

Monitoring System in the Experimental Investigations of the Temperature in the Cutting Process by Machining With Turning

M. Kuzinovski^{1*}, N. Trajcevski¹, S. Fita^{2**}, M. Tomov¹

¹ Faculty of Mechanical Engineering, University "Ss. Cyril and Methodius", P.O. Box 464, 1000 Skopje, Republic of Macedonia

² Institute of Mechanical Engineering And Automation of The Wroclaw University of Techology, Wroclaw, Poland

* mikolaj@mf.ukim.edu.mk

** stanislaw.fita@pwr.wroc.pl

Abstract

The development of computer aided research systems, used for experimental measuring of the temperature in the cutting process, forms conditions for decreasing of the measuring uncertainty. This paper describes new monitoring system for temperature measuring in the machining with turning. A method of the nature thermocouple has been used for measuring the temperature. A specially constructed device transmits the voltage signal from the workpiece side and a reconstruction of the cutting insert holder provides the transmission of the voltage signal from the cutting insert. The transfer of the generated thermocouple voltage to the personal computer is done by original interface, which consists of amplifier and A/D converter. An application that was created in Microsoft Visual C++ 6.0 receives the data and displays the curves of the thermocouple voltage that is generated in the cutting process.

1. INTRODUCTION

The energetic transformations during machining in the cutting zone release a significant thermal energy. Unacceptable effects in the surface layer could occur during big contact temperatures, which are a result of the generated thermal energy. That could decrease the positive tribology characteristics of the surface layer. The knowledge of this temperature is important within the fact that the temperature has a direct influence on the value of the cutting forces and the abrasive wear of the cutting insert. The temperature in the cutting process might be determined analytically and experimentally. For this purpose many methods are developed [1, 2]. The mostly used among the experimental methods is the method of the nature thermocouple that consists of the workpiece and the cutting insert. This method is simple but it is necessary to determinate the thermo-electric characteristics for each workpiece-cutting insert couple. The new cutting materials enable high-speed machining, higher temperatures and more intensive material removal. A higher stiffness is required by the Machine-Device-Workpiece-Cutting tool system [1]. The temperature measuring system has to provide decreasing of the errors that are result of the signal trace including the contact on the workpiece and the cutting insert, fast conducting of the experiments, precise measuring of the values, fast and reliable

acquisition of the experimental data, collecting large amount of measuring values in short intervals and fast data processing. This is essential to make the uncertainty of the measurements in the desired limits [3]. The solving of this complex task is possible only with usage of own monitoring system for measuring of the temperature in the cutting process, which is described in this paper.

2. DESCRIPTION OF THE NEW MONITORING SYSTEM FOR MEASURING OF THE TEMPERATURE

The Figure 1 shows the new computer aided research system for temperature measuring in the cutting process by machining with turning. The method of nature thermocouple is used [4]. The special constructed device is used for transmission of the voltage signal from the workpiece [5]. C 1630 is used as workpiece material for the experiment example in this paper. This device is showed on the Figure 2. The generated voltage signal from the cutting insert, which is based on mixed ceramic MC2 and manufactured by Hertel, transmits through the holder, which was previously reconstructed for this purpose, Figure 3. Interface for personal computer transforms the generated thermovoltage from the nature thermocouple workpiece - cutting insert to digital signal [6]. The interface consists of an amplifier of the signals and analog-digital (A/D) converter.

