Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 100 (2015) 1616 – 1624

Procedia Engineering

www.elsevier.com/locate/procedia

25th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM 2014

Assessment of the Production Quality in Machining by Integrating a System of High Precision Measurement

Gokcen Bas[a]*, Lachezar Stoev[b], Numan M. Durakbasa[a]

[a]*Vienna University of Technology, Getreidemarkt 9 BA-09, Vienna 1060, Austria*
[b]*Tecnical University of Sofia, 8 Kliment Ohridski blvd., Sofia 1000, Bulgaria*

Abstract

The development activities in machining are targeted towards improvement of the quality of the end product as well as the appearance and surface finish for geometric and work accuracy. The present work proposes a step-by-step integrated metrology scheme for evaluation of the machine tool structure before, during and after machining that affect the cutting processes. The techniques of high precision measurement are considered as realistic evaluation of the system process accuracy in compliant with the international standards of the geometrical product specification and quality. Hence, both contact and optical measurement techniques are proposed as an application for the machining industry to assess precision and quality.

Peer-review under responsibility of DAAAM International Vienna

Keywords: Machining tool; high precision metrology; geometrical product specification; surface topography; quality

1. Introduction

Machining is an indispensable part of the modern manufacturing industry that offers complex, accurate and precise components and assembly. Machining has gone through a process evolution over the past few decades by introduction of the modern industry demands of high-end production. To achieve the desired surface finish and product tolerances, the process and quality control of today's modern machining industry require monitoring and analysis.

* Corresponding author. Tel.: +43-(1)-58801-31145; fax: +43-(1)-58801-31196.
E-mail address: goekcen.bas@tuwien.ac.at

Peer-review under responsibility of DAAAM International Vienna
doi:10.1016/j.proeng.2015.01.535

The existing methods for improvement of the machining tools and cutting processes are limited with the characteristics of the machining. Developments in the field of manufacturing technology have made the production metrology essential to assess the manufacturing processes before the start of design, series manufacturing and during the quality control of the workpieces/products [1]. Combined with enabling metrology solutions, the machining systems will offer cost reduction and efficiency increase.

The recent studies have provided the results of functional performance in the machining processes with a fundamental relationship to the surface integrity that is attributed to the tool and machined surface [2]. The surface finish is described as a fingerprint that can be used to monitor and control the manufacturing processes and quality [3]. Particular emphasis is given to the surface topography measurement development enabled by both different stylus and non-contacting optical methods for an assessment of high precision [4]. The studies investigating requirements of the quality and accuracy of the workpieces in machining industry focus on the surface roughness and the surface layer [5, 6]. The studies indicate that the measurement and analysis of the machining quality is based on the quality of surface and form of the products [7, 8, 9, 10]. There have been studies to develop a model for determining the process precision and finished surface quality by establishing a correlation between the tool and workpiece [11]. Previous studies regarding precision in the machinery for different materials focus on quality aspects as an inevitable part of the successful advanced technology applications [12].

The present work proposes an integrated scheme for evaluation of the machine tool structure to fulfil the required specifications, standards and quality of the end product using the interdisciplinary techniques of high precision metrology. The geometrical product specifications and surface topography evaluation of the machine tool structure before, during and after machining are studied as realistic comparative inspection of the machining system process accuracy.

2. Quality in Machining Enabled by High Precision Measurement

Modern production metrology and its industrial applications have developed on the basis of scientific, technical and organizational work of E. Abbe, W. Taylor and F.W. Taylor with essential contributions to increase the quality of products and production processes. Quality control and quality management comprise a diversity of tasks, measures and activities that extend over the entire product life cycle for each product [13].

The quality management standard ISO 9000:2005 is regarded as one of the international standard guidance in this work to establish the integrated concept of quality management for measurement processes in the machining industry. The standard compliant concepts related to the metrology are represented in the Fig. 1.

