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the Cutting Tools 2024 Conference**



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Preface

The international scientific and professional conference Cutting Tools 2024, held on 20–22 November 2024 at the Faculty of Materials Science and Technology of the Slovak University of Technology in Bratislava with seat in Trnava, represented an important platform for professional discussion, knowledge exchange, and presentation of current trends in the field of cutting tools and machining technologies. The conference was organized by the Faculty of Materials Science and Technology STU in cooperation with MASAM s.r.o.

The main objective of the conference was to strengthen the connection between academia and industrial practice and to create a space for expert discussion on current challenges, innovative approaches, and future perspectives in the research, development, and application of cutting tools. Particular attention was devoted to modern machining technologies, forming, welding, optimization of manufacturing processes, advanced materials, and practical industrial experience.

The professional significance of the conference was confirmed by the participation of representatives from universities, research institutions, and industrial companies from Slovakia, the Czech Republic, Hungary, and Romania. Research findings and professional experiences were presented not only by academic researchers, but also by experts from industrial companies.

This conference proceedings volume provides scientific knowledge, practical experience, and innovative solutions that may contribute to the advancement of academia, research organizations, and industrial practice.

We believe that Cutting Tools 2024 conference and abstract proceedings will contribute to the further development of international cooperation, support the transfer of knowledge between academia and industry, and foster innovation in the field of modern manufacturing technologies.

Development of a compact screw extruder for robotic additive manufacturing

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Abstract

This study focuses on the theoretical design of a lightweight screw extruder for robotic additive manufacturing (AM). The primary objective is to enhance material flow control, minimize extruder weight for seamless robotic integration, and improve thermal efficiency. A mathematical model is used to analyze material transport, pressure distribution, and extrusion rate stability. Key design parameters, including screw geometry, barrel dimensions, motor torque, and heating efficiency, are calculated. The proposed extruder ensures precise and reliable material deposition, making it suitable for industrial AM applications. The findings provide a foundation for further development of efficient extrusion systems in robotic additive manufacturing printing.

Keywords:

Additive Manufacturing; Industrial Robotics; Screw Extrusion; Extruder

Acknowledgements

This work was funded by the Grant Scheme for Supporting Excellent Teams of Young Researchers under internal project number 1353, titled "Research on path generation and motion planning of industrial robot and its use in hybrid manufacturing with MEX technology and subtractive processes."

Additionally, this research was supported by the project APVV-23-0084 "Robotic-Based Hybrid Manufacturing of Workpieces for the Concept of Smart Production" funded by the Slovak Research and Development Agency.

This work was also carried out within the Young Researcher Support Grant for the project "Development of a Screw Extruder for Robotic Additive Manufacturing."

Geometric analysis and mathematical model of a polycentric knee mechanism

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Abstract

This paper focuses on calculating the central distances of polycentric joints designed to replicate the natural motion of the human knee. A key aspect is the shortening of the central distance during the swing phase, which reduces tripping risk and improves gait stability. Using mathematical modeling, the study analyzes the dynamic changes in instantaneous centers of rotation and their impact on knee biomechanics. The results enable a more precise design of polycentric prosthetic joints, enhancing their functionality and adaptability for users.

Keywords:

Polycentric; Joint; Ellipse; Knee; Prothesis

Acknowledgements

The paper is a part of the research done within the project VEGA 1/0391/24 “Research and Development of a Methodology for Sensor Calibration in Diagnostic Devices for Automated and Robotic Systems” funded by the Slovak Research and Development Agency.

The paper is a part of the research done within the project APVV-23-0084 “Robotic-Based Hybrid Manufacturing of Workpiece for the Concept of Smart Production” funded by the Slovak Research and Development Agency.

Optimization of parameters in robotic additive manufacturing of thin-walled tubes: Experimental analysis and path planning

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Abstract

Robotic Additive Manufacturing (RAM) represents an innovative approach to 3D printing, utilizing multi-axis industrial robots to execute complex printing tasks. This study focuses on path planning and the investigation of key parameters affecting the print quality of thin-walled tubes printed using a planar method. The experiments analyzed the effects of cooling, robot movement speed, material feed rate, and the number of perimeter layers on print quality. The results indicate that the combination of these parameters influences the quality and overall success of the printing process. Path generation was based on G-code created in open-source slicers, which was adapted for the ABB IRB 120 industrial robot. Future research will focus on expanding the study to the printing of non-planar curved tubes.