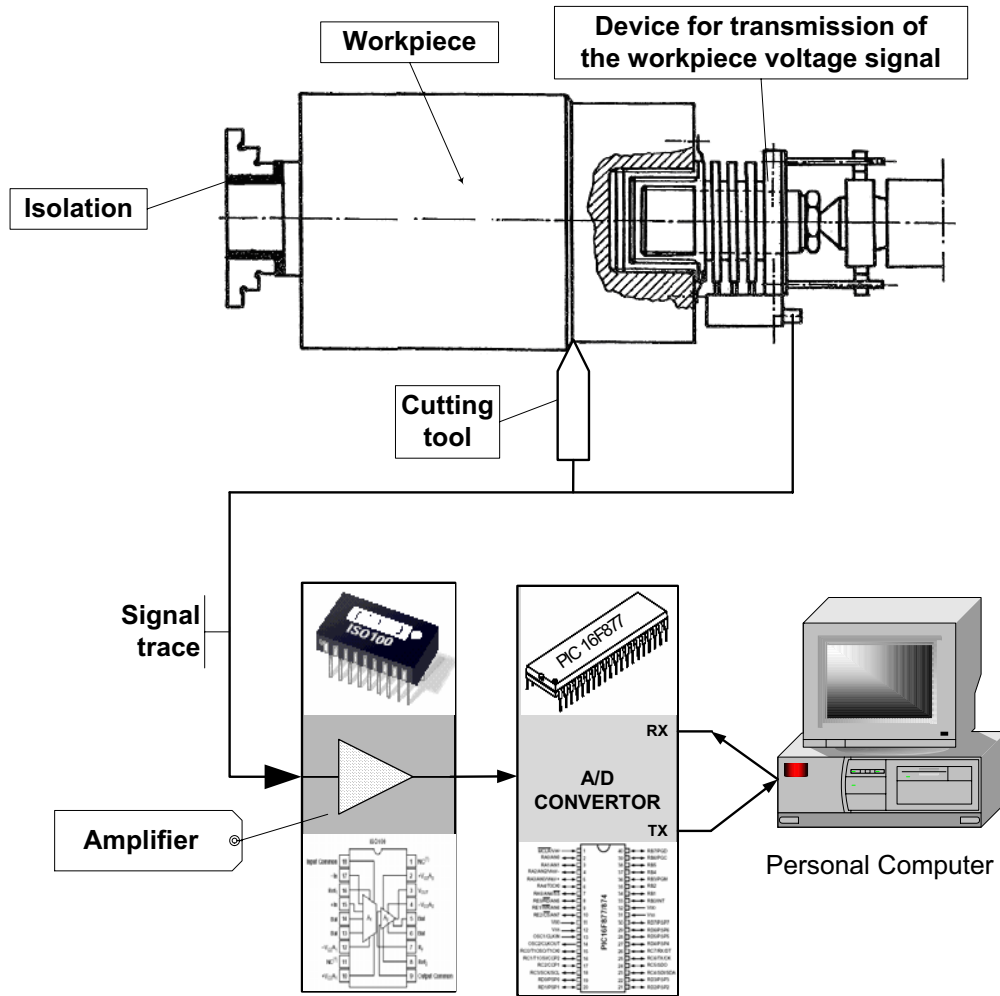


Figure 1: Monitoring system for measuring and determining of the cutting temperature.

The amplifier has three roles as a part of the interface. At first, to amplify the thermo-voltage that is generated by the natural thermocouple workpiece-cutting insert to the required level. That means that the signal after amplifying complies within the domain of the A/D converter.

The second role of the amplifier is galvanic separation of the thermocouple electric circuit from the A/D converter and the personal computer. The role of this galvanic separation is protection from eventual current pulses that could damage this part of the measuring system. The third role is to remove the influence of the electrical circuit consisting of the A/D converter and personal computer to the electrical circuit with the thermocouples.

