the coordinate measurements results may vary from one operator to another, depending on the accepted values.

The research presented here was conducted on 29.5 mm diameter hole (Fig. 1). Measuring speed ranged from 1.5 mm/s to 16.5 mm/s and number of points from 200 to 12000. Each measuring strategy with set parameters was repeated 3 times for certainty of the results. Measurements were performed using the Contura machine equipped with the active scanning head VAST XT from ZEISS, along with the Calypso software.

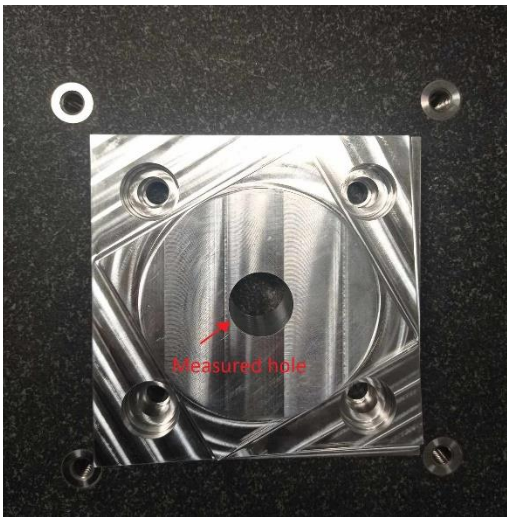

Fig. 1. *Measured part*

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ACCURACY OF THIN-WALLED ELEMENTS MANUFACTURED WITH END MILLS OF DIFFERENT STIFFNESSES

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Keywords: thin-walled elements, stiffness, milling, High Speed Cutting, end mill.

In modern designs, especially aircraft, the aim is to reduce the weight of components. It requires the use of new construction materials or manufacturing these elements with increasingly thinner wall thicknesses. Such structures often have a complicated (thin-walled) geometry with deep pockets, which forces the use of tools of considerable lengths and small diameters, and therefore of low stiffness. This paper presents a determination of the influence of static stiffnesses of end mills on the results of machining thin-walled elements. Machining tests were carried out with different cutting speeds. It allowed for a comparison of the geometric accuracy of parts manufactured under conventional machining and High Speed Cutting conditions.

Introduction

The variable geometry of the cutting layer (typical of milling) translates into periodic changes in cutting force. It causes self-excited vibrations, which have an adverse effect on the accuracy of the machined elements. It is particularly important during milling with tools of low stiffness. The use of an appropriate cutting speed can minimize the occurrence of self-vibrations and stabilize the cutting process. Additionally, High Speed Cutting is characterized by reduced cutting force, which translates into smaller deformations of both the workpiece and the tool.

Methodology

Cutting tests were carried out on the AVIA VMC 800HS vertical machining center. Thin-walled samples with wall dimensions of 0.7x20x90 mm (thickness x height x length) were made of the EN AW-7050 T7451 aluminum alloy. Custom-made two-flute end mills of FENES with different lengths ranging from 60 to 140 mm were used. Their stiffnesses were determined by experimental modal analysis. A variable cutting speed was used (v_c = 150-900 m/min with a step of 150 m/min). The remaining cutting parameters were constant (f_z = 0.07 mm/tooth, a_p = 20 mm). Accuracy measurements of thin-walled elements were performed directly on the machine tool using the TS640 inspection probe of Heidenhain.

Results

Fig. 1 shows exemplary outlines of the side surface of the walls machined at a cutting speed of v_c = 600 m/min with tools of different stiffnesses.

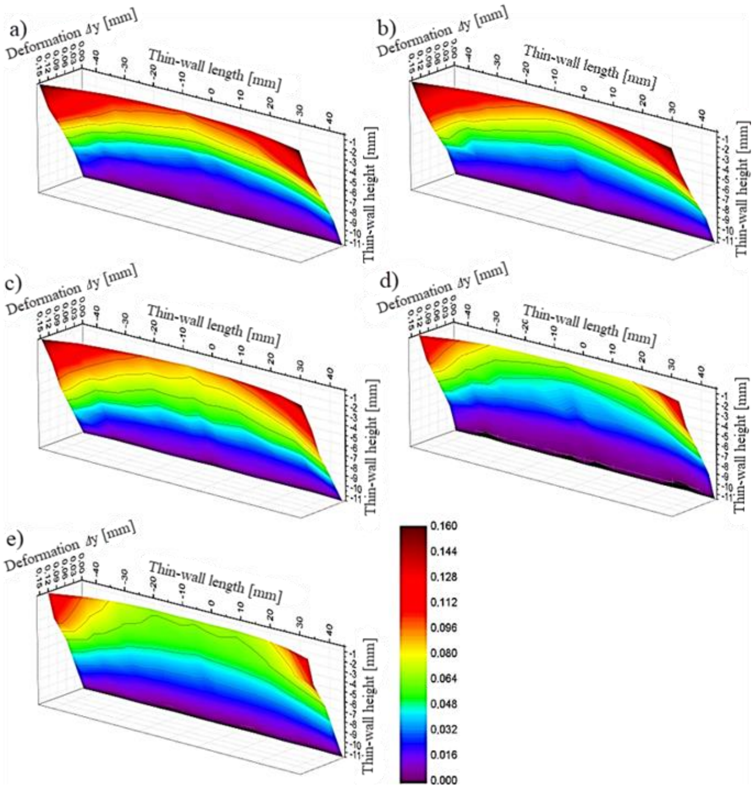

Fig. 1. *The outlines of the side surface of the walls machined at a cutting speed of v_c = 600 m/min, using tools with stiffnesses: a) 107, b) 72, c) 26, d) 4, e) 2 N/µm*

According to Fig. 1, the largest wall deformations were observed in their extreme cross-sections. The values of these deformations for tools of different stiffnesses and three cutting speeds are shown in Fig. 2.

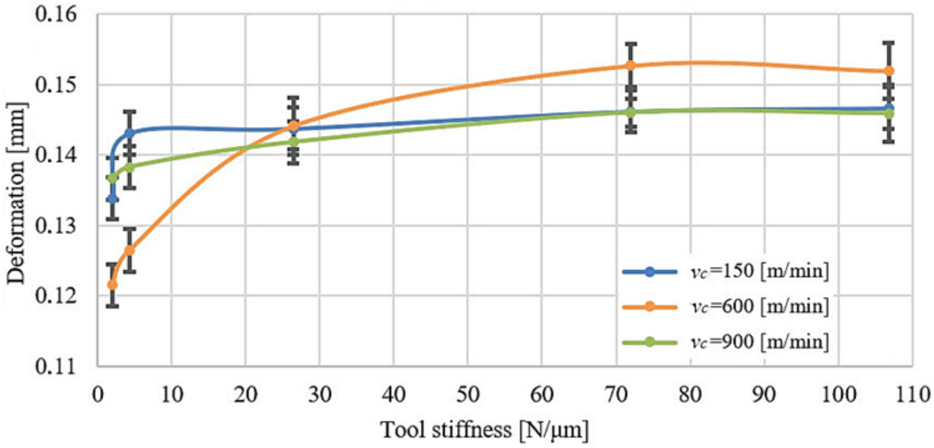

Fig. 2. *Deformation of thin-walls machined with tools of different stiffnesses*

Conclusions

The research results confirm that the stiffness of the end mill affects the geometric accuracy of the thin-walled elements. The reduction of the tool stiffness causes its greater deformation, which translates into a minimalization of the deformation of the machined thin walls. At the same time, it leads to loss of end mill stability during machining and, consequently, contributes to deterioration in the surface quality. Increase in cutting speed in the range between conventional machining and High Speed Cutting (EN AW-7050 T7451: approx. v_c = 600 m/min) causes greater machining errors. The use of cutting speed above the limit value results in a reduction in the deformation value of the workpiece and the tool. This results from two phenomena:

- a reduction of cutting force with an increase in the cutting speed (above the limit speed),
- an increase in the stability of the tool in certain cutting speed ranges.

Acknowledgment

The research was financed in the framework of the project: „Development of the milling technique of thin-walled integral elements made of aviation light metal alloys in the context of minimalisation post-machining deformations", agreement no.: LIDER14/0153/2023, total cost of the project: 1 543 750.00 PLN. The project is financed by the National Centre for Research and Development under the 14th edition of the LIDER Program.

DAY BOUNDARY DISCONTINUITY IN GNSS CLOCK PRODUCTS: SCALE AND MAGNITUDE

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Keywords: GNSS, DBD, PPP, precise product, clock

Precise GNSS (Global Navigation Satellite System) products are key in precision satellite positioning, especially in PPP (Precise Point Positioning) technique. Such precise products might be provided by the IGS (International GNSS Service) or CODE (Center for Orbit Determination in Europe) and are created for all or part of the day. Changing the date at midnight causes a so-called DBD (Daily Boundary Discontinuity), which is a discontinuity appears due to the creation of a new, consecutive file. In this study, the authors analyzed the scale and magnitude of the DBD phenomenon in the precise clock products for four GNSS systems.

The DBD problem in GNSS (Global Navigation Satellite System) clock products refers to a discontinuity that occurs at the boundary of consecutive midnight days [1, 2]. This is a phenomenon that can affect the accuracy of time or position data in precision GNSS products for GPS, GLONASS, Galileo or Beidou signals [3]. For example 1D mean DBD of final GPS orbit products is a scale of dozen of millimeters (mm) or even tens of millimeters [4] and the performance of analysis center (AC) products varies between themselves [5]. In this paper, the authors analyzed precise GNSS clock products with a 30s interval for the years 2017-2021 obtained from the Multi-GNSS Experiment (MGEX).

Fig. 1 shows a daily DBDs for one of Beidou satellites, which proofs a high instability and stochastic character of this phenomenon. In the presentation author will show a comparative research for whole satellite segment of each of four GNSS systems (GPS, Galileo, GLONASS, Beidou) together with a mean standard deviation for each of GNSS segment with changes over time.

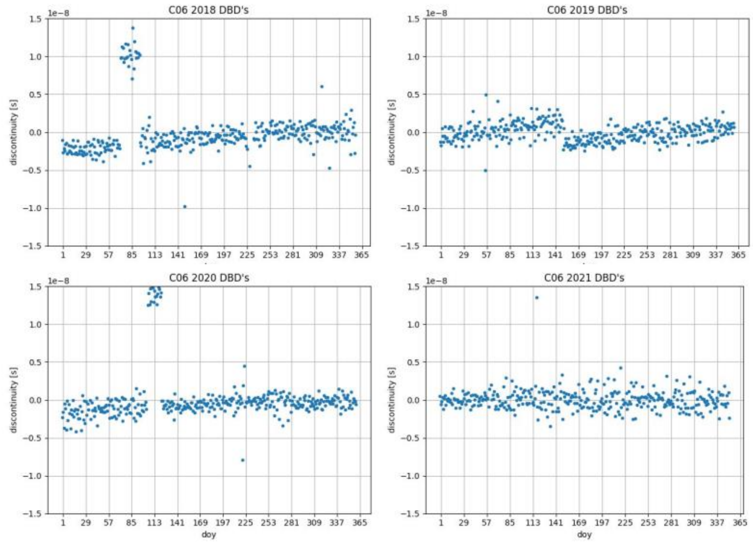

Fig. 1. *DBDs values for C06 satellite and 4 consecutive years (2018-2021)*

Problem of daily boundary discontinuity is crucial in precise positioning. The parameters of the satellite clock might change, for example due to the influence of temperature or cosmic radiation. Clocks corrections are approximated using interpolation methods to minimize errors, but these methods do not handle date changes well, resulting in a sudden jump in its values.

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SEASONAL ANNUAL AND SEMIANNUAL OSCILLATIONS OF THE PERMANENT GNSS STATIONS' TIME SERIES. A GLOBAL ANALYSIS

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Keywords: GNSS, DBD, PPP, precise product, clock

GNSS stations play an important role in earth movement monitoring research. Networks of permanent stations continuously, uninterruptedly and stably provide this type of information. In this study, the authors analyzed daily coordinates time series of globally distributed almost 3,000 permanent GNSS stations and using a fitting function, determined annual and semi-annual oscillations for each of topocentric components.

The expansion of GNSS permanent stations around the world through the last decade is a basis of conducting research not only in navigation and positioning, but especially geodynamics [1, 2]. The stations share the data and make it possible to compute the stability in long-term time-series in case of changes caused by local or/and global movements of tectonic plates [3, 4]. As previous studies have shown, the highest seasonal oscillation occur with an annual and semiannual period [5, 6].

The experiment shows the analysis of long-term daily time-series of GNSS permanent stations with use of the NASA's Jet Propulsion Laboratory data. The authors analysed almost 3,000 stations located on the whole Earth and for each determined the fitting function for each topocentric coordinate (NEU components).

The biggest values in case of the annual components were observed on RDJH (Alaska, USA), NETT (New Zealand) and AV04 (Alaska, USA) stations, for N, E and U component respectively. In addition, it was shown that large magnitudes of amplitudes were shown by the fitting function for stations with periodic data deficiencies (e.g. solar stations with large data deficiencies in winter). Furthermore, there was no high correlation between the magnitudes of the amplitudes for the individual components and the geographical location of the permanent station.

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SPM PIEZORESISTIVE CANTILEVERS CALIBRATION

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SPM (Scanning Probe Microscopy) measurement systems are a commonly used tool for determining surface parameters. In order for these systems to be reliable, they must be calibrated. One of the very important and crucial elements in this systems are cantilevers. Metrological characterization of their properties allows for the selection of the appropriate cantilever for specific applications, ensuring accurate and traceable measurements. The paper will present the comparison results of active cantilevers calibration of using two different measuring systems. The first one is national standard for mechanical vibration measurement which is maintained at the Mechanical Vibrations Laboratory of the Central Office Measures. The second system (based on a commercial laser interferometer) was built in the Precise Geometric Measuremets Laboratory.

ZDOLNOŚCI POMIAROWE STANOWISKA PARAMETRÓW KLIMATU ŚKLGUM W KIELCACH

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Temperatura jest wielkością pomiarową wpływającą na wszystko co nas otacza, a zatem również na inne wielkości pomiarowe. Kolejną wielkością pomiarową która ma istotny wpływ na wytwarzane produkty, systemy pomiarowe jest zawartość pary wodnej w powietrzu, która jest mierzona za pomocą higrometrów i termohigrometrów.

W celu prowadzenia prac badawczo – rozwojowych stanowisko Parametrów Klimatu zostało wyposażone w: komory klimatyczne, termostaty oraz układy pomiarowe dla temperatury, temperatury punktu rosy/szronu oraz wilgotności względnej.

Głównym obszarem prac badawczych, które będą prowadzone na stanowisku pomiarowym jest określenie wpływu dokładnie zmierzonej temperatury i wilgotności względnej na inne układy pomiarowe lub produkty np. z przemysłu farmaceutycznego, spożywczego lub motoryzacyjnego.

Wdrażane systemy generujące temperaturę pozwolą na osiągnięcie zakresu pomiarowego od -90 °C do +180 °C z niepewnościami rozszerzonymi dla powietrza poniżej 0,1 °C oraz cieczy poniżej 0,05 °C.

Przeprowadzono wstępne badania charakterystyk metrologicznych dla przestrzeni roboczych komór klimatycznych i termostatów.

Dokładne zdefiniowanie wpływu temperatury i wilgotności względnej powietrza pozwoli na dokładniejsze pomiary innych wielkości pomiarowych.

Zakres generowanych temperatur punktu rosy/szronu dzięki dodatkowym układom osuszania pozwoli na pomiary w bardzo suchym medium gdzie zawartość objętościowa pary wodnej w suchym powietrzu jest rzędu kilku ppm.