Keywords:

Robotic Additive Manufacturing; Industrial Robot; 3D Printing; Path Planning; Thin-Walled Tubes

Acknowledgements

This work was funded by the Grant Scheme for Supporting Excellent Teams of Young Researchers under internal project number 1353, titled "Research on path generation and motion planning of industrial robot and its use in hybrid manufacturing with MEX technology and subtractive processes."

Additionally, this research was supported by the project APVV-23-0084 "Robotic-Based Hybrid Manufacturing of Workpieces for the Concept of Smart Production" funded by the Slovak Research and Development Agency.

Microhardness and elastic modulus of thin coatings Applied via PVD and CVD Techniques

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Abstract

This study investigates the microhardness and mechanical properties of thin coatings applied to cemented carbide cutting tools. Two primary coating techniques were examined: Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD). PVD coatings of titanium carbonitride (TiCN) and aluminium titanium nitride (AlTiN) were applied, along with multi-layer CVD coatings consisting of TiCN, titanium carbide (TiC), and aluminium oxide (Al₂O₃). Depth-sensing indentation (DSI) tests using a Vickers indenter were conducted to determine the microhardness and elastic modulus of the coatings. The Oliver and Pharr method, was employed to analyse load-unload curves, enabling precise evaluation without direct measurement of imprint areas.

The results demonstrated that TiCN coatings applied via PVD exhibited the highest microhardness and elastic modulus among all tested samples. This superior performance indicates enhanced wear resistance and mechanical stability, which are critical for extending the lifespan and efficiency of cutting tools. While multi-layer CVD coatings also offered benefits, their overall performance was inferior to that of TiCN PVD coatings.

Keywords:

Microhardness; Cutting Tools; TiCN Coatings; PVD; CVD DSI; Elastic Modulus

Comparison of geometrical accuracy of machine tool and manufactured part

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Abstract

The main characteristics of a machine tool include its ability to produce products in compliance with the dimensions and shapes specified in the production drawing. The static accuracy of a machine tool for chip machining is given primarily by the geometric accuracy of its guide surfaces and moving components. The resulting shape and dimensional accuracy of the workpiece is given by a combination of the state of the machine tool geometry and the influence of the machining process. In its introductory part, this contribution presents classical and progressive approaches to measuring the geometric accuracy of machine tools with an emphasis on the method of measurement using the circular interpolation accuracy test using the Ball-bar system. The second part of the contribution describes the practical implementation of the circular interpolation accuracy test on a three-axis vertical machining center MAS MCV 1270 using the Renishaw Ball bar QC 20 W system. The results of this test are compared with the circularity deviations of shaped elements manufactured on a pair of test plates at standard and increased feed rates. A three-axis coordinate measuring machine Wenzel LH 65 X3M Premium was used to measure roundness deviations. The aim of the paper is to provide information regarding the control of geometric accuracy of machine tools with subsequent verification and prediction of the accuracy of manufactured workpieces.

Keywords:

Geometrical Accuracy; Static Accuracy; Machine Tools; Ball-bar; Comparison

Acknowledgements

This work was supported by TACR project FW03010587 Development of a new series of welded gate valves for industry, energy and design of production technology using the principles of Industry 4.0.

ANN-based tool life prediction in micro-milling using a dataset derived by central composite design of experiments methodology

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Abstract

Artificial Intelligence (AI) applications are now prevalent in nearly every field that involves process optimization and predicting future events. Artificial Neural Networks (ANN) can be universally applied to both regression and classification tasks, effectively handling datasets of various sizes and dimensions. In many cases, these modern data-driven modelling techniques surpass traditional regression methods. Therefore, ANN-based predictive models are becoming increasingly popular in machining technologies as well.

Our research focused on the potential applications of AI-based predictive models in micro-milling, using a dataset from a cutting experiment designed to analyse the tool life. This dataset was previously utilized solely to develop traditional regression models, so our goal was to create an Artificial Neural Network (ANN) that could more efficiently predict tool life based on this data. Given the small sample size of the dataset, leave-one-out cross-validation (LOOCV) was employed during validation. By experimenting with various network structures—modifying the number of layers neurons, and types of activation functions—we determined an appropriate ANN model to outperform the original regression models. The details of this work will be presented in this presentation.