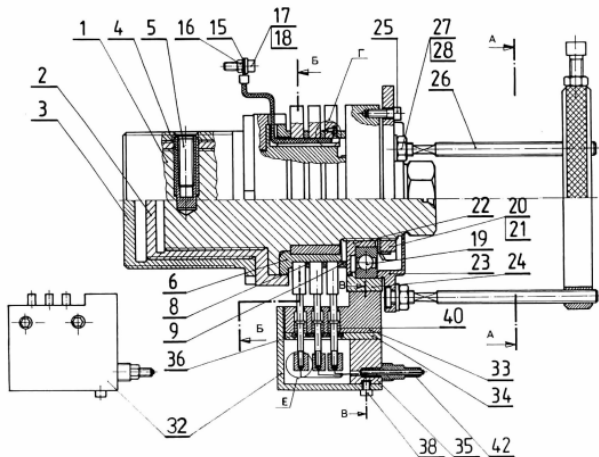


Figure 2: Device for transmission of the workpiece voltage signal

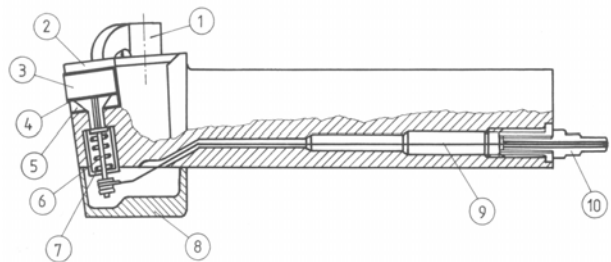


Figure 3: Reconstructed cutting insert holder

The basic component of the amplifier is the integrated circuit ISO 100 [7]. The A/D

converter is a part of integrated circuit (IC) PIC16F877 [8]. This IC is a new generation Microchip microcontroller, which has 10-bit built in A/D converter. It has an option for defining intern or extern voltage references and it is possible to make 8-channel digitalization. For 10-bit conversion it uses 12 clock-periods for conversion with time interval shorter than 1,6 us, and that is 20 us total time for the conversion. In real conditions this time is a little longer, because of the additional time necessary for selection of the channel, determining the end of conversion, adding control bits for the channel and working with low and high byte.



Figure 4: Prototype version of the monitoring system interface for personal computer

The maximum frequency of the clock generator is 20 MHz. That means that the microcontroller provides 50000 conversions per second. The nature of our research imposes necessity of couple of samples per turn of the workpiece. For the maximum speed of 2000 turns per minute and 5 samples per turn, the system should make conversion and acquisition of $2000 \cdot 5 / 60$ samples. That is 167 samples and which is under the possibilities of the chosen system. The microcontroller has a built-in module for serial synchronous and asynchronous full duplex communication, which is called USART (Universal Synchronous Asynchronous Receiver Transmitter). The communication speed is very easy adaptable. It was decided that 115200 bps is the most convenient communication speed, because it

allows transfer of maximum data samples through the communication line. The communication protocol that was chosen is 8 data bits, start and stop bit, and frequency of the clock generator of 20 MHz. Taking in consideration that one temperature sample is $2 \cdot 8 = 16$ bits, using this protocol we can send, in "real time", $115200 / 16 = 7200$ samples per second. That is 10 times faster than we need even using four channels at the same time. This way of sending data to the personal computer avoids temporary saving of the data in the microcontroller's system and provides the data flow to be in "real time". The prototype version of the interface is showed on Figure 4. A Microsoft Visual C++ application receives the data from the personal computer RS232 interface. The application window that is showed on Figure 5 has two panels. The left panel has a grid, which allows graphic interpretation of the dynamic character of the thermo voltage and determining of the evaluation length on the time axis, which is essential for average temperature determining during the cutting process. The right panel that is marked by arrow on the Figure 5, has set of controls that are used for making settings and displaying of the average temperature values on the previously selected evaluation length on the time axis, based on the mathematics model (1) of the thermoelectric characteristics. Correlation of the thermo voltage and the temperature, which is presented on Figure 6, is based on the experimental results.