Możliwości pomiarowe realizowane za pomocą higrometrów punktu rosy z chłodzonym lustrem pozwolą na prowadzenie pomiarów od -90 °C temperatury punktu szronu do +98°C dla temperatury punktu rosy z niepewnościami rozszerzonymi poniżej 0,1°C.

Rozszerzone zakresy pomiarowe, precyzyjne zdefiniowanie układów pomiarowych pozwoli na prowadzenie prac badawczych w szerokim zakresie gdzie wpływ temperatury powietrza i wilgotności względnej odgrywa duże znaczenie na daną wielkość wyjściową.

POMIAR PRZEWODNOŚCI CIEPLNEJ IZOLATORÓW NA APARACIE HFM 446M

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Prace badawczo-rozwojowe w przemyśle i środowisku akademickim dotyczą tematów, które przyczyniają się do oszczędzania energii lub wytwarzania energii z alternatywnych źródeł. Istnieje zatem potencjał, szczególnie w obszarach materiałów izolacyjnych i skutecznej izolacji termicznej budynków mieszkalnych i komercyjnych. Ważne jest, aby materiały izolacyjne mogły być produkowane z zachowaniem wysokiego i stałego poziomu jakości oraz aby były wprowadzane na rynek pod ścisłą kontrolą ich właściwości użytkowych. Pomiary przewodności cieplnej można prowadzić dla dużej gamy materiałów do $\lambda < 0,5$ W/mK, tj. styropian (EPS), polistyren ekstrudowany (XPS), sztywną piankę PU, wełnę mineralną, perlit, szkło piankowe, korek, flizelinę czy materiały z włókien naturalnych itp. HFM 446 Lambda Medium charakteryzuje się nową, znormalizowaną metodą pomiaru przewodności cieplnej, która ma zastosowanie w badaniach materiałów, a głównie zapewnieniu ich jakości.

Pomiar przewodności cieplnej realizowany jest na podstawie różnicy temperatur pomiędzy dwiema płytkami w mierzonym materiale. Za pomocą dwóch czujników temperatury w płytkach mierzony jest przepływ ciepła odpowiednio do materiału i z materiału. Jeżeli układ osiąga stan równowagi cieplnej, a przepływ ciepła jest stały, przewodność cieplną można obliczyć za pomocą równania Fouriera, przy znanej powierzchni pomiarowej i grubość próbki. Pomiary można wykonywać w temperaturach od -20 do 80°C. Badania można także wykonywać w osłonie N_2 aby nie występowało zjawisko roszenia.

Wykonano wstępne badania celem sprawdzenia poprawności działania instrumentu z materiałami o znanym współczynniku przewodności cieplnej (na styropianie , wełnie mineralnej oraz szkle) w zadanym zakresie temperatur. Błąd względny nie przekroczył 5%.

ACOUSTIC SENSOR'S RANGE EVALUATION

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Keywords: Acoustic Sensor, Acoustic Signal Propagation, signal-to-noise ratio.

This study investigates the relationship between sound intensity level of sound sources and the range of acoustic sensor that detect these sources. The sensor's range estimation is based on acoustics wave propagation in an anisotropic environment. The sound intensity level decreases in distance, compared with the sound intensity level of the environment noise. Analysis show strong correlation between sensor's range and source acoustic intensity level as well as reverse correlation between sensor's range and noise level.

Introduction

An analysis of open source information shows that during Russia's war against Ukraine in 2014-2022 and at the initial stage of the war after beginning Russia's large-scale invasion of Ukraine in 2022, the vast majority of combat missions were performed with cannon and rocket artillery. Even though at the current stage of the war, artillery is inferior to FPV drones in terms of the number of targets hit, it remains an important component of firepower capable of massively hitting equipment and manpower in the tactical depth of defense. Therefore, the task of counter-battery warfare remains extremely relevant. Real-time artillery intelligence is the most important combat support in counter-battery warfare. The automatic sound-ranging systems of Ukrainian forces – Posyazhenie-2, AZK-7 and AZK-5 do not provide sufficient performance, primarily due to the long deployment time. The distributed sound-ranging system[1], as well as the distributed modular acoustic airspace monitoring system [2] being developed at Lviv Polytechnic National University, consist of a set of automatic acoustic sensors (AS) connected to a server via wireless communication channels. These systems provide automatic 24/7 operation. An insufficiently studied issue is the range of these ASs, which is the purpose of this paper.

Methodology

To estimate the range of AS, the law of energy conservation of the acoustic signal generated by the source propagating in all directions with the same specific density is used [3]. The criterion for assessing the range of the AS is the signal-to-noise ratio ($K_{S/N}$) at the location of the AS [4], where the signal is the sound intensity of the remote source and the noise is the intensity of the ambient AS. The ambient sound intensity level of noise (L_N), depending on the installation location and weather conditions, is 30-60 dB. The normalized value of sound intensity level of different sources of acoustic signal (L_S) ranges from 220 dB – atomic bomb explosion, to 90 dB – motorcycle engine (gunshot – 130-180 dB, airplane jet engine – 120 dB).

$$\begin{cases} L_S = \frac{10 \lg I_S}{I_0} \\ L_N = \frac{10 \lg I_N}{I_0} \end{cases} \Rightarrow \begin{cases} I_S = I_0 10^{\frac{L_S}{10}} \\ I_N = I_0 10^{\frac{L_N}{10}} \end{cases},$$

where I_S – the sound intensity of source signal, I_N – the sound intensity of noise, I_0 – reference sound intensity.

$$K_{S/N} = \frac{I_S}{I_N} \ .$$

The acoustic signal propagation in anisotropic environment implies propagation in all directions with the same speed and specific power within the body angle. The total energy of source of acoustic signal (W_S) we can evaluate as

$$W_S = I_S 4\pi x^2 \ ,$$

where x – distance to the source of acoustic signal.

The dependence of sound intensity of source acoustic signal vs distance to the source of this signal $I_S(x)$

$$I_S(x) = \frac{W_S}{4\pi x^2}$$

Taking into consideration these equations the dependence of signal to noise ratio vs distance to the source of acoustic signal $K_{S/N}(x)$

$$K_{S/N}(x) = \frac{10^{\frac{L_S - L_N}{10}}}{x^2} \ .$$

The estimation of the range of the AS (x) for different values of $K_{S/N}$, which are determined by the requirements of the acoustic signal processing algorithm, is presented in the table 1.

Tab. 1. *The estimation of the range of the AS (x) for different values of $K_{(S/N)}$, which are determined by the requirements of the acoustic signal processing algorithm*

$L_S - L_N$, dB	20	30	40	50	60	70	80	90	100
x, km (for $K_{S/N} = 1.5$)	0.008	0.026	0.08	0.26	0.82	2.6	8.2	26	82
x, km (for $K_{S/N} = 2$)	0.007	0.022	0.07	0.22	0.71	2.2	7.1	22	71
x, km (for $K_{S/N} = 3$)	0.006	0.018	0.06	0.18	0.6	1.8	6	18	60

The polynomial functions approximating the individual cases are described by the equations below:

$$x_{(KS/N=1.5)} = 0.1605 \cdot \Delta L^4 - 2.5035 \cdot \Delta L^3 + 13.379 \cdot \Delta L^2 - 27.547 \cdot \Delta L + 17.228$$
$$R^2 = 0.9964$$
$$x_{(KS/N=2)} = 0.142 \cdot \Delta L^4 - 2.2247 \cdot \Delta L^3 + 11.935 \cdot \Delta L^2 - 24.656 \cdot \Delta L + 15.463$$
$$R^2 = 0.9958$$
$$x_{(KS/N=3)} = 0.1234 \cdot \Delta L^4 - 1.9451 \cdot \Delta L^3 + 10.485 \cdot \Delta L^2 - 21.746 \cdot \Delta L + 13.675$$
$$R^2 = 0.9950$$

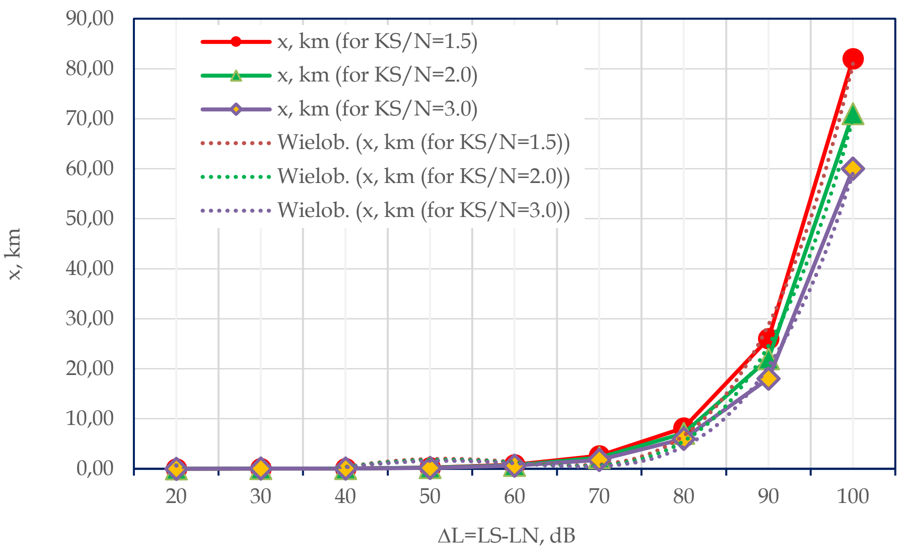

Fig. 1. *The graphic visualization of mathematical estimation of the range of the AS (x) for different values of $K_{(S/N)}$, which are determined by the requirements of the acoustic signal processing algorithm*

Conclusions

The range of the AS is estimated based on the assumption that the sound wave of the acoustic signal source propagating in the ground direction is absorbed, and in other directions, it propagates in all directions with the same specific power. The results obtained allow us to estimate the density of the AS and optimize the topology of the systems to cover an exploration area of arbitrary configuration. The attenuation of the acoustic signal in the atmosphere due to sound absorption is proportional to the distance of this signal propagation. It is normalized within 0.76-9.25 dB/km, depending on the frequency and atmospheric condition. Attenuation will appear only for relatively long distances and will reduce them. The reflection of the acoustic signal from the ground surface increases its power at the AS, and hence its range, which is especially important for short distances, so one can expect an increase in the calculated small range values. In order to increase the range of the AS, it is advisable to select signals in the band that are characteristic of certain types of targets and suppress other signals, which can increase the signal-to-noise ratio in the band of useful signals.

Acknowledgment

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AN IN VITRO METHOD FOR TESTING BURN WOUND HEALING USING A MICROHEATER

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Keywords: cell culture, wound healing assay, magnetron sputtering.

Wound healing is essential for restoring the skin's barrier function. During this process, cells at the wound edges proliferate and migrate, leading to the re-epithelialization of the wound surface. By studying the wound healing process, potential treatments can be investigated using in vitro techniques before initiating in vivo experiments. Therefore, in vitro tests are an excellent tool for examining the impact of specific compounds as well as the effect of genetic modifications on the healing process. Wound healing assays are typically conducted in a conventional two-dimensional cell monolayer format. The basic principle of any wound healing assay is the deliberate destruction of the cell monolayer, thereby creating a cell-free region that is then available for cells to repair. The most popular wound healing assay is the "scratch assay," which involves mechanically creating a wound in the cell layer by scratching. Mechanical cell destruction is also possible through "stamping" methods. Additional methods of cell damage include thermal, electrical, and optical injuries (Fig. 1) [1-2].

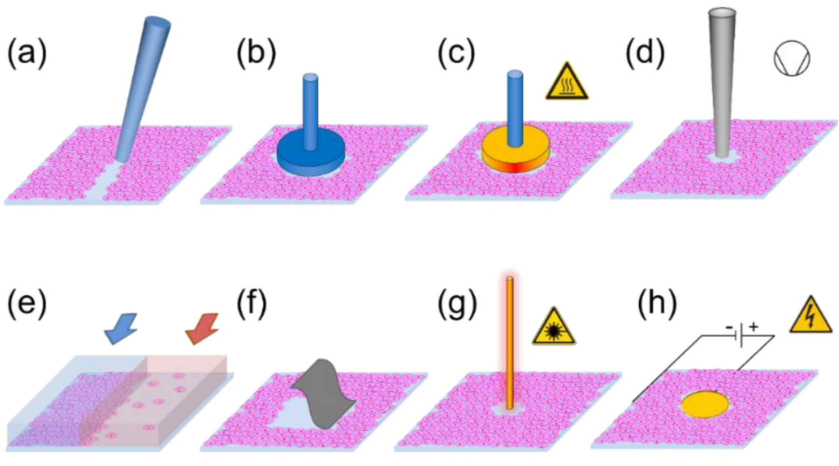

Fig. 1. *Wound-healing assays based on (a) scratching, (b) stamping, (c) stamping with high temperature, (d) vacuum, (e) microfluidic chemical assay, (f) solid barrier, (g) laser ablation, and (h) electrical assay.*

The aim of this work was to analyze the possibilities of non-standard application of the ECIS (electric cell-substrate impedance sensing) measurement system [3] for conducting burn wound healing studies using an in vitro method. The innovative element of the measurement setup is the generation of a local temperature change with high dynamics and short duration in order to create burn injuries on a specific fragment of the cell monolayer. The heating element is shaped as a narrow rectangle, allowing for a temperature increase in a small area of the substrate with attached cells. Their behavior is monitored through measurements of electrical parameters. This approach enables the replication of the actual effect of cell burning caused by high temperature and the behavior of the remaining cells after the occurrence of this factor.

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THE NEW MODEL OF CONDUCTION-COOLED CURRENT LEADS FOR SUPERCONDUCTING FAULT CURRENT LIMITERS

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Keywords: cryostat, cryocooler, current leads, superconductivity.

Current leads are part of superconducting electrical equipment. Current leads are part of a cryostat connecting external devices operating at room temperature to devices operating at cryogenic temperatures. The warm end of the current lead connected to the current source is at room temperature (T_H = 293 K), the cold end of the current lead connected to the superconducting device operates at cryogenic temperatures T_L. Current leads can be made of both non-superconducting and superconducting material, both HTS and LTS (Fig. 1). The paper presents the problem of cooling current leads, which are the main elements of superconducting devices, and the aim of the paper is to present a method for calculating contact-cooled copper current leads.

In superconducting devices, the power losses generated in the current leads have a large portion of the thermal energy that the cooling system is designed to dissipate so as to maintain the temperature of the superconducting device at a specified level. When the cooling power of the cryocooler is too low, the heat flux entering the cryostat through the current leads and the Joule heat generated in the current leads by the current supplying the electrical device can prevent the superconducting device from cooling to the required operating temperature. Due to the need to minimize resistance, current leads should have as large a cross-section as possible. On the other hand, a large heat flux flows through the large cross-section to the inside of the cryostat by thermal conduction. Reducing the cross-sectional area of the current leads reduces the heat input from the outside, but at the same time increases the Joule losses in the current leads, through which a large current flows.