Keywords:

Micro-milling; ANN; Tool life prediction; Central Composite Design; Leave-One-Out Cross-Validation

Heuristic Local Search Algorithms in Tool Path Planning - A Review

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Abstract

Tool path planning is a critical component of CNC machining, significantly affecting machining time, tool wear, surface quality, and energy efficiency. In industrial CAM systems, tool paths are typically generated based on geometric constraints without global optimization, leaving considerable potential for improvement. This presentation provides an overview of heuristic and local search-based optimization methods applied to tool path planning, with a focus on their role in addressing complex, multi-objective manufacturing problems. The discussed approaches include classical combinatorial formulations such as the Traveling Salesman Problem (TSP), which is widely used for modeling drilling sequencing and feature-based machining. Common heuristic and metaheuristic methods are reviewed, along with hybrid strategies that combine global and local search techniques to improve solution quality and robustness. The presentation also highlights emerging directions, including AI-based prediction of cutting parameters, energy-aware machining strategies, and integrated optimization of tool paths and process parameters. Key challenges such as high computational complexity, dynamic machining constraints, and multi-objective optimization are also discussed. Overall, heuristic local search methods provide effective improvements in tool path optimization, with further potential expected from AI-driven and real-time adaptive approaches.

Keywords:

Tool path planning; Heuristic optimization; CNC machining; Metaheuristic algorithms

The effect of technological parameters on the change in surface microhardness during the external cylindrical burnishing of X5CrNi18-10 steel workpieces

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Abstract

Among the finishing machining operations, burnishing is an economical process with a low environmental impact. In special cases, grinding can be replaced by burnishing, creating the same roughness with a much lower environmental load. The purpose of the study was to determine the effect of the technological parameters of the burnishing process on the surface roughness and hardness. The hardening experiments were performed on X5CrNi18-10 stainless steel specimens. The burnishing parameters used during the experimental examinations were burnishing speed, feed, and burnishing force. The experiments were carried out using the full factorial experimental design method.

After the evaluation of the measured results, it was determined that due to burnishing, from the pre-burnishing value of the Vickers hardness HV: 330-370 increased to HV: 380-490. A special improvement-ratio formula was developed to evaluate the effectiveness of the burnishing process in terms of hardness and roughness.

Keywords:

Sliding friction burnishing; Stainless steel; Surface roughness; Hardness; Surface layer

AI for quality optimization in turning: A short review

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Abstract

The advancement of Artificial Intelligence (AI) in manufacturing begins with the Fourth Industrial Revolution. AI allows manufacturing with efficiency optimization, product quality improvement, cost reduction, and ease of real-time predictive maintenance. The topic is clearly stated in the literature. However, it fails to note the turning operation and quality optimization. This review attempts to clarify the factors influencing the quality of the finished product, related challenges, and the integration of AI to address these issues. The article highlights several methods for developing AI models and their real-world implementation. The paper systematically assesses the available literature, categorizing process characteristics and AI techniques based on data sources and management methodologies. The key result demonstrates that artificial neural networks and regression analysis are widely used in machining and optimization procedures, with fuzzy logic proving advantageous. Data management and filtration are essential for a reliable AI model. This paper offers insights into pre-processing, algorithm choice, and optimization methodologies, guiding researchers in constructing successful AI models for quality optimization in turning operations.

Keywords:

Artificial Intelligence; Turning; Industry 5.0; Smart manufacturing

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Chip breaker machining with abrasive water jet milling

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Abstract

In the paper, an innovative machining method for chip breakers on cutting tools is presented. A chip breaker is a feature on cutting tools, such as those used in turning, milling, and drilling, designed to control and break up chips during the machining process. It helps prevent long, continuous chips from forming. This study introduces a groundbreaking approach using Abrasive Water Jet Milling (AWJM) to directly machine chip breakers onto sintered carbide inserts. The AWJM process offers flexibility and precision, enabling the creation of complex chip breaker geometries tailored to specific machining applications. A case study is presented, where a chip breaker is machined in a turning insert. Experimental results validate the effectiveness of this innovative method in improving chip control, reducing tool wear, and enhancing overall machining performance.