$$T = 104,4 - 42,6u + 44,7u^2 - 4,9u^3 + 0,17u^4 \quad (1)$$

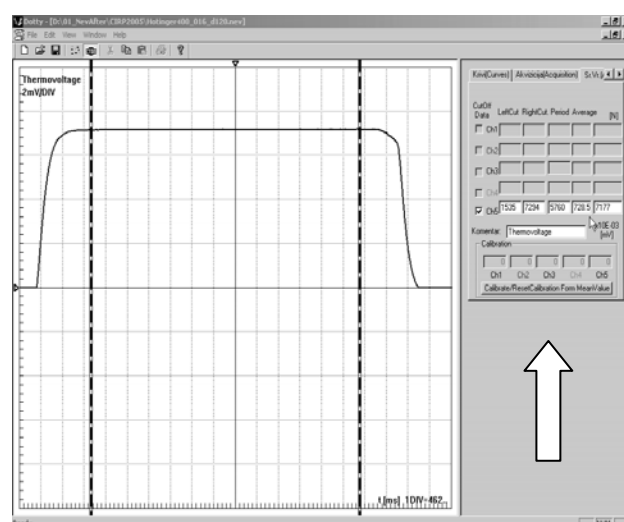


Figure 5: Screen capture of the monitoring system software

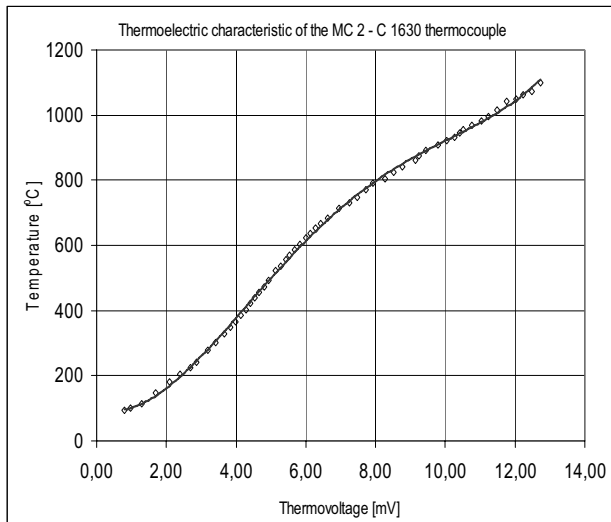


Figure 6: Thermoelectric characteristics of the nature thermocouple MC 2 – C 1630

The functional verification of the new computer aided monitoring system for temperature measuring in the cutting process by machining with turning was done by making series of experiments in our laboratory on the Faculty of Mechanical Engineering in Skopje and comparing them with results of experiments with same parameters of machining from Wroclaw Polytechnic, Poland. The obtain results for the average value of the temperature are within $\pm 5\%$ [4].

3. CONCLUSION

The intensive activities which are conducted with purpose to decrease the interval of measuring uncertainty of the realized measuring and determining of the influence of single factors and decreasing or eliminating of their negative influence in the research hardware and software equipment are reasonable.

Development and possessing of own hardware and software scientific-research equipment for investigation of the physical phenomena in the cutting process and the technological effects in the surface layer, with open access to the hardware and the software components is basic postulate for achieving cognizable results.

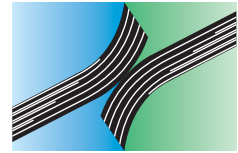
The monitoring system for temperature measuring in the cutting process is helping creation of knowledge databases with information about the changes of the temperature in the cutting process by

machining with turning for different machining and cutting materials.

This creates conditions for optimal choice of the machining parameters, which is a way of conducting with the thermal model of creation of residual stress.