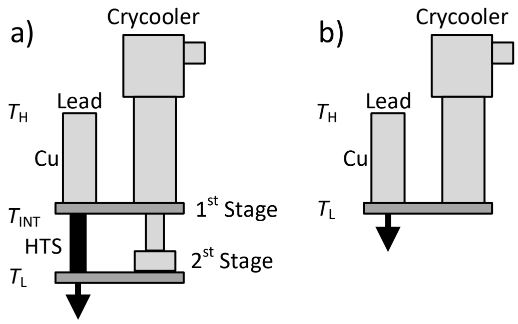

Fig. 1. *Conduction-cooled current leads: a) hybrid copper-HTS leads (cooled by a 2 stage cryocooler), b) copper leads (cooled by a 1 stage cryocooler)*

Copper current leads may have a graduated cross-section, because as the temperature of the pass decreases, the resistivity of copper decreases and the cross-section can be reduced without causing an increase in Joule losses but reducing the heat flow along the current leads. Current leads adapted for contact cooling operate in a vacuum, and heat is removed from them by thermal conduction [1-2]. Power losses that occur in current leads amount to about 30–50% of the total power losses in the cryostat. Reducing power losses in current leads is crucial for reducing cooling costs and increasing the stability of operation and minimizing the operating costs of superconducting devices. Several methods have been developed so far to optimize the cooling of current feedthroughs cooled by gas vapors and using contact cooling [3-10]. In this paper, the mathematical model of conduction-cooled current leads for superconducting fault current limiters will be presented.

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MEASUREMENTS OF PHYSICOCHEMICAL PARAMETERS OF FRESH JUICE AFTER ATMOSPHERIC PRESSURE PLASMA CONDITIONING

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Keywords: cold atmospheric plasma, GlidArc, plasma treatment, measurements of physicochemical properties.

The aim of the study was to develop a cold plasma treatment system to improve the microbiological safety of freshly squeezed apple juice while preserving its basic physicochemical properties.

As part of the research work, a Cold Atmospheric Plasma (CAP) treatment system was developed to improve the microbiological safety of juices while preserving their basic physicochemical properties.

During the experiments, samples of freshly squeezed apple juice were treated with CAP operating in a stationary system, a flow system, and a flow system with an attachment. Using the GlidArc plasma reactor with air as the working gas, 50 ml of the tested juice was processed each time.

Using the multifunctional laboratory instrument Elmetron CX-461, the pH level, redox potential, and conductivity of the plasma-treated liquids were measured. The CIE Lab color parameters (L*, a*, b*) were measured using the 3Color SF80 spectrophotometer. Additionally, extensive microbiological tests were conducted.

The results indicate that the juice did not undergo significant color changes after plasma treatment, as measured in the CIE Lab system. Additionally, it retained a relatively high content of polyphenols and natural sugars, or extract.

PRIMARY TEETH ENAMEL AFTER NON THERMAL PLASMA TREATMENT

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Keywords: atmospheric pressure plasma jet, primary teeth, surface properties, measurements for dentistry.

The impact of plasma treatment duration on the enamel of primary teeth was investigated. A dielectric barrier discharge (DBD) jet was utilized to generate plasma. The enamel properties, including color, contact angles, surface roughness, surface topography, and elemental composition, were analyzed before and after plasma treatment.

Cold atmospheric pressure plasma resulted in increased surface microroughness. Prolonged treatment time led to changes in morphology. An immediate improvement in the wettability of the enamel surface and a lighter color (L* parameter) compared to the control were noted.

The findings indicate that plasma treatment time is a critical factor in achieving desired effects, such as whitening or enhanced wettability. However, extended plasma exposure may result in permanent damage to the enamel surface. Plasma treatment of teeth presents new opportunities as an alternative for whitening or as a pre-treatment before other dental procedures.

METHOD FOR METROLOGICAL IDENTIFICATION OF DAMAGE PARAMETERS IN MATERIALS OF BIOLOGICAL ORIGIN

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Keywords: material of biological origin, micro-damage, external loading of samples, tomography, Monte Carlo method.

Technological processing of loose materials of biological origin involves their contact with the working parts of the equipment. This causes damage at both micro- and macrolevels. A method for identifying the level of damage to biological origin has been proposed. The developed algorithm for metrological identification includes the following stages: preparation of the samples; static / dynamic loading of samples; tomography of objects (Zeiss Xradia 510 tomograph); analysis and identification of damage parameters (Monte Carlo static processing method). Due to the preliminary calibration of materials of biological origin on laboratory sieves of the sifter, they were weighed and dried, we obtained samples with identical parameters [1]: thickness, width, length, density, moisture content. The second stage is an external simulation load of the selected samples, which was performed by: Zwick/Roell 2.5 universal test bench (static nature of the load), developed impact test bench (dynamic nature of the load) [2]. During this process, the position of the samples was changed: horizontal or vertical. The obtained critical loads (complete destruction of the samples) were differentiated into three levels: 30%, 60%, and 90% of the critical load. This allowed for the preparation of samples with varying magnitudes and directions of external load. The next stage involved tomography of the damaged samples, which was carried out using the Zeiss Xradia 510 Versa 3D tomograph at LUT. Parameters of tomograph: 4X lens; maximum 3D FOV (WFM) – 6(10) mm; voxel size – 0,7÷3 μm; average tomography time is 3.4 hours. Results of the tomography: a series of 2D images (10 horizontal and 10 vertical cross-sections of the BO); 3D images. The difficulty is in analyzing 3D images and determining of damage parameters. For analyses of 20 pieces (2D images) for one BO we proposed the Monte Carlo statistical testing method with the following algorithm data processing [3]: applied a grid on the tomographic image of the BO (we used 3400 points per 1 image), checked if the points of this grid hit the cracks (ξi), error analysis, analysis of the BO damage level. In the resulting equation for identifying the micro-damage coefficient we have 3 options: first, when a point getting into a crack we got random variable equals 0, second, a point getting into a boundary – got random variable equals 0.5, and getting a point into a solid equals 1. The verification of this metrological identification was conducted on loose materials – specifically, corn seeds. A dependency of the microdamage coefficient on the parameters of the external load was established. The adequacy of this method was verified using sample microscopy, with data discrepancies not exceeding 3.6%. The developed method allows to perform metrological measurements of the damage levels of loose material particles of biological origin, which determines their quality, period of storage and reproductive properties [4].

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SIMPLIFIED APPROACH TO MEASUREMENTS OF UNMANNED GROUND VEHICLE DYNAMICS USING ON-BOARD SENSORS

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Keywords: Unmanned Ground Vehicles, on-board sensors, vehicle dynamics.

Unmanned Ground Vehicles (UGVs) are significant in various applications, including military operations, evacuation, and logistic. A critical aspect of UGV functionality is the accurate measurement of their dynamics – such as speed, acceleration, orientation, and position – which is essential for ensuring robust performance and operational safety. Traditional methods of measuring vehicle dynamics often involve complex and expensive external instrumentation. A simplified approach that utilizes on-board sensors for real-time dynamic measurements was proposed in this study. The common installed sensors, the data processing techniques and the challenges faced in implementing related methods are discussed.

Introduction

The dynamic performance of unmanned platforms is a critical factor that directly influences their operational effectiveness. Accurate measurement of these dynamics is essential for tasks such as navigation, obstacle avoidance, and stability control [1]. Traditional methods for measuring UGV dynamics often depend on external systems, such as motion capture cameras or GPS-based tracking, which, although precise, are generally expensive, cumbersome, and limited in their applicability.

In contrast, on-board sensors are regarded as a more practical and scalable solution for dynamic measurements, providing real-time data that can be processed to determine various dynamic parameters. However, the use of these sensors is associated with challenges, such as noise, drift, and the necessity for sophisticated data fusion algorithms. Many advanced sensors have been developed specifically for mobile platforms, incorporating highly refined algorithms to address these issues. This paper presents a simplified approach to measuring UGV dynamics using on-board sensors, with a focus on the practical application of commercially available integrated systems and the parameters they provide.

Sensor types used in ugvs

The effectiveness of on-board sensor-based dynamic measurement largely depends on the selection and integration of appropriate sensors. The key sensors used in UGVs for dynamic measurements include: Inertial Measurement Units (IMUs), wheel encoder and Global Positioning System (GPS) [2].

IMUs are critical for measuring acceleration and angular velocity. Such unit typically consists of accelerometers, gyroscopes, and sometimes magnetometers, providing data on linear acceleration, rotational velocity, and orientation relative to the Earth's magnetic field. These sensors are crucial for estimating the UGV's position, velocity, and attitude.

Wheel encoders measure the rotational speed of the vehicle's wheels, which can be used to estimate the vehicle's speed and traveled distance. These sensors are particularly useful in applications where GPS signals may be unreliable, such as in indoor or subterranean environments.

GPS sensors provide absolute position data, essential for navigation tasks. While GPS is highly effective in open environments, it can suffer from signal loss or multipath effects in urban or heavily forested areas. When combined with IMU data, GPS can help to correct drift in the IMU readings.

There are also other type of sensors like LiDAR and Cameras which are primarily used for mapping and obstacle detection but can also contribute to dynamic measurements. Visual odometry, for example, uses camera images to estimate the vehicle’s movement by tracking feature points across successive frames.

The raw data obtained from on-board sensors must be processed and often fused to derive meaningful dynamic measurements. Key techniques in this process include sensor calibration, filtering, sensor fusion, and state estimation [3]. Sensor calibration is essential for accurate dynamic measurements, as it involves identifying and correcting systematic errors such as bias, scale factor inaccuracies, and misalignment, which is particularly important for Inertial Measurement Units (IMUs) to minimize drift in velocity and position estimates. Filtering techniques, like Kalman filters or complementary filters, are used to smooth the often noisy data from sensors like IMUs, eliminating high-frequency components that do not reflect actual vehicle dynamics, and integrating data from multiple sensors. Sensor fusion, the integration of data from various sensors, allows for a more precise estimation of the UGV’s state. For instance, fusing IMU data with GPS can significantly enhance the accuracy of position and velocity estimates, especially in environments where GPS signals may be unreliable. Advanced methods such as Extended Kalman Filters (EKF) and particle filters are often utilized to manage non-linearities and uncertainties in the sensor data. Finally, state estimation, which is crucial for control and navigation, involves determining the UGV's current state – such as position, velocity, and orientation – using the fused sensor data.

Example of measurements

As part of the study, experimental measurements were carried out using the TAERO manned-unmanned vehicle developed by consortium: Military Institute of Armoured and Automotive Technology, STEKOP, AutoPodlasie, and AP Solutions (Fig. 1a). This vehicle is equipped with a central processing unit that included the necessary IT infrastructure, situation awareness sensors, and mechatronic drives designed to manage the factory-fitted mechanisms of the platform. Additionally, the vehicle is equipped with a precise GPS system integrated with an Inertial Navigation System (Fig. 1b).

a) b)

Fig. 1. *View of developed TAERO vehicle (a) and installed GNSS INS module (b)*

A new generation of integrated navigation systems was used, combining GPS, GLONASS, GALILEO, QZSS, BEIDOU, and L-band technologies, alongside a high-performance module from Inertial Labs that determines the vehicle's position, speed, and orientation [4]. This module features an advanced GNSS receiver with dual antennas, a barometer, and 3-axis precision Fluxgate magnetometers calibrated across the full operating temperature range. Additionally, it includes accelerometers and gyroscopes, enabling accurate measurement of the vehicle's position, speed, direction, pitch, and roll.

The inertial unit is further enhanced by an extended filter that processes data from the on-board sensors, ensuring refined output (Fig. 2). These INS systems estimate position, attitude, and velocity by utilizing the gyroscopes and accelerometers within the IMU. Position accuracy is further improved when the INS is supplemented by a Global Navigation Satellite System (GNSS). However, GNSS availability can be limited due to interference or challenging operational environments, such as tunnels, canyons, or roads beneath bridges.

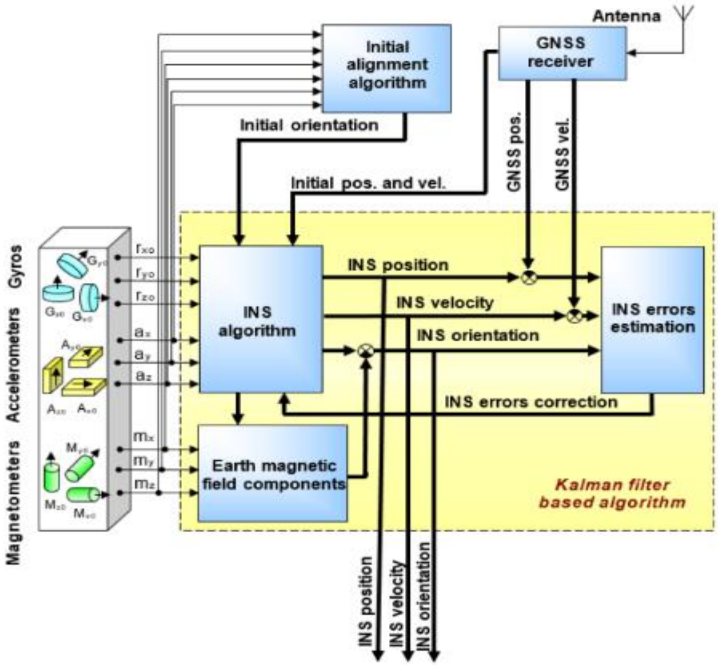

Fig. 2. *Block diagram of Inertial Labs navigation system [4]*

Based on the described system, measurements were carried out using the presented IMU unit to determine the braking distance of the TAERO vehicle design in relation to the initial speed. The results of these measurements are shown in Fig. 3.

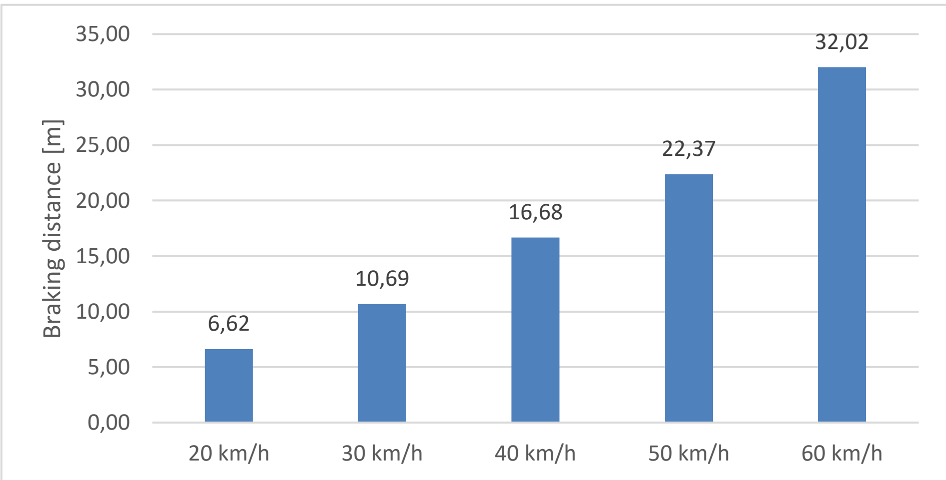

Fig. 3. *Measured braking distance of the TAERO on a dry asphalt surface*

The braking distance is a critical parameter in assessing vehicle safety and control, and it is influenced by several factors, including the vehicle's initial speed and the coefficient of friction between the tires and the road surface. The measurements also illustrated the efficacy of the integrated inertial navigation and sensor systems in accurately capturing the dynamic behaviour of the vehicle during braking. The precise data provided by the IMU, coupled with the GNSS and other on-board sensors, enabled a detailed analysis of the vehicle's deceleration profile and the factors influencing braking distance. The advanced filtering and sensor fusion techniques ensured that the measurements were reliable, even in scenarios where GNSS signals were compromised, such as in tunnels or under bridges.