Keywords:

Cutting tools; Chip breaker; Abrasive Water Jet Milling, Turning

3D-printed clamping device for vibration damping

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Abstract

This research presents a novel approach to designing and manufacturing 3D-printed clamping devices to mitigate vibrations during the machining of thin-walled parts. Excessive vibrations can significantly degrade surface quality, dimensional accuracy, and tool life, limiting the efficiency and effectiveness of machining processes. By carefully selecting materials, optimizing geometric design, and leveraging 3D printing technology, the proposed clamping devices aim to enhance workpiece stability and reduce vibration transmission. Experimental testing will be conducted to evaluate the performance of these devices in terms of vibration reduction, surface finish improvement, dimensional accuracy, and tool life extension. The results of this study will provide valuable insights into the potential benefits of 3D-printed clamping devices for improving the machining of thin-walled parts.

Keywords:

3D-printed; Clamping devices; Vibration

Specifics of WAAM process in terms of geometry, mechanical and structural properties of manufactured component

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Abstract

Enormously rising prices of raw materials and energy currently make it possible to apply AM technologies to an even greater extent. Among these technologies is WAAM. However, the gradual deposition of layers creates structures in the created components that are different from semi-finished products, from which parts are made by machining or forming. In addition, the arc deposition process variables cause deviations in the resulting geometry of the produced components.

The paper deals with the evaluation of geometrical, mechanical and microstructural properties of components made by the WAAM method at various selected modes and process parameters.

As expected, the smallest heat input was achieved when applying the CMT mode. When applying an interpass temperature of 100 °C, a greater height, smaller width, smaller waviness, but also a reduction in the mechanical properties of the manufactured components were achieved. In terms of the surface waviness achieved, the smallest waviness was achieved in the Pulse Synergic mode when the interpass temperature was applied, and in the CMT mode when the interpass temperature was kept and the Inoxline shielding gas was used. This gas also increased the mechanical properties of the components. Microstructure analysis identified a coarse-grained dendritic structure and the presence of γ' and γ'' phases in the manufactured components.

Keywords:

Additive manufacturing; Overlay geometry; Interpass temperature; Stainless steel

Acknowledgements

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Lifetime assessment of welding tool for AW70075 aluminium alloy

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Abstract

Welding of aluminium alloys is currently a huge topic in all industries starting with bigger application in automotive or aerospace, up to small electronic application. Normally, high productivity technologies are used in order to fulfil high production demands. Nowadays, with respect to ecological and sustainability demands, new technologies and procedures are getting to prominence. One of the latest technologies developed is friction stir welding which is easy to use and safe for the operator. Aluminium alloy AW7075 was used within the experiment in order to find suitable welding parameters to weld 5 mm thick plate. Based on previous research The change of the tool geometry rise the question of its lifetime. For newly developed welding tool the lifetime test was proposed in order to compare its performance. F06, F08 and F10 tools steels were used to produce the FSW tools with the same tool geometry and lifetime up to 1 km of weld joints was observed.

Keywords:

Friction stir welding; Lifetime assessment; AW7075; Welding tool

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-21-0111.

Magnetic monitoring of surfaces from austenitic steels after plastic deformation

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Abstract

The study is dealing with the Barkhausen noise technique employment for monitoring of phase stability of austenitic steels with respect of their plastic deformation. The high sensitivity of this magnetic technique is based on the contrast between the paramagnetic austenite, which produces zero Barkhausen noise emission and the strain induced martensite in the parental austenite which represents the ferromagnetic component of these steels. For this reason, the whole Barkhausen noise emission can be directly related to the weight fraction of the strain induced martensite and its properties. The study presents some deformation processes such as rolling contact wear, shot-peening, cavitation as well as research in the field of model metals. Apart from the effective value of Barkhausen noise, it can be extracted further Barkhausen noise features from the raw signal such as pulses height distribution function, Barkhausen noise envelopes and extracted parameters.

Keywords:

Austenitic matrix; Barkhausen noise; Plastic deformation; Strain-induced martensite

The impact of generator parameters on coated electrode wear in the WEDM process

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Abstract

This paper investigates the wear of a coated wire electrode during the WEDM process. The electrode used was a multi-layer coated wire with a copper core and a special GAMA Cu5Zn8 alloy coating. The electrode was electrolytically coated. The machined material was a K-grade cemented carbide rod with a diameter of 25 mm. Experiments were conducted on a Charmilles Robofil 310 machine. Electrode wear was evaluated based on the weight loss of a 3-meter wire, measured with 0.001 g resolution. The experiment was designed using the Taguchi methodology and evaluated by ANOVA. Machining stability was monitored using an oscilloscope.