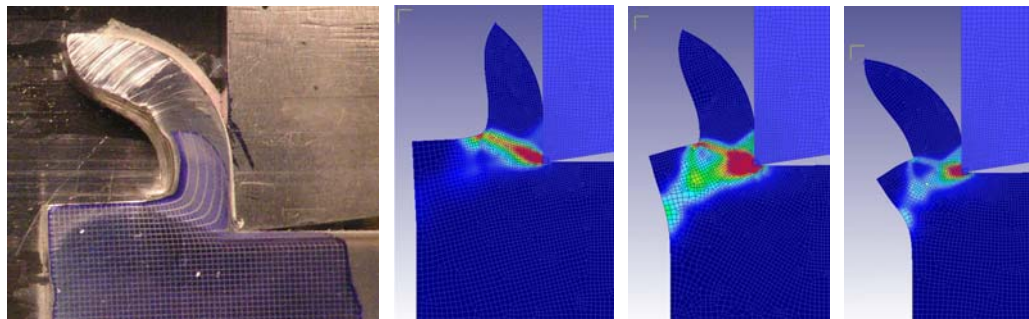
4. REFERENCES

- [1] Kuzinovski M., Pavlovski V., Zebrovski H., Cichosz P., 1995-1997, Razvoj na metodika i laboratoriska oprema za izveduvanje na analiticko eksperimentalni istrazivanja vo oblata na obrabotkata so rezenje, Ministerstvo za nauka, RM.
- [2] Cichosz P., 1990, Methods of temperature measurement in high-speed turning. VI Ogolnopska Konferencija Naukovo-Techniczna pt.: 'Tendencje Rozwojowe w Technologii Maszyn', Zielona Gora. p.117-122.
- [3] Guide to the expression of uncertainty in measurement (Published by ISO in the name of BIMP, IEC, IFCC, IUPAC, IUPAP and OIML, 1993).
- [4] Trajcevski N., Kuzinovski M, Filiposki V., Cichosz P., 2004, Computer aided measurement of the temperature in the cutting process by machining with turning. Scientific Conference with International Participation. Manufacturing and management in 21st century, Ohrid, p.129-134.
- [5] Kuzinovski M., 2000, Patentno resenie br.62/96, delovoden broj 09 6287/1, od 27.12.1996. PATENT MKP B23Q 11/14, G01K 13/08, 900602 od 30.09.2000. Pomagalo za prenos na signal pri merenje na temperatura. Glasnik IPPO, 7/3, p.2-58, p.13.
- [6] Trajcevski N, Filiposki V, Kuzinovski M., 2004, Personal computer interface for temperature measuring in the cutting process with turning, Proceedings, Faculty of Mechanical Engineering, Skopje, Vol.23, No.2, pp.65-74, ISSN 0351-6067, UDK: 681.536.5: 621.91.
- [7] ISO100, Datasheet, Burr-Brown
- [8] PIC16F87X, Datasheet, Microchip



Proceedings of the **9th CIRP International Workshop on Modeling of Machining Operations**

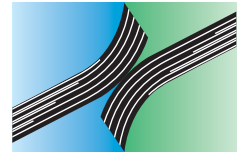
May 11-12, 2006
Bled, Slovenia



Editors:
I. Grabec, E. Govekar
University of Ljubljana, Faculty of Mechanical Engineering



University of Ljubljana
Faculty of Mechanical Engineering



Proceedings of the
9th CIRP International Workshop
on Modeling of Machining Operations

May 11-12, 2006
Bled, Slovenia

Editors:
I. Grabec, E. Govekar
University of Ljubljana, Faculty of Mechanical Engineering

Proceedings of the
**9th CIRP International Workshop
on Modeling of Machining Operations**

Editors

I. Grabec, E. Govekar

Published by

University of Ljubljana
Faculty of Mechanical Engineering
Aškerčeva 6, SI-1000 Ljubljana, Slovenia

© 2006

All rights reserved.

No part of this publication may be reproduced or transmitted by any other means,
electronic, mechanical, photocopying or otherwise
without the prior permission of the publisher.

Front cover figures are taken by permission from the paper by
A. Stoll, J. Leopold, R. Neugebauer

Printed

April 2006

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

621(063)(082)

CIRP International Workshop on Modeling of Machinig Operations (9 ;
2006 ; Bled)

Proceedings of the 9th CIRP International Workshop on Modeling
of Machinig Operations, May 11-12, 2006, Bled, Slovenia / editors
I. Grabec, E. Govekar. - Ljubljana : Faculty of Mechanical
Engineering, 2006

ISBN 961-6536-06-0

1. Grabec, Igor
226413568

Foreword

The current Workshop is the 9th in the series sponsored by CIRP and initiated in 1998, in Atlanta, Georgia, USA and is a continuation of the 2005 Workshop held in Chemnitz, Germany.

This Series has its origins in a Working Group on "Modeling of Machining Operations" established in 1995 within the CIRP Scientific Technical Committee for Cutting [STC C]. The aim of this group was to stimulate the development of models capable of quantitatively predicting the performance of metal cutting operations better adapted to the needs of metal cutting industry in the future.