Conclusions

A simplified approach to measuring UGV dynamics using on-board sensors has been presented in this paper. The selection of suitable sensors and the application of robust data processing techniques have demonstrated the effectiveness of on-board sensors as reliable and cost-efficient alternatives to traditional external measurement systems. The integration of high-performance inertial navigation systems with real-time data processing from on-board sensors has proven to be a robust and accurate method for evaluating dynamic vehicle behaviour, such as braking, across various conditions. This approach not only improve the precision and reliability of dynamic measurements but also ensures that unmanned ground vehicles operate safely and effectively in a wide range of challenging environments. This capability is essential for advancing the deployment and operational success of UGVs in diverse applications, from autonomous navigation to complex mission scenarios.

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ATMOSPHERIC PRESSURE PLASMA JETS FOR POLYMERIC SURFACES' CONDITIONING

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Keywords: atmospheric pressure plasma, plasma jets, cold plasma, polymer treatment.

Polymeric materials were treated using low temperature atmospheric pressure plasmas. RF-type and DBD-type atmospheric pressure plasma jets (APPJ) were used and measurements of the selected surface properties including wettability were performed.

Two APPJ reactors were used for polymeric surface treatment: an RF reactor operating at 14.24 MHz and 500 V, and a DBD reactor operating at 19.7 kHz and 4.13 kV. The gas temperature was monitored using a K-type thermocouple connected to an electronic temperature compensation multimeter. Key properties of the APPJ, including electrical characteristics, spatial distribution of outlet gas temperature, and concentrations of active gas species as a function of feed gas parameters, were measured. To gain insights into the system's operating principles and optimize its application performance, a zero-dimensional (0D) time-dependent chemical kinetic global model was developed to solve the governing rate equation for species concentration over time. AFM analysis was employed to examine surface structure, and the surface wettability of high-impact polystyrene improved following APPJ treatment. The effect of atmospheric pressure plasma on E. coli was also studied, focusing on variables such as exposure time, distance, and treatment gas temperature.

PREPARATION AND CHARACTERIZATION OF NANOSTRUCTURES FOR SCANNING PROBE MICROSCOPES

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Keywords: AFM/STM microscopes, nanostructures, calibration.

The rapid advancement of nanotechnology is increasingly demanding measurements carried out at nano-scale be more accurate, comparable and traceable to the international standards of units (the SI). The Atomic Force Microscope (AFM) is a very powerful tool for the measurement of surface texture and micro-/nano-structures, with wide applications in nanotechnology. On the Polish market standards for AFM/STM calibration are not available. Microscope operators use standards manufactures by foreign companies. The prices of such standards are very high and their availability is limited. The developments of new standards can reduce maintenance costs of AFM/STM microscopes, will also be introduced to the Polish market new specialized reference materials.

Introduction

The enormous technological progress that has occurred in the last few decades made it possible to undertake advanced research on the elementary structure of materials.

The significant importance related to the development of this research was connected with the invention of microscopes with a scanning probe (SPM), and in particular the atomic force microscope (AFM) and scanning tunneling microscope (STM). They made it possible to image materials in nanometer scale (<100 nm) with uncertainties at the sub-nanometer scale [1-2].

Nowadays, these devices are routinely used in industry. The precise knowledge of the properties of materials at the nanoscale has enabled a technological revolution in areas such as electronics, optics, medicine and the pharmaceutical industry, construction or space technologies. Particularly spectacular progress occurred in the electronics industry, where nanometer-sized structures are used to produce electronics based on finFET transistors.

Currently, there are more and more research and development laboratories in Poland equipped with modern microscopes with a scanning probe and perform tests for industry. Due to the dynamic development of nanotechnology, the number of this type devices will systematically increase in the coming years. But so far only few of these devices are subjected to rigorous calibration procedures, which may lead to results with high uncertainties.

Moreover, laboratories that use AFM/STM microscopes do not have them either developed research procedures for calibration of devices with using measurement standards and estimating measurement uncertainty. This is probably related to the high cost of calibration standards and their limited availability on the Polish market and high complexity measurements performed using microscopes with a scanning probe and in therefore, the need for a person to have extensive experience performing calibration [3-5].

Illustrations

In the conducted research, atomic force microscopy (AFM) was used to analyze the geometric structure of the tested certified calibration sample. The tests were carried out using an AFM MultiMode™8, NanoScope® V microscope from Bruker-Veeco. Standard topography is a periodic structure with a specific period in two directions perpendicular to each other (x-axis, y-axis) and with a specific step height. Structures were measured on the tested sample. The obtained results correspond well with the data provided by Russian Research Institute for Metrological Service what confirms the usefulness of the selected AFM microscope for the research.

The research was carried out as part of the project: Preparation and characterization of nanostructures for scanning probe microscopes, contract number: PM-II/SP/0044/2024/02.

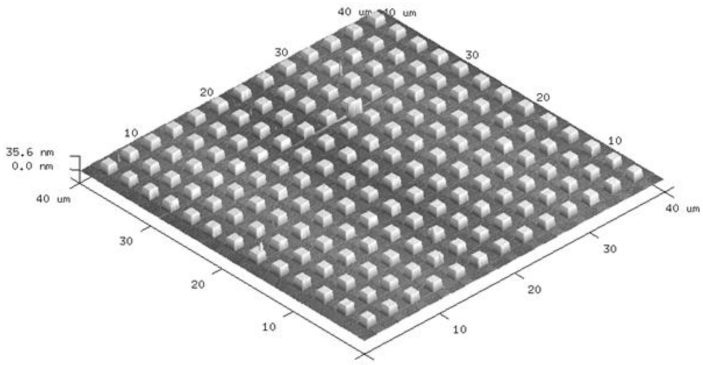

Fig. 1. *Mapping the surface microstructure of the reference sample using atomic force microscopy*

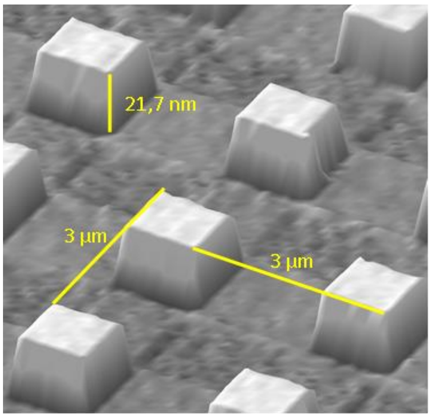

Fig. 2. *Dimensions of the structures.*

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ADAPTATION OF MEASUREMENT METHODS TO METROLOGICAL REQUIREMENTS FOR DOSIMETRIC EQUIPMENT USED IN THE POLISH ARMED FORCES

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Keywords: dosimetry, military standard, military metrology.

Ensuring the uniformity and accuracy of measurements is crucial for a subsystem of the technical safety of military equipment in accordance with the tactical, technical and combat requirements of the modern battlefield. Dosimetry is a specific field that ensures early detection and protection of the population against ionizing radiation. Due to the importance of the equipment used, it must strictly comply with the requirements of the Military Standard NO-42-A204:2024 [1].

Conformity assessment of military dosimetry equipment includes in particular the performance of tests based on the requirements, thresholds and procedures strictly described in defense standards. Test methods based on defense standards cover all theoretical and practical problems related to measurements, specific to the tested object, the type of the measured quantity and the accuracy of measurement.

In order to properly implement methods that have not been strictly defined in the standards, it is necessary to prepare internal procedures that will substantially meet all metrological requirements stated within those standards.

The aim of this paper is to present the development of an internal procedure based on the principles of metrology, taking into account all phases of measurement, i.e.:

- establishing a measurement model;
- designing and preparing the measurement system;
- performing the measurement;
- the measurement result, including its uncertainty.

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GEOMETRIC STRUCTURE OF THE SURFACE AFTER MILLING OF A THIN-WALLED ELEMENT MADE OF A SELECTED TITANIUM ALLOY

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Keywords: thin-walled element, milling, titanium alloy, surface quality, residual stress.

The paper presents selected aspects of the geometric structure of the surface after milling of a thin-walled element made of Ti6Al4V titanium alloy. The effect of cutting speed was analyzed. The surface quality was assessed based on measurements of roughness parameters and generated 3D maps. Based on the obtained data, it can be clearly stated that with increasing speed, the values of roughness parameters increase, which is also reflected in the three-dimensional surface topography.

Introduction

Milling of a thin-walled elements is one of the most demanding challenges in machining, mainly due to the difficulties associated with obtaining the appropriate dimensional and shape accuracy and surface quality. A characteristic feature of such elements is their susceptibility to deformation during machining, which can lead to the formation of inconsistencies, as well as the formation of vibrations affecting the geometric structure of the surface. In addition, titanium alloys are classified as relatively difficult to machine, which additionally complicates the production of structures.

Methodology

The tests were carried out on the most commonly used in the aerospace industry two-phase (α+β) titanium alloy Ti6Al4V. Cutting tests were carried out on the Avia VMC 800HS vertical machining center using the JCO710200D2R250.3Z4A end mill from SECO. A variable cutting speed of v_c = 10-30 m/min was used with a step of 5 m/min and the remaining parameters were constant: f_z = 0.05 mm/tooth, a_p = 25 mm, a_e = 1 mm. The machining was performed with MobilCut230 cooling. The thickness of the thin wall was 1 mm, height – 25 mm, and width – 90 mm.

Surface roughness was assessed based on measurements taken using a Keyence VK-X3000 confocal microscope. Additionally, 3D topography maps were generated.

Results

Fig. 1 shows example 3D topography maps of the surface after milling at the speed v_c = 10 m/min and v_c = 15 m/min, respectively.

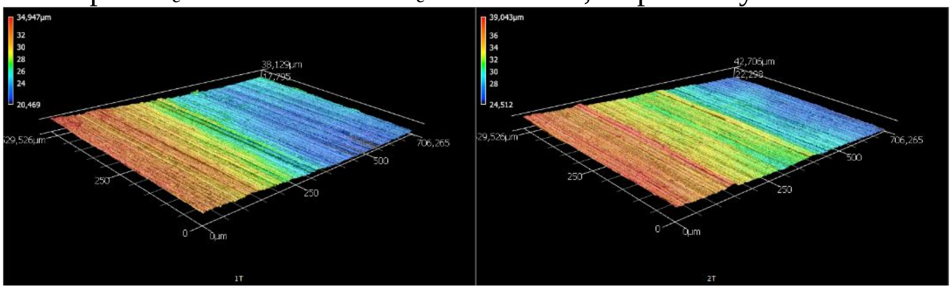

Fig. 1. *Example isometric images of the surface after machining at the cutting speed: a) v_c = 10 m/min, b) v_c = 15 m/min*

Conclusions

The research results confirm that technological parameters have a significant impact on the geometric structure of the surface of a thin-walled element made of Ti6Al4V alloy. Increasing the cutting speed leads to a deterioration of the surface quality. Based on the obtained results, it was clearly stated that the roughness parameters increase with cutting speed, which can also be observed in 3D topography. The selected titanium alloy, due to its physical and mechanical properties, creates additional challenges during machining. This requires the optimization of cutting parameters in order to minimize tool wear and improve surface quality.

Acknowledgment

The research was financed in the framework of the project: „Development of the milling technique of thin-walled integral elements made of aviation light metal alloys in the context of minimalisation post-machining deformations", agreement no.: LIDER14/0153/2023, total cost of the project: 1 543 750.00 PLN. The project is financed by the National Centre for Research and Development under the 14th edition of the LIDER Program.

GENERAL PROCEDURE FOR IMPLEMENTATION OF HYBRID MEASURING SYSTEMS CONSISTING OF TACTILE AND OPTICAL MEASURING SYSTEMS

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Keywords: coordinate measuring systems, tactile measurements, optical measurements, hybrid systems, multisensor measurements.

This paper presents general procedure for constructing and implementing hybrid measuring systems (HMS), consisting of tactile and optical measuring systems, the main application of which is the implementation of hierarchical measurements of large engineering objects (with the largest object dimensions reaching 10 m). Example of such HMSs and their applications are also given.

Introduction

Manufacturing of large-scale engineering structures, many of which must adhere to strict tolerance requirements, demand precise measurements over extended distances. These measurements present a significant challenge for metrologists responsible for ensuring product quality across various industries, including energy, aviation, automotive, and machinery sectors. Contact-based measurements are often time-consuming due to the need to move tactile probe heads across large distances [1]. While optical measurements are much faster, their range is usually limited to only a few meters, and they generally offer lower accuracy compared to tactile methods [2]. Additionally, measuring large-scale components is complicated due to varying environmental conditions, such as temperature gradients along the measured lengths, which can compound errors [3, 4].

Ensuring high accuracy in such measurements is therefore a complex task [5, 6]. These challenges motivated the authors to explore the development of hybrid measurement systems (HMSs) and methods to enhance the accuracy of measurements conducted with these systems.

This paper presents the description on how to build such HMS, how to assure their traceability and in what way determine uncertainty of measurements performed using HMS.

General procedure

The general procedure for constructing and implementing hybrid measuring systems, consisting of tactile and optical measuring systems, is as follows:

1. Selection of measuring systems that are parts of the HMS.

HMS uses in their functioning two (or more) measuring systems from which at least one has to be a system implementing point measurement method (for example coordinate measuring machine, articulated arm coordinate measuring machine, laser tracker system) and at least one has to be a system implementing field measurement method (it may be for example structured light scanner, laser triangulation scanner, methods based on digital image processing, etc.).

In authors opinion HMSs are (and will be in future) very often built using measuring systems that are already available in laboratories. In cases when there are plenty of measuring systems available or there are no measuring systems available the selection of measuring system used for creating HMS should be based on following criteria:

- main tasks that will be solved by HMS,
- required accuracy of measurements,
- required resolution of measurement,
- required amount of data that should be acquired in short amount of time,
- available budget.

The most important question here is the type of a task that has to be solved by HMS. Some systems are better suited for tasks known from geometrical product specification (GPS) framework while some others are more convenient for solving tasks more related to structural health monitoring of engineering structures (tasks like detection of deformations or discontinuities). Authors of this paper developed two different HMSs. The first one created in Cracow University of Technology is used for measurement of dimensions and forms of large-volume objects. It is based on the use of an accurate large-volume coordinate measuring machine PMM-G 50.30.20 and a structured light scanner 3D Scanner MINI (Fig. 1).

The second HMS that was developed and is now used in Warsaw University of Technology is based on the Leica AT901 laser tracking system (the point-wise measurement method) and the 3D Digital Image Correlation (3D DIC) system implementing the full-field measurement method (Fig. 2). It is used for solving measuring task that is the displacement, or more precisely, measurements of the displacement vector d(u(x,y),v(x,y),w(x,y)) in the entire field of view, in which the displacement components u,v,w denote the in-plane (u,v) and out-of-plane (w) displacements of the object subjected to external influences (e.g. forces).

Fig. 1. *Hybrid measuring system based on the use of an accurate large-volume coordinate measuring machine PMM-G 50.30.20 and a structured light scanner 3D Scanner MINI*

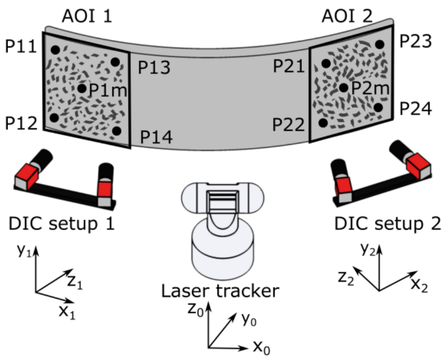

Fig. 2. *Schematic idea of HMS based on use of a laser tracker system and the 3D Digital Image Correlation system*

2. Defining the single coordinate system for both measuring systems and (if required) application of data fusion method.

In a hybrid measuring system, a unified coordinate system must be established for both measurement systems. The less accurate system, such as a structured light scanner (or 3D DIC system in case of second described HMS), is typically aligned to the coordinate system of the more precise system, like a CMM (or laser tracker system). This alignment is achieved by measuring a reference object consisting of three spheres with both systems within the HMS (Fig. 3). Each system performs measurements in its own coordinate system, and then a best-fit algorithm is used to determine the relationship between the two systems, identifying the translation of the origin and the rotation of the coordinate axes relative to one another. The transformation of coordinates can then be applied using equation (1).