Keywords:

WEDM; Electrode wear; Taguchi method; ANOVA; Machining stability

Acknowledgements

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Effect of WAAM parameters on the aluminum alloy single layer bead geometry

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Abstract

This study investigates the impact of process parameters on the geometry of single-layer overlay welds of AA5087 aluminum alloy, fabricated using Wire and Arc Additive Manufacturing (WAAM-MIG), a technique valued for its productivity and material efficiency. This method layers material as weld beads to build 3D structures. Key characteristics analyzed include bead width, bead height, penetration depth, porosity, and costs related to shielding gas flow rates. Using the Taguchi method with an L27 orthogonal array, the study optimized experimental designs while reducing trial numbers. Grey relational analysis enabled the simultaneous evaluation of multiple parameters. Optimization was conducted for individual responses and through multi-objective analysis to determine the significance of parameters for each characteristic. The findings enhance understanding of the WAAM-MIG process and its application in manufacturing components with precise geometric characteristics, supporting advancements in additive manufacturing.

Keywords:

Taguchi method; Individual optimization; Multi-objective optimization; Grey relation analysis

Acknowledgements

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Sensing the vibrations of grinding wheels by contact and non-contact methods

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Abstract

This article examines the application of vibration diagnostics and balancing methods for grinding wheels, utilizing non-contact technologies to precisely measure vibrations and optimize the operation of rotating equipment. The aim of the study is to analyse the impact of static balancing on vibration reduction using a laser interferometer, which enables detailed monitoring of frequency parameters. The theoretical section introduces the fundamentals of technical diagnostics, including fault detection and localization methods, along with specifics of vibration diagnostics in rotating systems. A key aspect of the study is the use of FFT (Fast Fourier Transform) for frequency analysis, aiding in identifying causes of increased vibrations, such as manufacturing inaccuracies. The study also compares contact and non-contact measurement techniques, with experimental data showing that proper balancing significantly improves operational stability and extends the lifespan of grinding wheels. The findings highlight the advantages of non-contact vibration diagnostics for industrial applications, providing higher measurement accuracy and enabling maintenance planning based on actual equipment conditions, which positively impacts both operational efficiency and safety.

Keywords:

Technical Diagnostics; Vibration; FFT; Evaluation; Abrasive Wheel

Comparison of digitization of geometric objects produced by additive FDM technology in the context of application for reverse geometric modelling

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Abstract

Additive manufacturing is already a commonly used production method that is commonly encountered in industry. With the increasing demands of accuracy in manufacturing, the needs of reverse engineering must also be addressed. The aim of this study is to compare the results of digitizing primitive geometric objects using a coordinate measuring machine and an industrial computed tomography. Reverse geometric modelling principles are applied to samples produced by additive FDM technology to produce a geometrically accurate 3D CAD model from the acquired data. In the experiment, curves obtained from primitive geometric objects (cylinder, cube, sphere) were compared. 5 curves were obtained from each object. These curves were fitted with a nominal curve and the resulting curve dimension was compared with reference to the data acquisition method used.

Keywords:

Reverse geometric modelling; Digitization; Computed tomography; Coordinate measuring machine

Monitoring of physical parameters during the processing of cemented carbide end mills using plasma discharge in electrolyte

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Abstract

This study introduces an innovative Plasma Discharges in Electrolyte (PDE) as a novel method for cutting edge preparation of cemented carbide tools. Unlike traditional abrasive methods, PDE removes material through localized discharges in a vapor–plasma envelope, enabling non-contact edge rounding. The aim of the article is to evaluate observed parameters such as voltage, current, cutting edge radius during the PDE process. Experimental results on a 4-flute end mill show that edge radius develops non-linearly, with the highest material removal at the beginning. PDE proved up to 110% faster than drag finishing for larger radii.