The objectives of the Workshop were to bring together professionals from industry and from academia: firstly to present and discuss recent advances in Modeling of Machining Operations and Cutting Processes, secondly to establish a fruitful dialogue between machining model developers and users, and thirdly to formalize conclusions, recommendations and more useful directions for future research.

In response to the call for papers, 81 abstracts were submitted. After a stringent review of the manuscripts, 60 contributions from 25 countries were accepted and appear in these proceedings after being classified according to the following topics: stability, simulation, cutting force modeling, drilling, grinding, process optimization, tribology, diagnostics, burr formation, tool wear and residual stress, chip formation, and high energy material processing.

The workshop provided a significant advance in knowledge in the field of modelling of machining operations and cutting technologies and we believe that its content will help to stimulate further development in the future.

I. Grabec, E. Govekar (Editors)

Acknowledgements

The Organizing Committee of the 9th CIRP International Workshop on Modeling of Machining Operations would like to thank the following individuals, groups and organizations:

- The CIRP for the sponsorship of the Workshop.
- Faculty of Mechanical Engineering, University of Ljubljana.
- CIMOS, d.d. for the co-sponsorship of the Workshop.
- The invited speakers: G. Stepan, P. Orbanić, I. Grabec, T. Marusich.

Finally, we would like to thank all the participants for their active role in the workshop and for their contributions to a pertinent and fruitful discussion on the future of modeling of machining operations.

The Organizing Committee

Organizing Committee

Chairman

Prof. I. Grabec
University of Ljubljana, Slovenia

Prof. I.S. Jawahir
University of Kentucky, USA

Co-Chairman

Prof. E. Govekar
University of Ljubljana, Slovenia

Prof. J. Kopač
University of Ljubljana, Slovenia

International Program Committee

Prof. Altan, T., USA
Prof. Altintas, Y., Canada
Prof. Bouzakis, K.-D., Greece
Prof. Budak, E., Turkey
Prof. Byrne, G., Ireland
Prof. Chandrasekaran, H., Sweden
Prof. Davies, M.A., USA
Prof. Dornfeld, D.A., USA
Prof. Ekinović, S., Bosnia and Herzegovina
Prof. Inasaki, I., Japan
Prof. Jemielniak, K., Poland
Prof. Julean, D., Romania
Prof. Klocke, F., Germany
Prof. Kuljanić, E., Croatia
Dr. Leopold, J., Germany

Prof. Levi, R., Italy
Prof. Milutinović, D.S., Serbia and
Montenegro
Prof. Moisan, A., France
Prof. Pandilov, Z., The F.Y.R. of Macedonia
Prof. Peklenik, J., Slovenia
Prof. Poulachon, G., France
Prof. Stépán, G., Hungary
Prof. Teti, R., Italy
Prof. Todorov, G., Bulgaria
Prof. Weck, M., Germany
Prof. Weinert, K., Germany
Prof. Wertheim, R., Israel
Dr. Zatarain, M., Spain

Organization

9th CIRP International Workshop on Modeling of Machining Operations is organized by the University of Ljubljana, Faculty of Mechanical Engineering.

General sponsor

CIRP – The International Academy for Production Engineering



Co-Sponsor

CIMOS d.d., Slovenia

CIMOS

Table of contents

Plenary session 1

Can Nonlinear Dynamics Contribute to Chatter Suppression?	3
Stépán G.	
Machinability and	31
Orbanić P.	

Plenary session 2

Synergetics of Cutting Processes	55
Grabec I.	
Selected Topics on Modeling Machining	81
Marusich T.	

Stability

Analytical prediction of stability limit in turning operations	99
Özlü E., Budak E.	
Period-two and quasi-periodic vibrations of high-speed milling	107
Szalai R., Mann B., Stépán G.	
The effect of runout on the chatter frequencies of milling processes	115
Inspurger T., Mann B. P., Edes B., Stépán G.	
Thin-walled features high speed machining simulation	123
Gonzalo O., Peigné G., González D.	
Experimental approach of milling stability of thin walled parts, comparison with time domain simulation	131
Corduan N., Costes J.-P., Lapujoulade F., Larue A.	
Analysis of the cutting tool vibration while milling with changing engagement conditions ..	139
Enk D., Surmann T.	