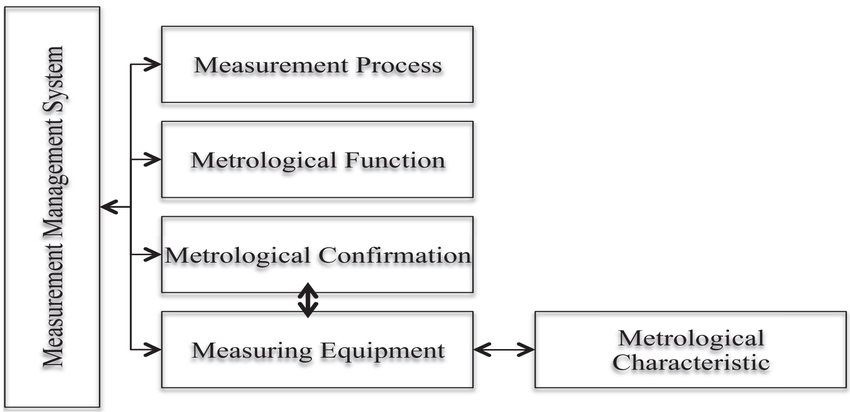


Fig. 1. The measurement management system integrated with quality management.

The measurement management system consists of a set of interrelated and interacting elements necessary to fulfil metrological confirmation, continual improvement and monitoring of the measurement process. Moreover, the metrological function set up the administrative and technical responsibility to define and implement the system. The metrological confirmation is related to the measuring equipment with different metrological characteristics where the modern manufacturing demand requires high precision and quality.

In the process of machining, high product quality is inseparable from the very fundamental rules of size, dimension, geometrical tolerance and geometrical properties of the surface [14]. Together with the globalization of the market, the field of the Geometrical Product Specification and Verification (GPS) has formed to be the necessity as international standardization in the manufacturing industry.

The ISO GPS system is defined in a hierarchy of standards that covers properties of the workpieces. A set of requirements as covered in the masterplan of a GPS standard is represented in the Fig. 2 [15].

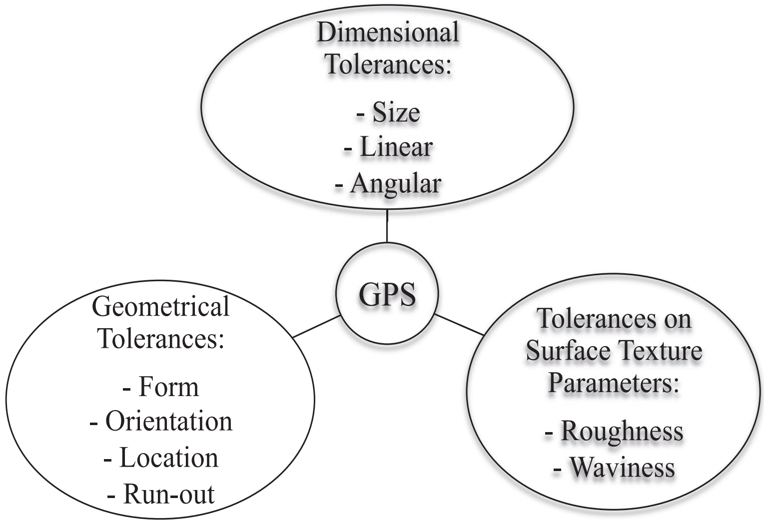


Fig. 2. A set of requirements covered in the ISO GPS standards.

The set of requirements defined in the GPS standards are considered as guidance in this work for high precision metrological applications by means of both optical and contact mode measurement processes.

2.1. Optical and Contact Mode Metrology

The geometrical and surface topography assessment of the machining tools can be carried out by both different contact and non-contacting optical methods. The proposed measurement system covers use of high precision metrology equipments for machining tools. In our study, the sample cutting tool geometrical and topographical assessment is carried out by means of a 3D laser scanning microscope as represented in the Fig. 3 and Fig. 4.