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = Tr \cdot R_z \cdot R_y \cdot R_x \cdot \begin{bmatrix} x' \\ y' \\ z' \\ 1' \end{bmatrix} \quad (1)$$

where: x,y,z – coordinates given in common coordinate system of HMS (the coordinate system of CMM); x’, y’, z’ – coordinates given in 3d scanner coordinate system; Tr – translation matrice; Rz, Ry, Rx – rotation matrices

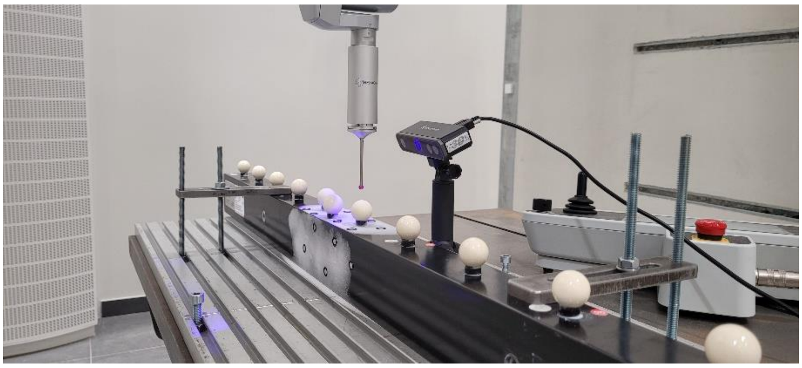

Fig. 3. *Measurements of the reference object consisting of three spheres with both systems within the HMS*

In the subsequent measurement phase, a local coordinate system is established on the object being measured. If feasible, geometric features on the object used to define this local coordinate system should be obtained using a point-based method to ensure higher accuracy. The object is then measured within this coordinate system using the structured light scanner. The resulting point cloud from these measurements is analyzed, segmenting it into areas that correspond to geometric features (such as planes, cylinders, cones, spheres, etc.) and freeform surfaces. Finally, the segmented point cloud is transferred to metrology software, where dimensions are assessed or deviations between the object's actual surface and its CAD model are checked.

Additionally, in this step of implementing HMS also a data fusion method for data coming from two component systems may be applied. It depends mainly on volume of data provided by HMS. Data fusion method is used for reducing the point cloud obtained as a result of functioning of HMS. It may also be used for improving the accuracy of HMS measurements by using results obtained from point-measurement method for accuracy improvement of field-measurement methods. For systems described in this paper the method based on one of the procedures presented in [7] was used. This approach involves using both systems to measure reference elements, which should be positioned around the measured workpiece prior to the measurement process. Reference elements such as spheres, circles, or cones can be used, as they can define a specific reference point. This reference point must be determined using both measurement methods within the HMS. Subsequently, a vector is calculated, with its starting point at the characteristic point of the reference element identified by the contactless method and its endpoint at the characteristic point identified by the tactile method. This process is repeated for all reference elements. In the following step, all points in the point cloud obtained from the contactless method are adjusted by translating them along the vector associated with the reference element closest to each point in the cloud. Studies on this method have demonstrated that this procedure significantly improves the accuracy of HMS measurements, with potential accuracy gains of up to several percent, depending on the specific measurement task.

3. Ensuring traceability of results produced by implemented HMS

The proposed method for ensuring traceability of HMS includes performing of four tests that should ensure consistency of the HMS results with the primary unit of length. All standards used in tests described below should be calibrated by an accredited laboratory (or National Metrology Institute) and have actual calibration certificate. The proposed tests include:

I. Verification of the point acquisition systems separately for both measurements methods included in the HMS (reference element: sphere made of material which allows tactile and contactless materials; number of positions: 3 positions for tactile measurements and 3 positions for contactless measurements; result: size and form deviations for all measurements are compared to the MPE values of both systems) (Fig. 4).

II. Verification of the combined operation of the point acquisition systems included in the HMS (reference element: sphere made of material which allows tactile and contactless materials, number of positions: 3 positions in measuring volume of HMS, result: determination of MPE value for HMS measurements of sphere diameter and form deviation).

Fig. 4. *Measurements of the standard sphere during tests no. I and II*

III. Verification of the length measurement error (reference element: length standards which can be measured using tactile and contactless measurements, preferably ball-bar standards, number of positions: 7 positions in measuring volume of HMS, result: determination of MPE value for length measurements performed using HMS obtained as difference between measurements results and values read from the calibration certificate of the standard).

IV. Verification of the error of flatness and roundness measurement (reference element: the flatness standard and the reference ring, number of positions: 7 positions in measuring volume of HMS, result: determination of MPE value for flatness deviation and roundness deviation measurements).

4. Application of a method for determination of the uncertainty of measurements performed using HMS.

It is commonly known that measurements results given without stating the measurement uncertainty are useless from the practical point of view. This is why, in order to utilize HMS it is also necessary to implement uncertainty determination method for measurements performed using them.

The uncertainty assessment method is based on a multiple measurement strategy, which typically involves taking multiple measurements of an uncalibrated object, and in some cases, a length standard, from various positions within the measurement system's volume and at different measurement points. This approach assumes that for each geometric feature (e.g., distance, angle), measurements will be conducted from a sufficient number of directions. This is essential to gather enough data to accurately evaluate the cumulative effect of all the components contributing to measurement uncertainty.

In the proposed uncertainty assessment method, it is recommended that the measured object (and, if necessary, a length standard, it applies when the measurement task involves determining distances, diameters, positions, etc., to correct systematic errors related to distance measurement) be placed in three positions: one primary position and two additional ones, which result from rotating the object around the individual axes of the CMM (or other measuring system implementing point-measurement method), starting from the primary position. However, considering that the objects measured in hybrid measurement systems are often very large and heavy, it may be feasible to reduce the number of positions required for measuring the object and the standard to two. The suggested minimum number of repetitions for each position is four if three positions are used, or six if only two positions are used.

The general formula for calculating the expanded measurement uncertainty according to the proposed method is given in equation (2):

$$U = k \times \sqrt{u_{\mathrm{rep}}^2 + u_{\mathrm{geo}}^2 + u_{\mathrm{corrL}}^2 + u_{\mathrm{D}}^2 + u_{\mathrm{temp}}^2} \quad (2)$$

where: U – expanded measurement uncertainty; k – expansion factor; u_{rep} – measurement uncertainty component related to the repeatability of the measurement system; u_{geo} – measurement uncertainty component related to geometric errors of the system based on the point-measurement method; u_{corrL} – uncertainty component related to the correction of the systematic error of length measurement; u_D – uncertainty component related to the correction of the systematic error of diameter measurement; u_{temp} – uncertainty component related to thermal influences.

Summary

In this paper the general procedure for implementation of hybrid measuring systems consisting of tactile and optical measuring systems was presented. Using this procedure it is possible to build HMS, make it fully functional and prove its traceability to the unit of length. HMS developed in such way and used with uncertainty determination method also presented in this paper may be utilized for solving different metrological tasks and may find application as a tool of quality control or structural health monitoring mainly of large-volume engineering objects, but also of objects with smaller dimensions. In the later mentioned application, it may be an alternative to buying expensive multisensor CMMs, especially if component systems of HMS are already available in the laboratory.

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MEASUREMENT OF THE DIELECTRIC PERMITTIVITY SPECTRUM WITH USE OF DIFFERENT MEASUREMENT TECHNIQUES

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Keywords: dielectric permittivity spectrum, measurement techniques

The paper presents overview of the dielectric permittivity spectrum measurement techniques with a particular focus on a unique solution for transmission measurements using a coaxial cell system.

Dielectric permittivity spectrum is crucial in various fields such as materials science, electronics, biomedical applications, geotechnical engineering, and agriculture. Dielectric permittivity describes a material's ability to store and dissipate electrical energy in an electric field. It is characterized by real (ε') and imaginary (ε") components. Different techniques can be used to measure the dielectric properties over a wide frequency range. Some common measurement techniques are: capacitive measurement techniques, time domain reflectometry (TDR), frequency domain reflectometry (FDR), impedance spectroscopy or microwave resonance techniques. Among the techniques in the high-frequency field, reflectometric and transmission methods for analysing the response of the material under test to a given electrical signal can be distinguished [1-5]. A system with coaxial cells (Fig. 1) constructed in the Laboratory of Dielectric Spectroscopy of the Institute of Agrophysics in Lublin is a unique solution for transmission measurements using an innovative apparatus for determining spectrum of complex dielectric permittivity of powdery (particularly soil), liquid, and solid materials in the frequency range 1 MHz-3 GHz. Each technique has its advantages and limitations, including frequency range, sensitivity, sample size requirements, and complexity of the setup. The choice of technique often depends on the specific application, the type of material under test, and the desired frequency range of the dielectric permittivity spectrum.

Fig. 1. *Coaxial cell system*

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DIELECTRIC SPECTROSCOPY AS A VALUABLE TOOL FOR MONITORING SOIL BEHAVIOR UNDER DIFFERENT CONDITIONS

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Keywords: dielectric permittivity spectrum measurement, soil, moisture, density

The paper presents an analysis of the soil complex dielectric permittivity spectrum after compaction for two measurement techniques in different frequency ranges. Experimental results showed that an increase in bulk density and volumetric water content of soil affects the complex dielectric permittivity spectrum.

Dielectric spectroscopy is a versatile and effective tool for monitoring soil behavior under varying conditions (e.g. different moisture and compaction, or different degrees of salinity). Its ability to provide real-time, non-invasive assessments makes it invaluable for understanding soil dynamics and informing best practices in agriculture, environmental monitoring, and soil conservation. Increasing compaction as a result of conventional agricultural practices impacts soil quality and agricultural productivity due to reduction of water and nutrients availability for plant roots in compacted layers [1]. Addressing this issue is critical for enhancing the long-term sustainability of agricultural systems and achieving food security among growing environmental concerns. An experiment of soil compaction performed in laboratory conditions allowed the simulation of the conditions to which the soil is exposed, for example, during the passage of agricultural machinery.

Measurements were carried out for a few soil types with different moisture content using open coaxial probe with an antenna (measuring complex reflection coefficient S11) operating in the frequency range of 20 MHz – 1.2 GHz [2] and a coaxial cell system (measuring reflection and transmission parameters S-parameters) in frequency range of 20 MHz – 3 GHz. Both methods indicated the dependence of dielectric permittivity on density and volumetric water content of the sample. The study showed that soil dielectric permittivity is a parameter reflecting soil moisture and density and consequently soil quality.

Acknowledgment

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FUNCTIONAL PROPERTIES OF COATING SYSTEMS FOR MILITARY TECHNOLOGY APPLICATIONS

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Keywords: coatings system, surface geometric structure, adhesion, military

Currently, there is a dynamic development of coating production processes using various surface engineering technologies, such as: plasma spraying, HVOF spraying, ESD method, laser cladding, laser alloying, physical vapor deposition, chemical vapor deposition, which mainly perform protective and anti-wear functions.

The evolution of paint coatings is quite rapid, multidirectional and most interesting . The progress in the field of polymer coating technology stems from the three most important functions, i.e. the decorative function, the protective function and the informative function. Paint systems account for approximately 50% of all coating systems. It is estimated that about 95% of steel structures are safeguarded against corrosion with protective coatings, including as much as 90% – with paint coatings. The service life of paint systems ranges from several months to several years.

A special group of paint systems are paint coatings for military applications, mainly for camouflaging weapon systems and military equipment. Paint coatings are fundamentals of camouflage – they camouflage vehicles/objects in the optical range, both in visible light (VIS) and in the near-infrared (NIR) range. The main task of effective camouflage is to eliminate those features, which may cause the object to be differentiated from its surroundings, i.e. those that make it possible to distinguish one's own assets from the background, and these may include, for example, colour, shape, size, gloss and texture.

The paper presents an analysis of the functional operational properties of two-layer coatings for use in military technology. The properties were evaluated by measuring the geometric structure of the surface and adhesion. The tests were carried out for two-layer masking coating systems made in three variants: coating system (SP1), coating system modified with carbon nanotubes (SP2), coating system modified with glass microspheres (SP3). Paint coating systems were applied by pneumatic spraying to DC01 steel samples using SATA guns. Due to their operational properties, the developed coating systems can be used on weapons and military equipment.

THE NEW MEASUREMENT SYSTEM OF AN ELECTRIC FIELD FOR AIRCRAFT

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Keywords: electricc field (EF), aircraft, measurement system, Machine Learning Model (MLM).

The article presents a new form of measurement system for measuring the electric component of the electromagnetic field is presented. To assess the correctness of the measurement system, tests were performed on 5 types of aircraft, and its readings were compared with a reference meter (NHT3DL) with 01E probe. An algorithm has been developed to calibrate a new measurement system using a machine learning model (MLM). Initial calibration was performed in the GTEM 1000 chamber. It has been shown that the proposed solution confirms the high consistency of the tests using the new measurement system and the reference meter. The differences between the average measurements taken by the developed measurement system and the reference meter were satisfactory.

The purpose of the created measurement system is to collect measurement data of the electric component of the electric field. All test flights were performed in similar weather conditions. The flights were carried out on paved runway at the Depultycze Krolewskie airfield near Chelm in the eastern part of Poland from 7.00 am to 7.00 pm UTC (Coordinated Universal Time) time. Air temperature was approximately 7-15°C. The wind direction at the ground level was between 210 and 240 degrees, the wind speed was between 6-7.5 m per second and the pressure was 1011-1016 hPa. The system was placed in the cockpit of the test aircrafts (Fig.2). The developed measurement system uses the AD8318 Logarithmic Detector in combination with an Arduino microcontroller board (Fig1). The microcontroller is responsible for sending data to the smartphone. The article examines regression models using Python with the scikit-learn, lightgbm and xgboost libraries.

a) b)

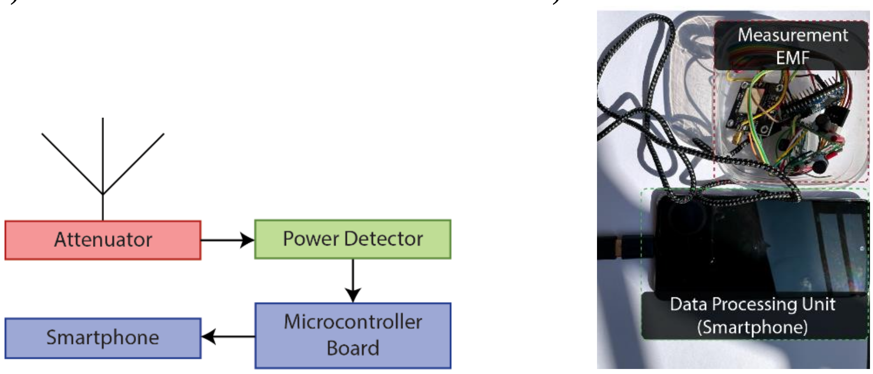

Fig. 1. *The developed new measurement system to measure the electric field: a) the schematic diagram of system, b) E measurement device*

In order to calibrate the system, measurements were made in the chamber with the wave generator. The reference meter and the developed system were placed in the chamber separately [1-3]. The time series of the readings of both devices were averaged to obtain a generalized characteristic of each device. The obtained readings were compared with each other using machine learning algorithms [4].