Simulation

Simulation of cutting stabilized by nonlinear model predictive control	147
Potočník P., Grabec I.	
A model of milling dynamics using Matlab and Simulink	155
Sims N. D., Turner M. S., Ridgway K.	
Aspects of the simulation of a cutting process with ABAQUS/Explicit including the interaction between the cutting process and the dynamic behavior of the machine tool	163
Schermann T., Marsolek J., Schmidt C., Fleischer J.	
Simulation of machine process interaction with flexible multi-body simulation	171
Brecher C., Witt S.	
Optimization of 5-axis milling processes using process models	179
Tunc L. T., Budak E., Ozturk E.	
Geometric model of the surface structure resulting from the dynamic milling process	187
Surmann T.	

Modeling energy utilization during machining operations 193
Pienkowski G., Krzyzanowski J., Maczka J.

A virtual test bed implementation using the precision model of feed-drive system for the verification of command generators 201
Emami M.M., Arezoo B.

Cutting force modeling

Milling force prediction by means of analytical model and 3D FEM simulations 211
Fortunato A., Mantega C., Donati L., Tani G.

Modeling cutting forces in high speed end-milling of titanium alloys using finite element analysis and mechanistic model 219
Okafor A. C., Aramalla S.

Identification of the specific cutting force coefficients for the mechanistic modelling of micro milling 227
Uriarte L., Zatarain M., Bueno R., Gonzalo O., Lopez de Lacalle L. N., Lamikiz A.

Influence of the captured border on cutting forces in turning processes 233
Denkena B., Reichstein M., Köhler J.

Analysis on nonlinear cutting forces in high-speed face-milling of difficult-to-machining materials 239
Long Z. H., Wang X. B., Zhao W. X., Wang H. C.

Drilling

Thermomechanical approach of drilling based on a CAD definition 247
Jrad M., Devillez A., Dudzinski D.

Adaptation of drill geometry with cutting forces, tool-life, and chip formation mechanisms . 255
Claudin C., Poulachon G., Lambertin M., Janosch J. J., Vecchi B., Gigé F.

3D modeling and scaling effects in drilling 263
Klocke F., Lung D., Gerschwiler K., Abouridouane M., Risse K.

Theoretical study of the influence of a PVD coating on the stability of the micro drilling process 271
Lugscheider E., Bobzin K., Nickel R., Hurevich V.

Innovative cutting tools for machining powertrain materials 279
Schwenck M., Hänle P., Garrn I., Hammer M., Gsänger D., Stolz Th.

Grinding

3D simulation of surface generation in grinding 287
Sakakura M., Tsukamoto S., Fujiwara T., Inasaki I.

Process forces modeling in grind-hardening 295
Salonitis K., Tsoukantas G., Stavropoulos P., Stournaras A., Chondros T., Chryssolouris G.

A method for assessment of steels grindability 303
Julean D.

Possibility of determination of material machinability over tribological parameters by use of tribometer "Block on disk" 307
Globočki - Lakić G., Nedić B., Ivković B., Golubović-Bugarski V., Čiča Dj.

A study of brittle materials grinding 313
Torres R., Duduch, Jasinevicius

Process optimization

High performance cutting in automotive and aerospace application	321
Herrmann Praturlon A., Gallino A., Durante S., Comoglio M.	
Optimization of cutting process at the high-speed broaching of gas-turbine engine parts ...	327
Makarov V. F., Chigodaev N. E., Tokarev D. I.	
Application of fuzzy logic for process design in sheet metal hydroforming	335
Hagenah H., Kohlbauer R.	
High performance cutting in automotive and aerospace application	343
Sánchez J. M., Rubio E., Sebastián M. A., Cano M. J., Marcos M.	
Factors of influence in the simultaneous optimization of the descriptive variables of the electro discharge machining	351
Diéguez J.L., Ares J.E., Sebastián M.A., Marcos M.	
Direct fastening components design and reliability parameters research	357
Todorov G., Romanov B., Kamberov K., Koychev M.	