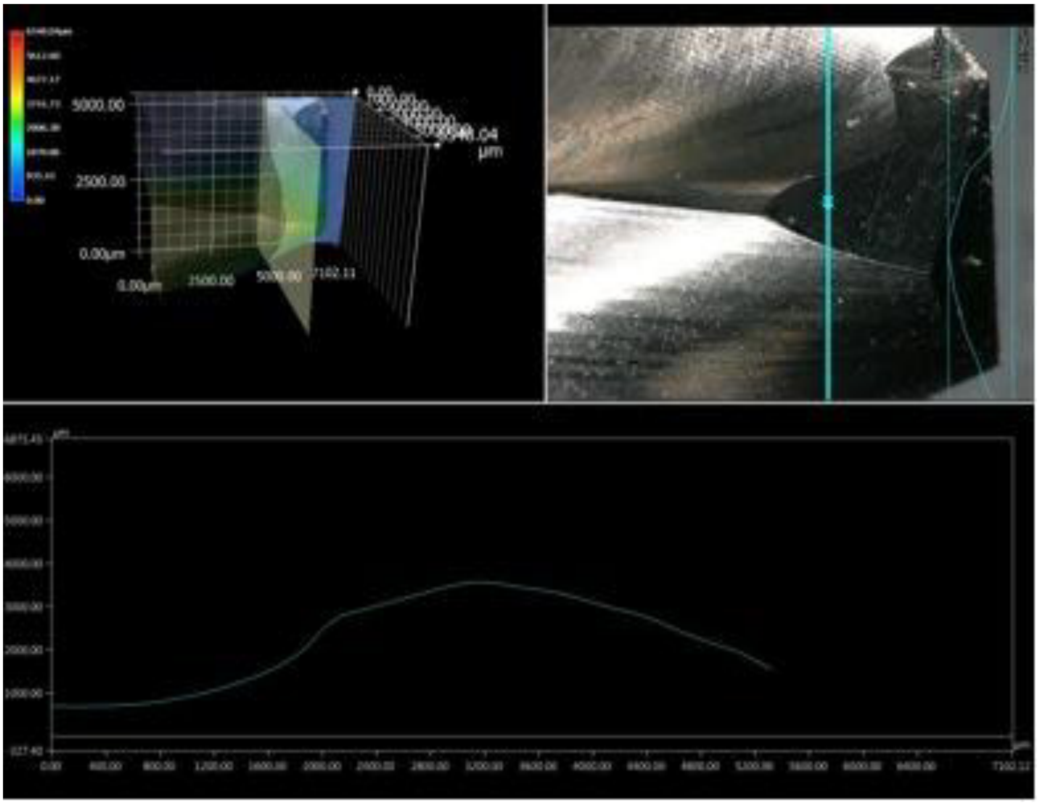
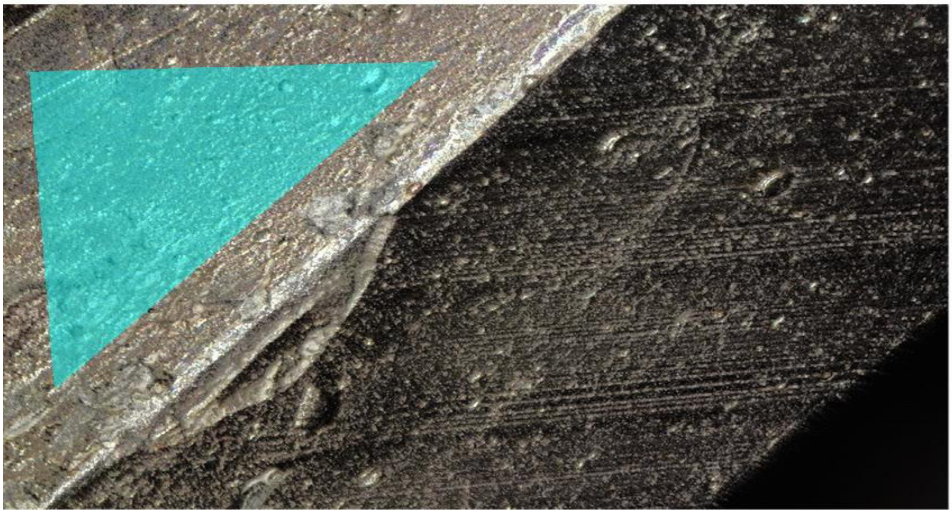


Fig. 3. An optical 3D assessment of a machining tool geometry.



	Rp	Rv	Rz	Ra	Rq	Rsk	Rku
Seg.1	62.0209u...	11.9783u...	73.9992u...	10.9784u...	15.2128u...	2.0602	6.3270

Fig. 4. An optical surface topography assessment of a machining tool.

The contact mode measurements are carried out by the coordinate measurement machine to collect the data of tool characteristics as represented in the Fig. 5, which are important for performance and surface finish quality.