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OPRACOWANIE METODYKI BADAŃ I ANALIZ SGP PRZEDMIOTÓW WYKONANYCH Z MATERIAŁÓW O RÓŻNEJ REFLEKSYJNOŚCI

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Słowa kluczowe: SGP, topografia powierzchni, stykowe i bezstykowe pomiary powierzchni, refleksyjność.

Zagadnienia objęte projektem PM-II/SP/0046/2024/02 dotyczą obszaru metrologii warstwy wierzchniej ze szczególnym uwzględnieniem struktury geometrycznej powierzchni (SGP) w zakresie topografii powierzchni, jakości wytworzonych przedmiotów i sposobu weryfikacji jakości w drodze badań stanowiskowych z wykorzystaniem różnych metod oraz technik pomiarowych.

Celem projektu jest opracowanie metodyki badań i analiz SGP w zakresie topografii powierzchni wytworzonych technologicznie przedmiotów wykonanych z materiałów o różnej refleksyjności. Umożliwi to zrealizowanie kompleksowej oceny jakości wyrobu przy wykorzystaniu bezstykowych systemów optycznych w odniesieniu do metod stykowych (referencyjnych). Projekt zakłada, że stworzone w jego ramach wytyczne do sposobu prowadzenia badań i analiz topografii powierzchni przedmiotów wykonanych z materiałów o różnej refleksyjności, pozwolą na sprawne i skuteczne przeprowadzenie kontroli jakości. Jest to bardzo ważny aspekt w praktyce przemysłowej z uwagi na potrzebę szybkiego reagowania, w tym diagnozowania błędów oraz wprowadzania działań korygujących lub zapobiegawczych.

Harmonogram projektu obejmuje realizację programu badań w ramach pięciu etapów, tzw. zadań badawczo analitycznych – Rysunek 1.

Rys. 1. *Program badań*

Otrzymane dane, zebrane w formie zbioru powierzchni, technicznych warunków pomiarowych, filtrów, wyróżników (parametrów i funkcji) będą stanowiły punkt wyjścia dla konstruktorów i technologów do opracowania założeń pod wymagania norm związanych z badaniami i charakteryzowaniem struktury geometrycznej powierzchni wyrobów stosowanych w technice medycznej na komponenty implantów oraz czy narzędzia.

Podziękowania

Projekt dofinansowany ze środków budżetu państwa, przyznanych przez Ministra Edukacji i Nauki w ramach programu Polska Metrologia II (numer rej. PM-II/SP/0046/2024/02).

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MEASUREMENT OF SELECTED BEVERAGES' PROPERTIES AFTER NON THERMAL PLASMA TREATMENT

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Keywords: atmospheric pressure plasma, wine, chemical properties, measurements for food industry.

The study examines the impact of atmospheric pressure plasma treatment on wine without sulphite additions, utilizing air and nitrogen as the working gases. Employing a miniature gliding arc reactor, the treatment effectively reduced aerobic mesophilic microorganisms while preserving the desired levels of anthocyanins.

The conducted research clearly indicates the potential of cold plasma as an alternative method for use in wine production, offering good microbiological quality. Wines treated with plasma exhibited higher anthocyanin content and fewer microorganisms, with the best results achieved using air as the working gas. The obtained results align with publications by other authors using different low-temperature plasma sources. The gliding arc reactor used in this study is characterized by its relatively simple design and low operating costs, which could contribute to the broader adoption of this method in the alcohol industry in the future.

ENSURE RELIABILITY OF VOLTAGE MEASUREMENTS BASED ON REFERENCE SEMICONDUCTOR SOURCES

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Keywords: metrology, reference source, voltage measurements, semiconductor voltage source, uncertainty.

Every laboratory or metrology institute needs to possess reference standards in its resources. In the case of metrological institutions dealing with voltage measurements, semiconductor voltage sources, e.g. Fluke type 732B, are often used as the most accurate reference standard. Supervising voltage sources based only on calibrations does not ensure the complete reliability of the measurements. The standards, even the most accurate ones available, require additional checks between calibrations. This publication presents a description of the verification methods based on the most commonly used reference multimeters along with a description of the uncertainty budget. The description includes a comparison of the results obtained for several types of reference multimeters.

Introduction

The direct check method using a reference multimeter is the quickest and easiest one to perform. However, when using the most accurate multimeter, the obtained uncertainty of the check is almost twice as high as the 1-year stability of the source at the 10 V point (Tab. 1). The ratio method is definitely more accurate. However, it requires having a minimum of two voltage sources. It is more difficult to apply, the measurements are more time-consuming, and the uncertainty budget is more complicated than the direct check method. As a result, however, we can obtain results that are almost two times more accurate than those obtained using the direct check method with a reference multimeter.

Materials and methods

The work contains an analysis of the uncertainty budget [1] for various types of reference multimeters. It also includes a comparison of the results obtained using various reference multimeters for the described measurement methods. The uncertainty budget is discussed for both the direct measurement method with a reference multimeter and the ratio method using expressions (1-Uncertainty for direct measurement) and (2-Uncertainty for ratio measurement):

$$U(W_m) = k * \sqrt{\left(\sqrt{\frac{1}{n(n-1)}\sum_{n=1}^{n}(W_m(n) - \overline{W_m})^2}\right)^2 + \left(\frac{R_{Wm}}{2\sqrt{3}}\right)^2 + \left(\frac{e_o * \overline{W_m} + e_z * Z}{\sqrt{3}\ (or\ 1{,}96)}\right)^2 + \left(\frac{U_w}{2}\right)^2} \quad (1)$$

$$U(W_m) = k * \sqrt{\left(\sqrt{\frac{1}{n(n-1)}\sum_{n=1}^{n}\left(W_r(n) * W_{ref} - \overline{W_r} * W_{ref}\right)^2}\right)^2 + \left(W_{ref} * \sqrt{\left(\frac{R_{Wr}}{2\sqrt{3}}\right)^2 + \left(\bar{r} * \frac{\sqrt{\left(e_{OTr} + e_{ZTr} * \frac{Z}{W_m}\right)^2 + \left(e_{OTr} + e_{ZTr} * \frac{Z}{W_{ref}}\right)^2}}{\sqrt{3}(or\ 1{,}96)}\right)^2}\right)^2 + \left(\bar{r} * \sqrt{\left(\frac{\Delta W_{ref}}{\sqrt{3}}\right)^2 + \left(\frac{U_{Wzref}}{2}\right)^2}\right)^2} \quad (2)$$

The most attention was paid to the influence of the way the manufacturer defines the multimeter (Fig. 1) specifications [2]. The advantages and disadvantages of checking the 1.018 V point using the ratio method are also described in relation to the 1.018 V point (on the 1 V measuring range of the multimeter) and in relation to the 10 V point (on the 10 V measuring range of the multimeter). The work also describes a possibility of improving the accuracy of used semiconductor voltage sources based on long-term trend analysis. It also significantly affects the accuracy of source checks carried out using the quotient method.

Tab. 1. *DC Reference Standard Fluke 732B [3]*

Output Voltage	Stability (± ppm)		
	30 Days	90 Days	1 Year
10 V	0.3	0.8	2.0
1.018 V	0.8	NA	NA

Keysight type: 3458A / 3458A(02)

Fluke type: 8508A

Fluke type: 8588A

Fig. 1. *Reference multimeters used in the experiments*

Conclusions

This article presents the comparison of two measurement methods for realizing internal checks of voltage reference sources. Three types of reference multimeters with 8.5-digit resolution are included in the comparison.

Demonstrating the superiority of the ratio-type method over the method of direct checking with a reference multimeter is the most important result of the carried-out research.

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IDENTIFICATION OF LONG-TERM NEEDS AND DIRECTIONS OF STRATEGIC ACTIVITIES FOR THE DEVELOPMENT OF POLISH METROLOGY

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pt. „Identyfikacja długofalowych potrzeb i kierunków działań strategicznych w zakresie polskiej metrologii oraz jej rozwoju"
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Program Ministra Nauki pod nazwą „Polska Metrologia"

Metrologia chemiczna

Słowa kluczowe: metrologia chemiczna, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii chemicznej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. Przeprowadzono analizę aktualnych wyzwań i możliwości w tym kluczowym dziale. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej zaprezentowano ośrodki akademickie zajmujące się metrologią chemiczną wraz ze wskazaniem zakresu prowadzonych badań oraz dydaktyki. Omówiono również inne jednostki, takie jak: Komitet Chemii Analitycznej Polskiej Akademii Nauk, Komitety Techniczne Polskiego Komitetu Normalizacyjnego oraz Klub Polskich Laboratoriów Badawczych POLLAB. Ponadto zawarto informacje o metodyce prowadzenia tego typu pomiarów, instytucjach posiadających akredytację potwierdzającą kompetencje producenta certyfikowanych materiałów odniesienia oraz realizowanych projektach. Zidentyfikowano także aktualne problemy i potrzeby. Następnie skoncentrowano się na przyszłości metrologii chemicznej w istotnych obszarach, wśród których wymieniono: przemysł, energię, środowisko,

zdrowie oraz bezpieczeństwo i dobrobyt. Podsumowując, stwierdzono przede wszystkim, że podstawowym wyzwaniem jest ciągły rozwój procedur pomiarowych oraz opracowywanie nowych wzorców chemicznych. Należy zaznaczyć, że metrologia chemiczna stanowi fundament do dalszych działań na rzecz wzmocnienia pozycji Polski w dziedzinie metrologii, podkreślając, że rozwój tej nauki jest niezbędny dla zwiększenia konkurencyjności gospodarki, bezpieczeństwa oraz jakości życia obywateli.

Biografia

Prof. dr hab. Ewa Bulska
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Pracownik Wydziału Chemii Uniwersytetu Warszawskiego. Kierownik Centrum Metrologii Chemicznej przy Uniwersytecie Warszawskim (UW) i dyrektor Centrum Nauk Biologiczno-Chemicznych UW. Członek Komitetu Chemii Analitycznej PAN oraz przewodnicząca Zespołu Spektrometrii Atomowej KChA PAN, członek Polskiego Towarzystwa Chemicznego, Vice-prezes Klubu POLLAB, członek zarządu międzynarodowej organizacji EUROLAB. W latach 2017-2022 przewodnicząca Rady Metrologii przy Prezesie Głównego Urzędu Miar. Obecnie przewodnicząca Rady Programowej wydawnictwa MALAMUT.

Współautorka ponad 240 publikacji naukowych w czasopismach międzynarodowych oraz rozdziałów w wydawnictwach polskich i międzynarodowych. Jest ekspertką w zakresie chemii analitycznej, spektrometrii atomowej i spektrometrii mas. Autorka podręcznika „Metrologia Chemiczna", wyd. MALAMUT, oraz powstałej na tej podstawie monografii „Metrology in Chemistry" (Springer, 2018). Jest laureatką wielu nagród, w tym nagrody im. Bunsena-Kirchhoffa przyznanej przez Niemieckie Towarzystwo Chemiczne (2004), nagrody Uniwersytetu Warszawskiego im. W. Świętosławskiego (2006), medalu im. Wiktora Kemuli przyznanego przez Polskie Towarzystwo Chemiczne (2012), nagrody im. Jerzego Fijałkowskiego przyznanej przez Komitet Chemii Analitycznej PAN (2016). Została odznaczona Złotym Krzyżem Zasługi oraz Krzyżem Kawalerskim Odrodzenia Polski. Została zaliczona przez międzynarodową organizację IUPAC (International Union of Pure and Applied Chemistry) do grona dwunastu najwybitniejszych kobiet chemików, a w 2015 roku uzyskała tytułu IUPAC Distinguished Women in Chemistry. W 2024 r. otrzymała nagrodę indywidualną I stopnia Ministra Nauki. W 2024 r. została również wyróżniona przez Czeskie Towarzystwo Spektroskopowe medalem im. Ioannes Marcus Marci of Kronland.

Była stypendystką Towarzystwa Maxa Plancka (MPG) oraz Fundacji Aleksandra von Humboldta. Była także profesorem wizytującym na kilku uniwersytetach w Chinach, Japonii, Niemczech, Słowenii, Szwecji i USA.

Metrologia pomiarowa

Słowa kluczowe: metrologia elektryczna, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii elektrycznej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. Przeprowadzono kompleksową analizę aktualnych wyzwań i możliwości, podkreślając mocne i słabe strony tego istotnego działu. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej zaprezentowano podmioty (zarówno naukowe, jak i przemysłowe) zajmujące się metrologią elektryczną. W przypadku ośrodków akademickich rozważania oparto o wyniki ankiety, do której odpowiedzi udzielili kierownicy jednostek prowadzących badania w analizowanym zakresie. W tej części zawarto informacje dotyczące tematyki prowadzonych prac badawczych, zespołów badawczych, najważniejszych osiągnięć, aparatury pomiarowo-badawczej oraz planów naukowych. Dodatkowo zidentyfikowano przeszkody ograniczające działalność naukową. Charakterystykę ośrodków przemysłowych przeprowadzono na bazie ankiety skierowanej do przedsiębiorstw i podmiotów prowadzących działania w zakresie metrologii. Następnie skoncentrowano się na przyszłości metrologii elektrycznej w aspekcie perspektyw jej rozwoju w powiązaniu ze strategicznymi kierunkami rozwoju społeczeństw, a także w obszarze czujników pomiarowych. Uwzględniono również kierunki, takie jak: transport i mobilność oraz elektroenergetyka. W pracy ujęto opinie wybranych przedstawicieli ankietowanych ośrodków. Stwierdzono przede wszystkim, że rozwój metrologii powinien być wszechstronny i dotyczyć zarówno rozwoju w sferze czujników, metod pomiarowych algorytmów przetwarzania danych pomiarowych, zwiększenia szybkości i objętości pozyskiwania danych pomiarowych, integracji systemów, wykorzystania sztucznej inteligencji w przyrządach i systemach pomiarowych, automatyzacji pomiarów i wreszcie obniżania kosztów związanych z oprzyrządowaniem pomiarowym i z wdrażaniem na szeroką skalę wyspecjalizowanych systemów pomiarowych. Warto podkreślić, że metrologia elektryczna jest kluczowym obszarem w dążeniu do umocnienia pozycji Polski w dziedzinie metrologii. Rozwój tej dziedziny nauki odgrywa istotną rolę w podnoszeniu konkurencyjności gospodarki, a także w zapewnieniu bezpieczeństwa i poprawie jakości życia obywateli.

Biografia

Prof. dr hab. inż. Janusz Gajda
Akademia Górniczo-Hutnicza
im. Stanisława Staszica w Krakowie

Uzyskał stopień magistra, stopień doktora, stopień doktora habilitowanego oraz tytuł profesora odpowiednio w latach 1978, 1985, 1993 i 2001 w dziedzinie nauk inżynieryjno-technicznych, w dyscyplinie elektrotechnika. Obecnie jest zatrudniony na stanowisku profesora w Katedrze Metrologii i Elektroniki Akademii Górniczo-Hutniczej w Krakowie. Obszary zainteresowań to: metrologia elektryczna i elektroniczna, identyfikacja obiektów, przetwarzanie sygnałów, pomiary parametrów ruchu drogowego oraz pomiary biomedyczne. Jest autorem ponad 250 publikacji naukowych, w tym 7 książek i 5 patentów. Wypromował 5 doktorów.

W latach 1999-2016 kierował Katedrą Metrologii i Elektroniki na Wydziale Elektrotechniki, Automatyki, Informatyki i Inżynierii Biomedycznej AGH. Od 2016 roku jest prodziekanem ds. nauki na tym Wydziale. W latach 2007–2023 był członkiem Komitetu Metrologii i Aparatury Naukowej PAN, a w latach 2016–2023 przewodniczącym tego Komitetu. Od 2017 roku jest członkiem Rady Metrologii przy Prezesie Głównego Urzędu Miar. Od 2008 roku jest członkiem International Society of Weight in Motion.