Tribology

Functional properties of PVD and CVD coated tool ceramics	365
Dobrzański L. A., Miłkula J., Gołombek K., Pakuła D., Kopač J., Soković M.	
Experimental modelling of cutting force, tool-wear and surface roughness when turning with ceramic inserts	371
Maňková I., Beno J., Markova G., Melcher M.	
Investigation of cutting tool influences on white layer formation for a turning process of hardened 16MnCr5 steel	379
Mehmedović M., Ekinović S., Dolinšek S., Šarić E.	

Diagnostics

On the vibrations in superfinish turning operation	389
Crolet A., Lambert-Campagne L., Costes J.-P., Barlier C., Bissey-Breton S.	
Estimation of cutter eccentricity for tool condition monitoring	397
Ritou M., Garnier S., Furet B., Hascoet J. Y.	
Indirect monitoring and diagnosis of drill wear	405
Jantunen, E.	
Possibilities for analysis of noisy time series data in machining	413
Gradišek J., Friedrich R., Govekar E., Grabec I.	
Vibration measurement as a machine health indicator	421
Golubović-Bugarski V., Blagojević D., Globočki-Lakić G.	
Monitoring system in the experimental investigations of the temperature in the cutting process by machining with turning	427
Kuzinovski M., Trajcevski N., Fita S., Tomov M.	
On the roughness profile modeling using Q-sequence	431
Ullah A. M. M. Sh., Harib K. H., Aldajah S.	

Burr formation

- Hybrid methods for analyzing burr formation in 2D-orthogonal cutting** 441
Stoll A., Leopold J., Neugebauer R.
- 3D finite element modeling of burr formation in grinding** 449
Aurich J. C., Sudermann H., Bil H.
- Influence of ultrasonically assisted cutting on burr formation** 457
Stoll A., Ahmed N., Mitrofanov A.V., Silberschmidt V., Leopold J.

Tool wear and residual stress

- Modelling and validation of the residual stresses induced in machining AISI 316L steel** 467
Umbrello D., Outeiro J. C., M'Saoubi R.
- Some observations on comparing the modelled and measured residual stresses on the machined surface induced by orthogonal cutting of AISI 316L steel** 475
Outeiro J. C., Ee K. C., Dillon Jr. O. W., Wanigarathne P. C., Jawahir I. S.
- Wear modeling in orthogonal cutting using coated tools** 483
Filice L., Micari F., Umbrello D.
- Tool wear geometry updating in Inconel 718 turning simulations** 491
Lorentzon J., Järnstråt N.
- Simulation of tool wear in hard turning** 499
Klocke F., Frank P.

Chip formation

- Finite element modeling of oblique cutting** 509
Arrazola P.-J., Pujana J., Llanos I., Villar A., Ugarte D., Aguirre A., Gallego I., Le Maître F.
- Effect of carbides and cutting parameters on chip morphology and cutting temperature during orthogonal hard turning of 100Cr6 bearing steel with a cBN cutting tool** 517
Habak M., Lebrun J.-L., Huneau B., Germain G., Robert P.
- Modeling the effect of tool edge preparation by ALE method** 525
Umer U., Xie L. J., Wang X. B.
- Dynamics of chip formation during orthogonal cutting of titanium alloy Ti-Al6-V4** 533
Cotterell M., Byrne G.

High density energy material processing

- Heat transfer in the fusion zone during electron-beam welding** 541
Ho C.Y., Chen D.N., Wen M.Y., Ho J.E.
- Modelling of laser pendant droplet formation and determination of a laser pulse** 549
Kokalj T., Mužič P., Grabec I., Govekar E.
- Modeling of Plasma Shielding in Laser Material Processing** 557
Rozman R., Govekar E., Grabec I.