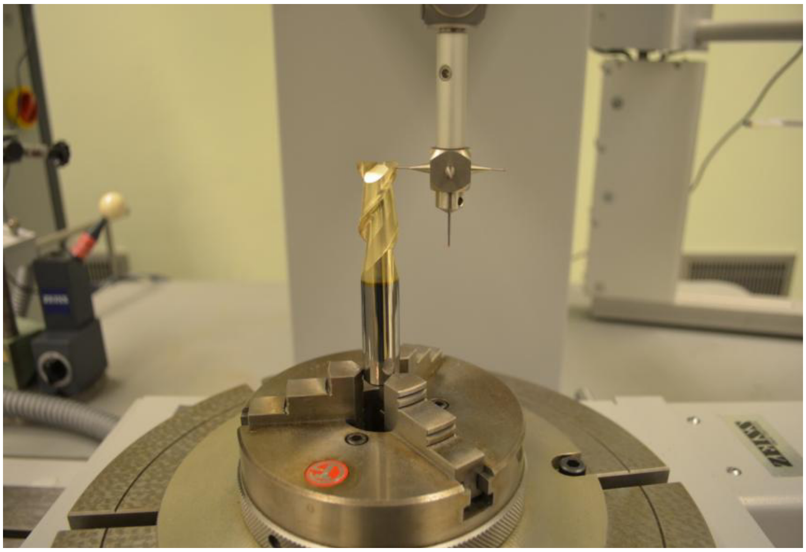


Fig. 5.A contact mode 3D assessment of a machining tool geometry.

The quality of the end product with increasing demand for functionally sophisticated end products at an economical price force the designers to state the exact specifications of the end product [16]. Any neglect or non-unique representation regarding the description of the specification leads to irreversible loss in manufacturing quality of the geometric and work accuracy as well as the appearance and surface finish of the end product. The proposed system targets to collect the data of the machining tool in a database to monitor and control quality the quality of the end product.

In modern machining systems there exist close interactions between high precision metrology and industrial and technological developments. Experimental works provide an insight into this relationship implementing precise metrology processes [17]. 2D and 3D metrology tools are significant means of solving various problems of production metrology as well as improving the process and product quality particularly when high accuracy and high flexibility are demanded simultaneously. Advanced measurement technique closes quality control loops in production, so that an early recognition of faulty production together with the analysis results are introduced and the preventive corrections can be introduced.

3. Machining Integrated Metrology Application

The machining process is of extreme important to use the resources efficient and overcome production challenges such as precise manufacturing. The measurement system proposes not only measurement before and after the machining processes, moreover during the machining by integrated measurement systems. The machine designs with integrated measurement systems are evolving to increase the efficiency by monitoring and controlling the processes.

Latest studies work on the novel control devices for machines [18] as represented in the Fig. 6.