Za swoją działalność naukową, dydaktyczną i organizacyjną został odznaczony Krzyżem Kawalerskim Orderu Odrodzenia Polski (2019), Złotym i Srebrnym Krzyżem Zasługi (2002 i 1998), Złotym Medalem za Wieloletnią Służbę (2009) oraz Medalem Komisji Edukacji Narodowej (1999).

Otrzymał 5 Złotych i 7 Srebrnych Medali na Międzynarodowych Targach Wynalazków m.in. w Warszawie, Seulu, Brukseli i Genewie. Wielokrotnie nagradzany Nagrodą Rektora AGH za osiągnięcia naukowe, dydaktyczne i organizacyjne.

Metrologia optyczna

Słowa kluczowe: metrologia optyczna, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii optycznej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. Przeprowadzono analizę aktualnych wyzwań, potrzeb i możliwości w tym istotnym dziale. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej zaprezentowano charakterystykę ośrodków akademickich i instytutów badawczych zajmujących się metrologią optyczną. Omówiono bardzo szczegółowo wyposażenie w optyczne systemy pomiarowe, w tym także w zakresie mikro- i nanotechnologii, oraz realizowane projekty badawcze. Dodatkowo zaprezentowano ogólnopolskie i międzynarodowe inicjatywy aparaturowe i organizacyjne w analizowanym zakresie. Następnie skoncentrowano się na przyszłości metrologii optycznej, nakreślając kierunki jej rozwoju, w tym odnosząc się do współczesnych i światowych trendów rozwojowych, co jest niezwykle ważne. Uwzględniono priorytetowe obszary, takie jak: przemysł, energia, zdrowie i rolnictwo, bezpieczeństwo, obronność i technologie kosmiczne oraz transformacja cyfrowa. Stwierdzono przede wszystkim, że metrologia optyczna spełnia ważną rolę właściwie we wszystkich działach gospodarki i zajmuje specjalne miejsce w dobie transformacji cyfrowej. Odpowiednie wykorzystanie istniejącej już infrastruktury oraz wzięcie pod uwagę planów rozwojowych i inwestycyjnych w nowych obszarach technologicznych, a także równoległe skoncentrowanie metrologicznych prac naukowo-badawczych na kluczowych obszarach, stwarza możliwość objęcia przez Polskę roli jednego z międzynarodowych liderów implementacji metrologii optycznej. Warto podkreślić znaczenie metrologii optycznej dla rozwoju polskiej gospodarki i nauki. Jej rozwój umożliwi wzmocnienie pozycji Polski w globalnym ekosystemie technik optycznych, przyczyniając się do wzrostu innowacyjności, poprawy jakości pomiarów oraz wsparcia sektorów przemysłowych.

Biografia

Prof. dr hab. inż. Małgorzata Kujawińska
Politechnika Warszawska

Uzyskała stopień magistra, stopień doktora, stopień doktora habilitowanego oraz tytuł profesora odpowiednio w latach 1976, 1982, 1990 i 1997 w dziedzinie nauk inżynieryjno-technicznych, w dyscyplinie budowa i eksploatacja maszyn. Obecnie jest zatrudniona na stanowisku profesora w Instytucie Mikromechaniki i Fotoniki Politechniki Warszawskiej (PW). Obszary zainteresowań to: optyka stosowana i inżynieria fotoniczna, metrologia optyczna, polowe pomiary optyczne w zastosowaniach do biomedycyny, mechaniki, inżynierii lądowej i multimediów, cyfrowe przetwarzanie obrazów. Jest autorem i współautorem ponad 500 publikacji naukowych, w tym 3 książek i 4 patentów. Wypromowała 26 doktorów i obecnie jest opiekunem 3 doktorantów.

W latach 1986-1989 pracowała w National Physical Laboratory (Wielka Brytania). W okresie 1997-2020 kierowała Zakładem Inżynierii Fotonicznej na Wydziale Mechatroniki PW. W latach 1998-2002 była prodziekanem ds. nauki na tym Wydziale. W 2003 r. weszła do prezydium SPIE - the International Society for Optics and Photonics, a w 2005 r. została Prezydentem tej organizacji. W latach 2005-2018 była vice-Prezydentem Europejskiej Platformy Technologicznej Photonics21. Kierowała licznymi projektami europejskimi oraz prestiżowymi projektami krajowymi (Mistrz FNP, Maestro NCN, Team i Team-Tech FNP).

W 1997 r. została Fellow'em SPIE, a w 2003 r. Fellow'em międzynarodowej organizacji OPTICA. Za swoją działalność naukową, dydaktyczną i organizacyjną została odznaczona Krzyżem Kawalerskim Orderu Odrodzenia Polski (2011 r.), Złotym Krzyżem Zasługi (1999 r.), licznymi nagrodami Ministra i Rektora PW. W 2013 r. uzyskała prestiżową nagrodę im. Chandra S. Vikram za osiągniecia w metrologii optycznej, a w 2022 r. nagrodę im. Denisa Gabora za prace w obszarze holografii cyfrowej.

Metrologia geometryczna

Słowa kluczowe: metrologia wielkości geometrycznych, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii wielkości geometrycznych w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej omówiono polskie wzorce państwowe oraz charakterystykę obecnego stanu w analizowanym zakresie. Zaprezentowano także zagadnienie związane z integracją pomiarów z procesem wytwórczym. Dodatkowo przeprowadzono analizę dotyczącą podmiotów zajmujących się metrologią wielkości geometrycznych i zawarto syntetyczne informacje o infrastrukturze badawczej i realizowanych projektach. Następnie skoncentrowano się na przyszłości metrologii wielkości geometrycznych w priorytetowych obszarach, takich jak: przemysł, energetyka i ochrona środowiska, zdrowie, transformacja cyfrowa oraz bezpieczeństwo i dobrobyt. Stwierdzono, że konieczne jest zapewnianie spójności pomiarowej (na najwyższym poziomie) odpowiadające aktualnym potrzebom polskiej gospodarki. Zmieniająca się technologia powinna być ściśle monitorowana w celu określenia, w jaki sposób krajowe instytucje metrologiczne mogą zaspokoić pojawiające się potrzeby otoczenia społeczno-gospodarczego. Śledzenie aktualnych potrzeb wynikających ze zmian w metodach produkcyjnych wymaga stałego dialogu pomiędzy zainteresowanymi stronami. Należy podkreślić, że rozwój metrologii wielkości geometrycznych wzmocni pozycję Polski w dziedzinie metrologii. Jest to kluczowe dla poprawy jakości i precyzji procesów produkcyjnych, a tym samym zwiększenia konkurencyjności polskiego przemysłu na arenie międzynarodowej.

Biografia

Prof. dr hab. inż. Adam Woźniak
Politechnika Warszawska

Profesor nauk technicznych i wykładowca akademicki. Specjalizuje się w metrologii wielkości geometrycznych, głównie w zakresie opracowania algorytmów, modelowania i badania dokładności szeroko rozumianych systemów pomiarowych na potrzeby przemysłu motoryzacyjnego, lotniczego, energetycznego oraz precyzyjnego. Jest autorem 2 monografii oraz ponad 170 publikacji, w tym kilkudziesięciu w uznanych, prestiżowych czasopismach naukowych. Prowadził kilkanaście projektów badawczych finansowanych m.in. ze środków: Narodowego Centrum Badań i Rozwoju, Ministerstwa Nauki i Szkolnictwa Wyższego i Fundacji Nauki Polskiej. Uczestniczył w badaniach międzynarodowych zespołów badawczych w ramach grantów Collaborative Research and Development Grants NSERC (Kanada). Wypromował 6 doktorów nauk technicznych, w tym również we współpracy międzynarodowej w programie thesis co-supervision. Promotor kilkudziesięciu prac magisterskich i inżynierskich. Recenzent w postępowaniach habilitacyjnych, doktorskich, a także w wielu czasopismach naukowych. Członek kolegiów redakcyjnych i rad naukowych. W latach 2012-2020 pełnił funkcję Dyrektora Instytutu Metrologii i Inżynierii Biomedycznej, a potem Dziekana Wydziału Mechatroniki Politechniki Warszawskiej (PW). Obecnie jest prorektorem ds. rozwoju PW. W latach 2005-2006 pracował jako visiting professor w Polytechnique de Montréal w Kanadzie. W okresie 2008-2011 był członkiem Rady Normalizacyjnej II kadencji, a w 2017 roku został powołany przez Ministra Rozwoju do Rady Metrologii I kadencji (2017-2022). Aktualnie jest przewodniczącym Rady Metrologii II kadencji (2022-2027). Jest członkiem prezydium Komisji Ewaluacji Nauki w kadencji 2023-2027, American Society for Precision Engineering, Rady Naukowej TVP Nauka oraz Towarzystwa Naukowego Warszawskiego. Za osiągnięcia naukowe otrzymał m.in. nagrodę Prezesa Rady Ministrów RP. Odznaczony Srebrnym Krzyżem Zasługi za działalność na rzecz rozwoju nauki.

Metrologia współrzędnościowa

Słowa kluczowe: metrologia współrzędnościowa, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii współrzędnościowej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej scharakteryzowano krajowe ośrodki badawcze, uwzględniając tematy prac naukowych, projekty naukowo-badawcze oraz wyposażenie w systemy współrzędnościowe. Dodatkowo omówiono laboratoria badawcze i wzorcujące oraz polską aktywność w zakresie normalizacji. Zidentyfikowano również kluczowe zagadnienia badawcze i potrzeby infrastrukturalne. Następnie skoncentrowano się na przyszłości metrologii współrzędnościowej, proponując kierunki badawcze i rozwojowe oraz opisując Narodową Sieć Metrologii Współrzędnościowej jako ważną inicjatywę. Stwierdzono, że kluczowym jest inwestowanie w najnowocześniejsze systemy pomiarowe polskich przedsiębiorstw i znaczące działania państwa we wspomaganiu tego procesu. Konieczne jest także kształcenie metrologiczne na uczelniach technicznych, w tym poprzez kursy i studia podyplomowe. Należy podkreślić, że rozwój metrologii współrzędnościowej jest istotny dla podniesienia konkurencyjności polskiego przemysłu na rynku globalnym. Podjęcie takich działań wzmocni pozycję kraju w tej dziedzinie oraz przyczyni się do poprawy jakości produkcji oraz zwiększenia precyzji i niezawodności pomiarów w różnych sektorach przemysłowych.

Biografia

Prof. dr hab. inż. Jerzy Sładek
Politechnika Krakowska

Od ponad 45 lat jest związany zawodowo z Politechniką Krakowską (PK). Wszystkie uzyskane stopnie i tytuły naukowe były pierwszymi w Polsce w rozwijanej przez niego specjalności naukowej – metrologii współrzędnościowej, która zawiera się w dyscyplinie inżynieria mechaniczna. Opracował oryginalną i unikalną metodę macierzową identyfikacji błędów systemów współrzędnościowych. Zbudował pionierskie modele tych systemów, tzw. wirtualne maszyny współrzędnościowe (bliźniaki cyfrowe), oparte na sztucznych sieciach neuronowych i metodzie Monte Carlo. Założył Laboratorium Metrologii Współrzędnościowej PK – obecnie jedno z najlepszych laboratoriów na świecie, które działa jako akredytowane przez Polskie Centrum Akredytacji laboratorium wzorcujące. Był kierownikiem 23 grantów, w tym 3 międzynarodowych, finansowanych przez UE, KBN, MNiSW i NCBR. Jest autorem i współautorem ok. 400 prac naukowych i badawczych, w tym ok. 200 publikacji, z czego ponad 50 w czasopismach z listy JCR oraz 3 książek naukowych (w tym monografii wydanej w 2016 r. w wydawnictwie o zasięgu światowym – Springer Verlag). Był promotorem 14 doktoratów, a kolejne 3 przewody doktorskie są zgłoszone. Był recenzentem w kilkudziesięciu postępowaniach na stopień doktora i doktora habilitowanego, doktora honoris causa oraz licznych recenzji dorobku do tytułu profesora. Jest członkiem Rady Doskonałości Naukowej w kadencji 2024-2027. W latach 1998-2002 był inicjatorem utworzenia Specjalnej Strefy Ekonomicznej – Krakowskiego Parku Technologicznego i pełnił funkcje wiceprezesa spółki skarbu państwa. W okresie 2016-2024 był dziekanem Wydziału Mechanicznego Politechniki Krakowskiej. Od 5 kadencji członek Komitetu Budowy Maszyn Polskiej Akademi Nauk (zasiada w prezydium), członek Rady Metrologii przy Prezesie Głównego Urzędu Miar w kadencji 2022-2027, członek Rady Innowacyjno-Naukowej Zakładów Mechanicznych "Tarnów" S.A. Aktywny członek szeregu międzynarodowych organizacji naukowych: European Virtual Institute for Geometry Measurements EVIGeM) – Member of Scientific Council od 2004, International Measurement Confederation (IMEKO) – member of Technical Committee TC 14 i innych. Z jego inicjatywy powstała Narodowa Siec Metrologii Współrzędnościowej (NSMET).

Metrologia przemysłowa

Słowa kluczowe: metrologia przemysłowa, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii przemysłowej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej omówiono funkcjonowanie klasycznego zakładu przemysłowego wraz z charakterystyką służb metrologicznych oraz opisem funkcjonowania laboratoriów pomiarowych i działu badawczo-rozwojowego. Scharakteryzowano także metrologiczne usługi zewnętrzne. Dodatkowo przeprowadzono analizę aktualnych problemów i potrzeb. Następnie skoncentrowano się na przyszłości metrologii przemysłowej w priorytetowych obszarach, takich jak: nowe systemy i rozwiązania pomiarowe, automatyzacja i robotyzacja, informatyzacja oraz zrównoważony rozwój. Przedstawiono również rolę człowieka w metrologii przyszłości. Stwierdzono, że ważnym aspektem będzie rozwój przyrządów pomiarowych, ze szczególnym uwzględnieniem kwestii informatycznych. Sztuczna inteligencja i duże zbiory danych to coś z czym już powoli należy się zaprzyjaźnić. Na pewno dużą rolę odgrywać będzie cyberbezpieczeństwo. Istotna będzie także kadra techniczna i problemy z pozyskaniem wysoko wykwalifikowanych specjalistów. Kluczowym elementem strategii jest również zwiększenie współpracy między przedsiębiorstwami, uczelniami technicznymi oraz ośrodkami badawczymi, co ma na celu przyspieszenie transferu wiedzy i innowacji do przemysłu. Konieczne do podkreślenia jest znaczenie metrologii przemysłowej, ze względu na aspekt aplikacyjny tej dziedziny nauki. Podjęte działania mają na celu wzmocnienie konkurencyjności polskiego przemysłu poprzez poprawę jakości i efektywności procesów zarówno pomiarowych, jak i produkcyjnych.

Biografia

Prof. dr hab. inż. Michał Wieczorowski
Politechnika Poznańska

Kierownik Zakładu Metrologii i Systemów Pomiarowych w Instytucie Technologii Mechanicznej na Wydziale Inżynierii Mechanicznej Politechniki Poznańskiej. Doktor od 1996 r., doktor habilitowany od 2009 r., profesor od 2015 r. W latach 2020-2024 Prorektor Politechniki Poznańskiej ds. rozwoju i współpracy z gospodarką oraz członek Prezydium Kolegium Prorektorów ds. Ogólnych, Organizacji i Kontaktów z Otoczeniem Społeczno-Gospodarczym Publicznych Wyższych Szkół Technicznych.