Keywords:

Cutting edge preparation; Cutting edge radius; Cemented carbide; Plasma discharges in electrolyte; Drag finishing

Acknowledgements

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Statistical evaluation of cutting force components as a function of cutting edge radius size for milling of austenitic stainless steel AISI 316L

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Abstract

In this study, the impact of cutting edge radius on the cutting forces generated during machining of AISI 316L material with uncoated cemented carbide tools is investigated. Four cutting edge radius sizes were evaluated, with sets of three tools assigned to each radius size. To assess the influence of edge radius across varying operational demands, milling was conducted with distinct machining parameters for roughing and finishing. Cutting forces were measured and transformed into two primary components for further analysis. Statistical evaluation was performed using linear regression and analysis of variance with the objective to determine the influence of factors on cutting forces, focusing on tool edge radius, machining conditions, and their interactions. The primary objective was to assess how each factor affects the two main components of cutting forces—tangential and radial—and to establish the reliability and significance of these effects using statistical methods. The analysis examined the reliability of each factor's influence, determining that both edge radius and machining condition substantially affect cutting forces, with varying degrees of statistical significance. The results provide insights into optimizing tool edge radius selection for improved cutting performance under different machining conditions, enhancing effective tool life in practical applications.

Keywords:

Cutting forces; Cutting edge radius; Cemented carbide tools; Machining conditions; Statistical analysis

The analysis of plasticity and formability of the dual phase steel DP 450 from the sheet forming aspects

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Abstract

The choice of suitable methods for establishing of plasticity and formability of new materials has great significance for high quality formed parts manufacturing from metals or plastics and also for tube production. The paper is focused on analysis of the dual phase steel DP 450 properties. This steel is used to produce selected parts in automotive industry. The properties are analysed on the base of plasticity and formability evaluation. The paper mentions results of several basic and technological tests such as static tensile tests, Erichsen cup tests, Fukui tests Schmidt cup tests and bending tests. These results are supplemented by microhardness measurements and calculations of strain hardening exponent that were based both on the Ludwik-Hollomon equation and on the strain to necking. The obtained results show that the investigated steel can be applied for forming parts not only for automotive industry.

Keywords:

Plasticity; Formability; Dual phase steel; Tensile test; Erichsen cup test

Acknowledgements

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The influence of cutting edge radius, cutting speed and feed on surface roughness and microhardness in machining stainless steel

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Abstract

The article investigates the impact of cutting edge radius and cutting parameters on the surface roughness and microhardness of austenitic stainless steel (AISI 321) during external turning. Experiment was performed for cemented carbide cutting inserts with cutting edge radii of 5 µm, 18 µm, and 50 µm. Cutting edge with radius size of 5 µm had sharp cutting edges containing small chamfers and burrs of approximately 5 µm in size. Cutting speed and feed were varied in the experiment. Surface roughness parameters (Ra, Rz) and microhardness (HV) were measured. The results indicate that feed and cutting edge radius significantly influence surface roughness, while cutting speed has minimal effect. Microhardness increases with larger cutting edge radii due to strain hardening caused by material deformation beneath the cutting tool. ANOVA analysis confirmed that the interaction between feed and cutting edge radius plays a crucial role in determining the final surface quality. These findings provide insights into optimizing machining parameters for improved surface integrity and mechanical properties in stainless steel turning.

Keywords:

Cutting edge radius; Work hardening; Strain hardening; Microhardness; Edge preparation

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Intergenerational collaboration in the framework of SME digital transformation

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Abstract

The digital transformation of small and medium-sized enterprises (SMEs) creates both challenges and opportunities that require the effective integration of diverse knowledge, competences, and experiences across generations. This contribution presents the outcomes of a research project focused on developing a conceptual model of intergenerational entrepreneurship in the era of digital transformation, a detailed methodological elaboration of its key modules and their application tools, and their testing and validation.

The proposed framework addresses the process of developing intergenerational collaboration through several phases, including understanding the digital transformation context, creating awareness of the benefits of intergenerational entrepreneurship in the digital age, analysing organisation's internal environment and external conditions, designing suitable development strategies, and implementing practical measures. The model emphasises the importance of knowledge exchange between younger and older generations, including mentoring, reverse mentoring, and cooperation in intergenerational teams. The practical relevance of the framework is demonstrated through its application and validation in cooperation with business practice. A good practice example is represented by the current and future collaboration between the Faculty of Management of Comenius University in Bratislava and MASAM, s.r.o. Vráble, which provides a platform for further development of intergenerational collaboration in SMEs.

Keywords:

Intergenerational entrepreneurship; Digitalisation; Digital transformation; Small and medium-sized enterprises (SMEs)

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