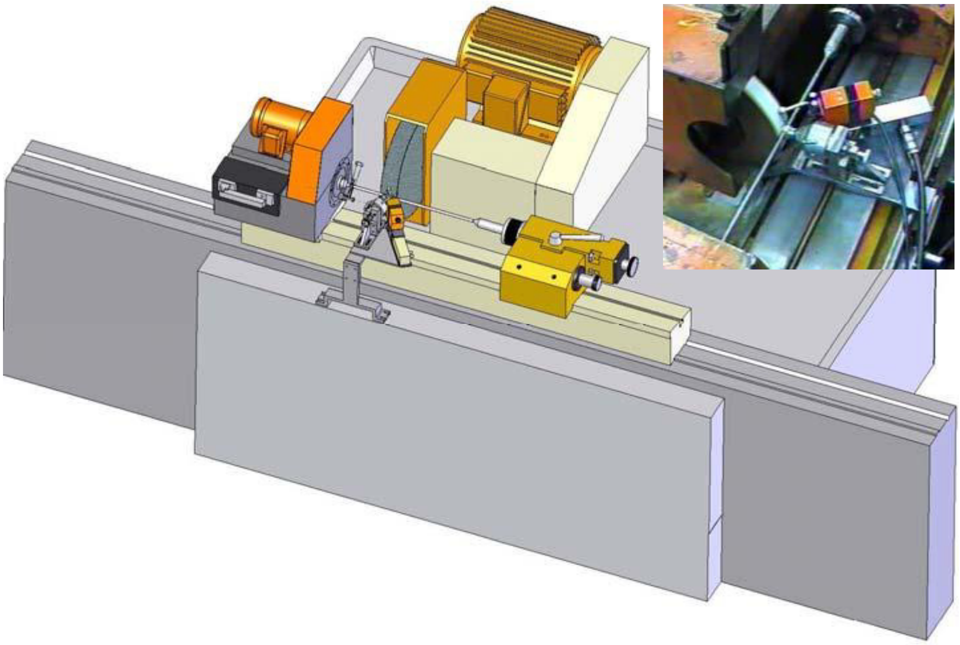


Fig. 6. A method of active control on a machining device.

There are different types of machining devices with geometric and operation accuracy, rotational frequency of the main and tool spindle, power and thermal stress. The numerical control of machine tools facilitates the most effective solution to the problems of monitoring and controlling of the machine.

The active control device placed on a bridge over the longitudinal grinding machine works for adaptive trimming steps by continuous monitoring until the predetermined final diameter of the product is achieved. Besides, continuous monitoring provides the size and shape of cut pieces in longitudinal and cross section. This will enable elimination of large portion of the errors by continuous measurement signal. Increase of efficiency and accuracy in machining are achieved experimentally through the proposed developments comparing to existing devices without any control unit [19]. The adapted measuring unit continuously measures the dimension (the ever-changing diameter) and the geometrical deviations of rotating shaft concerning the form accuracy as roundness as well as accuracies of run-out as either axial and radial run-out in the longitudinal and cross-section [20] and it is able to fulfil linear and circular interpolation along multiple axis.

There is an important aspect of choice for the measurement carried out by a scanning head in the machining integrated process concept. The surface geometry shall be evaluated beforehand to utilize the required measurement process as the surface scanning gathers the main information from the workpiece. The concept of in-process measurement defines the features of the physical surface topography during and after the machining process. The real feature and the ideal feature as defined in the design process can differ depending on the complexity of the geometry and quality of the machining process. The skin model is a geometric model of the physical interface between the workpiece and its environment as presented in the Fig. 7.

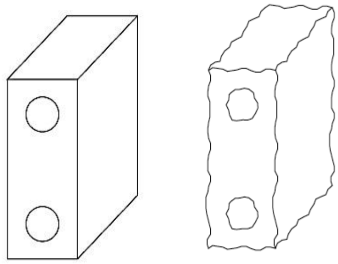


Fig. 7. The ideal model and skin-model of a workpiece.

The in-process measurement in a machining system can be applied as represented in the Fig. 8. The advantage of this method is the active control of the machining process by taking continuous measurements of the surface preventing uncontrollable tool wear and enabling the final correct geometry. The use of active control and adaptive management process is a part of this work's development strategy to fulfil the accuracy, shape and dimensions of the desired surface.