Członek Rady ds. innowacji w szkolnictwie wyższym i nauce, Rady Metrologii przy Prezesie GUM i Rady Normalizacyjnej przy Polskim Komitecie Normalizacyjnym. Przewodniczący Zespołu Doradczego do opracowania innowacyjnych kierunków w zakresie rozwoju usług metrologicznych GUM, członek Zespołu doradczego MEiN ds. programu „Doktorat wdrożeniowy" i Zespołu doradczego do spraw programu „Polska Metrologia". Wiceprzewodniczący Komitetu Budowy Maszyn PAN. Członek Akademii Inżynierskiej w Polsce. Członek Komisji Inżynierii Powierzchni przy O/PAN w Poznaniu. Członek Prezydium Wielkopolskiej Rady Regionalnej Przemysłu Przyszłości oraz Rady Rozwoju Obszaru Gospodarczego Kostrzyńsko-Słubickiej Specjalnej Strefy Ekonomicznej. Członek Komitetu Technicznego ISO TC 213 jako delegat Polski oraz Komitetów Technicznych 48 i 207 Polskiego Komitetu Normalizacyjnego. Członek Zarządu Polskiego Stowarzyszenia Stypendystów Fulbrighta.

Associate Editor w czasopismach: Measurement, Measurement: Sensors, Measurement: Food, Metrology and Measurement Systems oraz Metrology & Hallmark. Członek Rady Programowej czasopisma Mechanik.

Stypendysta fundacji Fulbright'a w Northwestern University w Evanston w USA. Visiting Professor w Université Polytechnique Hauts-de-France, Valenciennes (Francja).

Współzałożyciel ITA sp. z o.o. jednej z największych firm metrologicznych w Polsce.

Metrologia fizyczna

Słowa kluczowe: metrologia fizyczna, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii fizycznej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, zaznaczając, że jest to zagadnienie bardzo szerokie, wymagające pewnego zawężenia na potrzeby niniejszej monografii. W kolejnym rozdziale wymieniono podmioty, głównie naukowe, zajmujące się metrologią fizyczną. Zaprezentowano także syntetyczne informacje dotyczące zasobów techniczno-aparaturowych oraz kadry metrologicznej i jej kompetencji. Dodatkowo zidentyfikowano problemy i potrzeby. Następnie skoncentrowano się na przyszłości metrologii fizycznej w priorytetowych obszarach, takich jak: przemysł i zaawansowana produkcja, robotyzacja i automatyzacja procesów pomiarowych, energia, środowisko, zdrowie, transport i logistyka oraz transformacja cyfrowa. Stwierdzono przede wszystkim, że rozwój przyrządów pomiarowych i rejestrujących jest związany z rozwojem cyfryzacji oraz sieci komputerowych we wszystkich obszarach życia człowieka. Warto podkreślić, że rozwój metrologii fizycznej w Polsce przyczyni się nie tylko do zwiększenia precyzji i dokładności pomiarów, ale także dostosowania krajowego systemu metrologicznego do dynamicznie zmieniających się wymogów globalnych standardów. Opracowanie stanowi punkt wyjścia do dalszych działań, zwiększających konkurencyjności krajowej gospodarki.

Biografia

Prof. dr hab. inż. Grzegorz Budzik
Politechnika Rzeszowska
im. Ignacego Łukasiewicza

Uzyskał stopień magistra inżyniera na Wydziale Budowy Maszyn i Lotnictwa Politechniki Rzeszowskiej. Stopień doktora nauk technicznych otrzymał w roku 2001 na Wydziale Mechanicznym Politechniki Krakowskiej, stopień naukowy doktora habilitowanego uzyskał w roku 2010 na Wydziale Budowy Maszyn i Lotnictwa Politechniki Rzeszowskiej, a w roku 2014 otrzymał tytuł profesora nauk technicznych. W latach 2012-2016 pełnił funkcję prodziekana ds. nauki i rozwoju WBMiL, a w kadencji 2016-2020 pełnił funkcję prorektora ds. nauki Politechniki Rzeszowskiej. Od roku 2015 kieruje Katedrą Konstrukcji Maszyn Politechniki Rzeszowskiej. Jest współautorem i autorem ponad 400 opracowań i publikacji naukowych, w tym kilku książek i monografii, patentów, zgłoszeń patentowych oraz wdrożeń przemysłowych. Wypromował 12 doktorów nauk technicznych.

Obszary zainteresowań to: metrologia geometryczna i fizyczna, modelowanie numeryczne 3D-CAD, druk 3D, systemy cyber-fizyczne, inżynieria medyczna, technologie i narzędzia dla Industry 4.0/5.0 oraz Smart Manufacturing.

Ekspert Polskiego Komitetu Normalizacyjnego oraz Polskiej Komisji Akredytacyjnej, członek Rady do spraw innowacji w szkolnictwie wyższym i nauce przy Ministerstwie Nauki, członek Rady Naukowo-Programowej Podkarpackiego Centrum Nauki „Łukasiewicz", członek Komitetu Budowy Maszyn Polskiej Akademii Nauk, członek sekcji TC 261/WG 2 Additive Manufacturing ISO – International Organization for Standardization.

Metrologia medyczna

Słowa kluczowe: metrologia medyczna, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii medycznej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej wymieniono podmioty zajmujące się metrologią medyczną w zakresie wykorzystania promieniowania jonizującego oraz metod nieradiologicznych. Zaprezentowano także syntetyczne informacje dotyczące zasobów techniczno-aparaturowych oraz zidentyfikowanych problemów i potrzeb. Następnie skoncentrowano się na przyszłości metrologii medycznej, nakreślając kierunki jej rozwoju. Stwierdzono przede wszystkim, że w wyniku zmian podczas transformacji ustrojowej praktycznie zlikwidowano fabryki produkujące półprzewodniki oraz ośrodki rozwojowe przemysłu elektronicznego powszechnego użytku. Obecnie nie ma w Polsce nawet średniej wielkości firmy elektronicznej, która stanowiłaby naturalne zaplecze dla projektowania i produkcji zaawansowanych urządzeń medycznych. Należy podkreślić, że metrologia medyczna, będąca kluczowym elementem nowoczesnej opieki zdrowotnej, odgrywa istotną rolę w zapewnieniu dokładnych, rzetelnych i powtarzalnych pomiarów, niezbędnych w diagnostyce, terapii oraz monitorowaniu stanu zdrowia pacjentów. Jej rozwój wzmocni pozycję Polski na arenie międzynarodowej, co jest niezbędne dla podniesienia standardów opieki zdrowotnej.

Biografia

Prof. dr hab. inż. Gerard Cybulski
Politechnika Warszawska

Absolwent Wydziału Mechaniki Precyzyjnej (obecnie Mechatroniki) Politechniki Warszawskiej (1984 r.). Główne obszary jego zainteresowań badawczych to m.in: nieinwazyjna ocena mechanizmów regulacyjnych w układzie krążenia, rozwijanie metod pomiarowych umożliwiających nieinwazyjne monitorowanie czynności układu krążenia, analiza czynności układu krążenia oraz kliniczna weryfikacja proponowanych metod. Odbył staże naukowe w Center for Biological and Medical Systems Imperial College of Science Technology and Medicine (Londyn) oraz w Department of Engineering University of Leicester. W latach 1984-2018 był związany z Zakładem Fizjologii Stosowanej Instytutu Medycyny Doświadczalnej i Klinicznej im. M. Mossakowskieo PAN, gdzie Rada Naukowa nadała mu stopień doktora nauk przyrodniczych (1990 r.).

W styczniu 2008 r. Rada Naukowa Wydziału Mechatroniki PW nadała mu stopień doktora habilitowanego w dyscyplinie Biocybernetyka i inżynieria biomedyczna. 28 listopada 2019 r. Prezydent RP nadał mu tytuł profesora nauk inżynieryjno-technicznych. Jest autorem 3 monografii. Jest także autorem bądź współautorem ponad 70 prac naukowych opublikowanych w renomowanych czasopismach naukowych. Był kierownikiem w 2 i wykonawcą w 4 projektach badawczych finansowanych ze źródeł zewnętrznych. Wypromował czterech doktorów, 16 magistrów i 47 inżynierów.

W październiku 2019 r. został wybrany na stanowisko Przewodniczącego Pierwszej Rady Naukowej Dyscypliny Inżynieria Biomedyczna PW. Był członkiem Komitetu Naukowego Biocybernetyka i Inżynieria Biomedyczna Polskiej Akademii Nauk w kadencji 2020-2023. Został ponownie wybrany na kadencję 2024-2027 i pełni funkcję członka Zarządu tego komitetu. Ponadto został po raz pierwszy wybrany na członka Komitetu Naukowego Fizyki Medycznej, Radiobiologii i Diagnostyki Obrazowej PAN. W 2020 r. został powołany na stanowisko dziekana Wydziału Mechatroniki Politechniki Warszawskiej na kadencję 2020-2024. Jest członkiem Polskiego Towarzystwa Kardiologicznego oraz European Cardiac Society.

Metrologia prawna

Słowa kluczowe: metrologia prawna, Polska Metrologia, diagnoza stanu metrologii, strategiczne kierunki rozwoju metrologii.

W pracy przedstawiono diagnozę stanu metrologii prawnej w Polsce oraz opisano strategiczne kierunki jej dalszego rozwoju. W pierwszej części określono obszar merytoryczny, będący przedmiotem opracowania, a w kolejnej omówiono infrastrukturę jakości w aspekcie metrologii prawnej. Kompleksowo zaprezentowano elementy metrologii prawnej, w tym legalne jednostki miar, prawną kontrolę metrologiczną, system prawnej kontroli metrologicznej oraz nadzór. Dodatkowo scharakteryzowano zasoby kadrowe oraz odniesiono się do kontekstu międzynarodowego. Zidentyfikowano również problemy i potrzeby. Następnie skoncentrowano się na przyszłości metrologii prawnej, przedstawiając strategiczne kierunki jej rozwoju. Stwierdzono, że rozwój metrologii prawnej powinien uwzględniać konieczność regulacji w zakresie minimalnym do realizacji zadań, poprzez kształtowanie prawa przyczyniającego się i/lub sprzyjającego całościowo wzmocnieniu krajowej infrastruktury jakości, tworząc w ten sposób warunki do rozwoju przedsiębiorców krajowych i nowych technologii oraz służąc budowaniu wizerunku polski jako państwa przyjaznego nowoczesnej gospodarce przy jednoczesnym zapewnieniu bezpieczeństwa technicznego kraju. Nieodzowne jest przy tym zapewnienie, utrzymanie i stały rozwój odpowiedniego krajowego zaplecza kadrowo-badawczego. Należy podkreślić, że rozwój metrologii prawnej w Polsce przyczyni się do zwiększenia zaufania do pomiarów stosowanych w kluczowych obszarach życia społeczno-gospodarczego, poprawy jakości nadzoru oraz harmonizacji polskich regulacji z normami międzynarodowymi.

Biografia

Paulina Olszewska
Główny Urząd Miar

Absolwentka Wydziału Prawa i Administracji oraz Centrum Europejskiego Uniwersytetu Warszawskiego. Ukończyła studia podyplomowe z zakresu audytu i zarządzania oraz konsultacji publicznych. Uczestniczka krajowych i międzynarodowych projektów z zakresu prawa, zarządzania i spraw międzynarodowych. Ukończyła liczne szkolenia z zakresu zarządzania: strategicznego, procesowego, projektami, ryzykiem oraz komunikacji i negocjacji, a także wykorzystania nowych technologii w sektorze publicznym. Od 2013 r. urzędnik służby cywilnej.

Od 2008 r. jest pracownikiem Głównego Urzędu Miar na stanowiskach związanych z metrologią prawną i współpracą międzynarodową w tym obszarze.

Obecnie pełni funkcję Dyrektora Departamentu Certyfikacji, odpowiadając za realizację zadań w zakresie certyfikacji wyrobów, osób i usług w odniesieniu do przyrządów pomiarowych, kas rejestrujących, tachografów oraz koordynację jednostki notyfikowanej. Prowadzi szkolenia i seminaria z obszaru metrologii prawnej, w szczególności prawnej kontroli metrologicznej i systemów certyfikacji. Autorka licznych publikacji i uczestniczka konferencji branżowych.

Przedstawicielka Głównego Urzędu Miar w metrologicznych organizacjach międzynarodowych (OIML, WELMEC, NoBoMet). Zaangażowana w reformę prac technicznych oraz budowę systemu certyfikacji Międzynarodowej Organizacji Metrologii Prawnej (OIML). Pełni funkcję pełnomocnika ds. zapewnienia zgodności z wymaganiami normy PN-EN ISO/IEC 17065 (Ocena zgodności – Wymagania dla jednostek certyfikujących wyroby, procesy i usługi). Koordynatorka grup roboczych ds. przeglądu przyrządów pomiarowych oraz certyfikacji działających w strukturze Konsultacyjnego Zespołu Metrologicznego do spraw regulacji rynku.

Pasjonatka cyfryzacji i optymalizacji procesów. Inicjatorka projektu budowy elektronicznych usług publicznych Głównego Urzędu Miar „TRANS-TACHO”, realizowanego w ramach programu Polska Cyfrowa.

POLSKA METROLOGIA

AFFILIATED RESEARCH INSTITUTIONS

1. Academy of Applied Sciences in Krosno
2. AGH University of Krakow
3. Bialystok University of Technology
4. Casimir Pulaski Radom University
5. Cracow University of Technology
6. Czestochowa University of Technology
7. Ilmenau University of Technology
8. Institute of Agrophysics, Polish Academy of Sciences
9. Institute of Low Temperature and Structure Research, Polish Academy of Sciences
10. Jan Kochanowski University of Kielce
11. Kielce University of Technology
12. Kyushu University
13. Lublin University of Technology
14. Lukasiewicz Research Network
15. Lviv Polytechnic National University
16. Maria Curie-Skłodowska University
17. Military Institute of Armoured and Automotive Technology
18. Military Institute of Chemistry and Radiometry
19. National Metrology Institute of Italy
20. Opole University of Technology
21. Pomeranian Medical University
22. Poznan University of Technology
23. Rzeszow Univesity of Technology
24. Saga University
25. Seikei University
26. Silesian University of Technology
27. Sumy National Agrarian University
28. The University College of Applied Sciences in Chełm
29. University of Bialystok
30. University of Life Sciences in Lublin
31. University of Salento
32. University of Sannio

33. University of Warsaw
34. Warsaw University of Technology
35. Wroclaw University of Science and Technology

INSTITUTIONS

1. Central Office of Measures
2. European Association of National Metrology Institutes - EURAMET e.V.
3. European Commission
4. Lifelong Learning and Vocational Education Centre No. 2 in Radom
5. Swietokrzyskie Laboratory Campus of the Central Office of Measures
6. Ukrainian Academy of Metrology

COMPANIES

1. Barwa trading company
2. E-test Ltd
3. Hexagon Metrology Ltd
4. ITA Ltd
5. PLUM Measurement Laboratory
6. RADWAG Balances and Scales
7. Siemens Ltd, Digital Industries, RC-PL DI MC MTS
8. SMARTTECH Ltd
9. VTT MIKES Metrology
10. ZEISS Poland

The conference materials were prepared based on abstracts submitted by participants of the "New Trends in Metrology" conference. The submitted papers were reviewed by selected members of the Scientific Committee and approved as being in line with the conference theme. The organizers and editor are not responsible for their content.

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