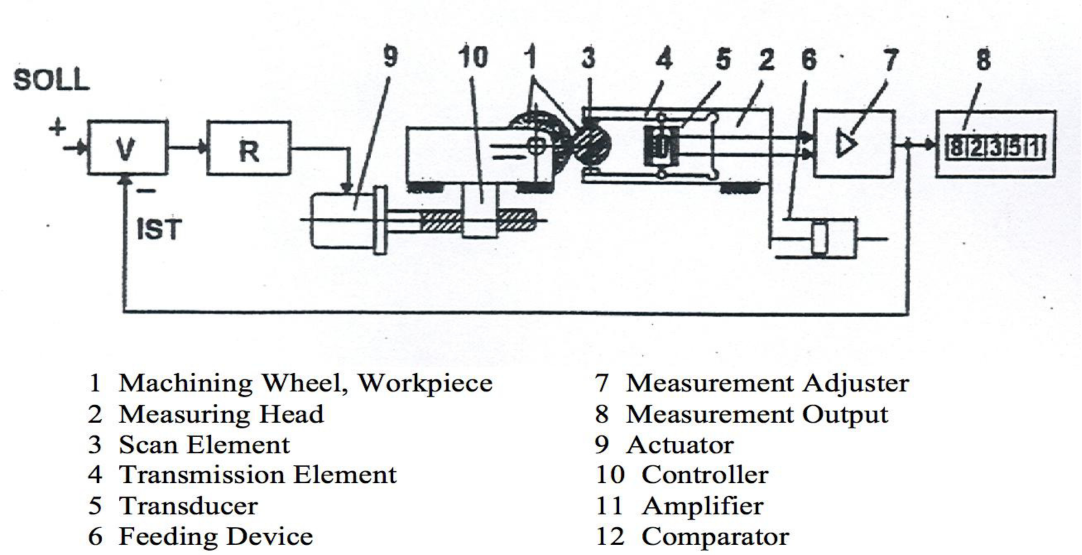


Fig. 8. The model of an in-process metrology application for a machining system.

4. The Measurement Management System for Production Industry

The proposed measurement management system can be considered as a part of an integrated management system in further steps. The data gathered by means of high precision measurement equipments are considered as knowledge to be analysed for process control starting from the design process till the manufacturing processes. The process control can be represented in the Fig. 7 where the knowledge database will be available with different functionalities of information flow. The expert knowledge of geometric and surface characteristics will then be available for moreover economic analysis. This methodology enables to learn stepwise from deviations and to improve the used processes continuously by fulfilling quality requirements.

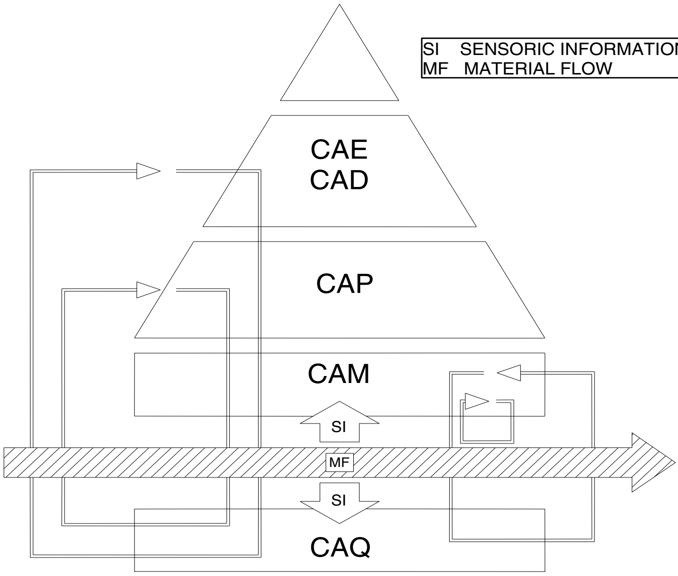


Fig. 9. A schematic of the process control in a machining system.

Conclusion

Modern manufacturing technologies address the complexity of the machining systems limited with characteristics of the machining tools and cutting processes. Enhancement of the existing methods for improvement of machining tools and their cutting processes will lead to a chain of outcomes that are essential for today's modern manufacturing industry. During the last few decades, there have been many attempts to improve the quality of machining end products by reducing the manufacturing defects that disrupt the processes become a severe cost burden to the industry in general. The modern high precision measurement technologies enable essential practice of quality management in the machining industry. This work focuses on international standards of quality and geometrical product specifications to develop a methodology for an integrated scheme in machining for high productivity, quality and accuracy in production.

The high precision measurement system is established by means of both contact and non-contacting mode measurement equipments and moreover a system during and after machining is discussed as a basis for further studies.

The requirements of high end products are defined to be monitored and controlled continuously by establishing a system of assessment starting at the design stage until end of the production. The information flow created by the database of measurement results will enable the conformity of the end products in quality and accuracy by applying the control loop of information and material flow as proposed.

As a result a concept of high quality and accuracy is proposed for demands in the advanced machining industry by means of a model of step-by-step high precision measurement model, starting from design stage by using both optical and contact mode equipments, during and after machining by in-process measurement system for further development.

References

[1] A. Weckenmann, P. Kramer, G. Akkasoglu, Metrology-Base for scientific cognition and technical production, American Institute of Physics Conf. Proc. 1431, 2012, 283-292.
[2] J.P. Davim, Surface Integrity in Machining, Springer-Verlag London Limited, 2010.
[3] D.J. Whitehouse, Process and Quality Control Using Surface Finish, 6th ISMQC Imeko Symposium of Metrology for Quality Control in Production, P.H Osanna, D. Prostrednik & N.M. Durakbasa (Ed.), Vienna, 1998, pp. 699-710.

[4] D.G. Chetwynd, S.T. Smith, High Precision Surface Profilometry: From Stylus to STM, In: From Instrumentation to Nanotechnology (Developments in Nanotechnology V.1), J.W Gardner, H.T. Hingle (Ed.), Gordon and Breach Science Publishers, University of Warwick, UK, 1990, pp. 273-300.
[5] J. Kundrak, K. Gyani, V. Bana, Roughness of ground and hard-tuned surfaces on the basis of 3D parameters, International Journal of Advanced Manufacturing Technology, 38(1-2), 2008, pp. 110-119.
[6] G. Varga. J. Kundrak, Effect of environmentally conscious machining on machined surface quality, Applied Mechanics and Materials, 309, 2013, pp. 35-42.
[7] A. Weckenmann, L. Shaw, A cooperative sensor approach for holistic geometrical measurement tasks on cutting tools, W. Osten, M. Kujawinska (Eds.): FRINGE 09 - The 6th International Workshop on Advanced Optical Metrology, Heidelberg et al. Springer, Stuttgart, 2009, pp. 550-555.
[8] B. Denkena, D. Biermann, Cutting edge geometries, CIRP Annals - Manufacturing Technology, Volume 63, Issue 2, 2014, pp. 631-653.
[9] L Shaw, S Ettl, F Mehari, A Weckenmann and G Häusle, Automatic registration method for multisensor datasets adopted for dimensional measurements on cutting tools, Measurement Science and Technology, Vol.24, No.4, 045002, 2013.
[10] J. Kyncl, L. Beranek, K. Kolarík, Z. Pala, The Research of the Surface Profile after Profiling of Inconel 738LC, Procedia Engineering, Vol.69, 2014, pp. 974–979.
[11] D. Popescu, D. Bolcu, Mathematical Model for Dynamic Analysis of the Contact between Tool and Workpiece at High-Speed Grinding, Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium, November 2009, Vienna, Austria, pp. 307-308.
[12] I.C. Ivan, G. Enciu, M. Ghinea, Some Quality Aspects Regarding Advanced Ceramics Mechanical Parts for Precision Machinery, Annals of DAAAM for 2008 & Proceedings of the 19th International DAAAM Symposium, October 2008, Trnava, Slovakia, pp. 613-614.
[13] ISO 9000: 2005, Quality management systems – Fundamentals and vocabulary
[14] N.M. Durakbasa, Geometrical Product Specifications and Verification For The Analytical Description Of Technical and Non-Technical Structures, Abteilung Austauschbau und Messtechnik, TU-Wien, Vienna, 2014.
[15] prEN ISO 14638: 2012, Geometrical product specification (GPS) – Masterplan.
[16] N.M. Durakbasa, P.H. Osanna, Development and State of the Art of Production Metrology for the 21st Century - From Micrometrology to Nanometrology and Picometrology, Proceedings of the 6th International Conference MTeM, Cluj-Napoca.
[17] N.M. Durakbasa, A. Akdogan, A. S. Vanli, A. Gunay, Surface Roughness Modeling with Edge Radius and End Milling Parameters on Al 7075 Alloy Using Taguchi and Regression Methods, Acta IMEKO, Vol.3, No.4, Article 9, December 2014, identifier: IMEKO-ACTA-03 (2014)-04-09.
[18] L. Stoev, Method for active monitoring and adaptive control of the process round longitudinal grinding, Part 2: System for active monitoring and adaptive control, Annual Conference of the University of Rousse, Vol. 47, series 2, Rousse, 2008, pp. 28-32.
[19] L. Stoev, S. Hristov, Active monitoring method for longitudinal grinding, International conference „Advanced manufacturing operations"-AMO, Kranevo, 2008, pp. 313-318.
[20] prEN ISO 1101: 2014, Geometrische Produktspezifikation (GPS) – Geometrische Tolerierung – Tolerierung von Form, Richtung, Ort und Lauf (Geometrical product specifications (GPS) - Geometrical tolerancing - Tolerances of form, orientation, location and run-out).