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

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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 transmition 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 thermo-voltage 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.

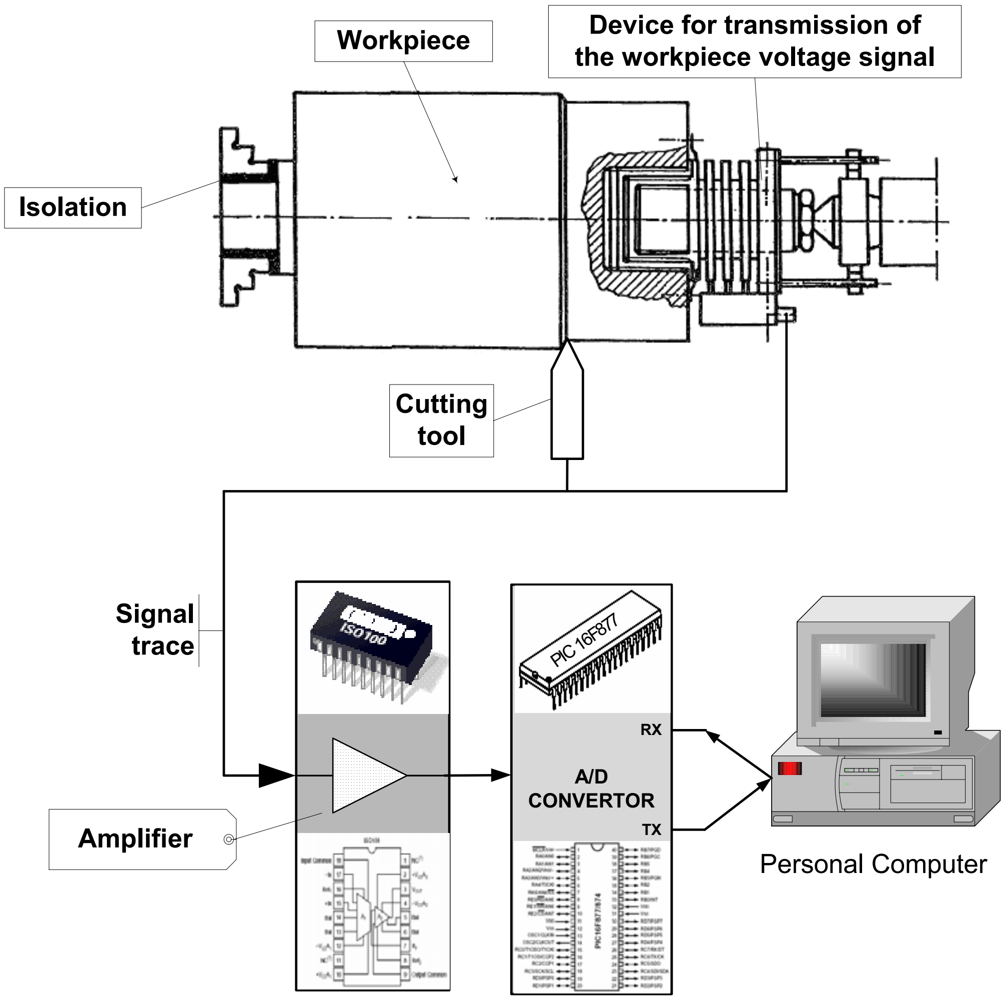

Figure 1: Monitoring system for measuring and determining of the cutting temperature.

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.

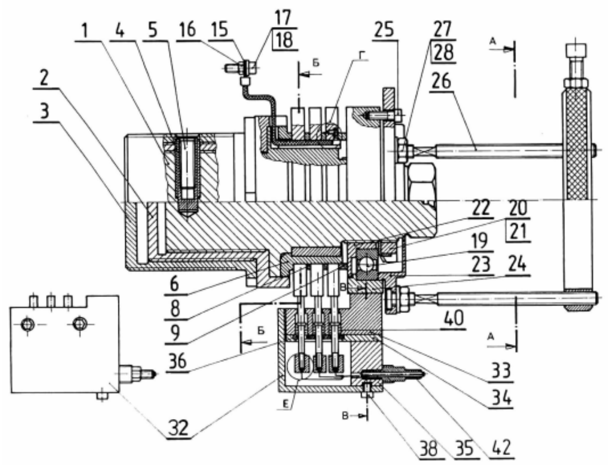

Figure 2: Device for transmission of the workpiece voltage signal

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.

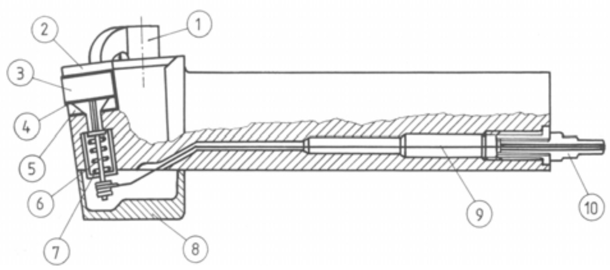

Figure 3: Reconstructed cutting insert holder

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 build 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 then 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*5/60 samples. That is 167 samples and which is under the possibilities of the chosen system. The microcontroller has a build-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*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.

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

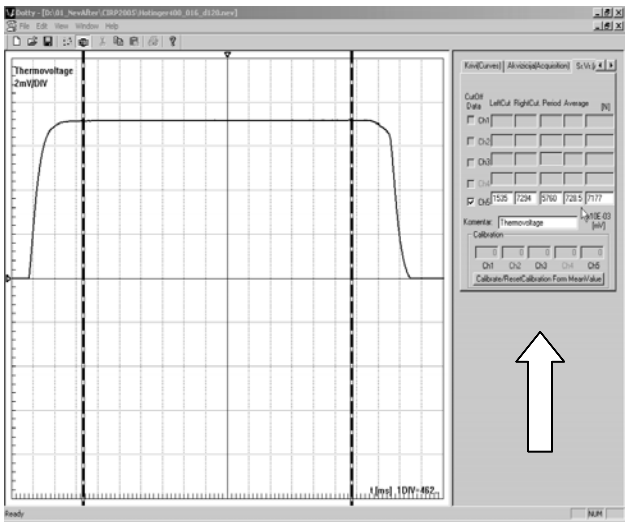

Figure 5: Screen capture of the monitoring system software

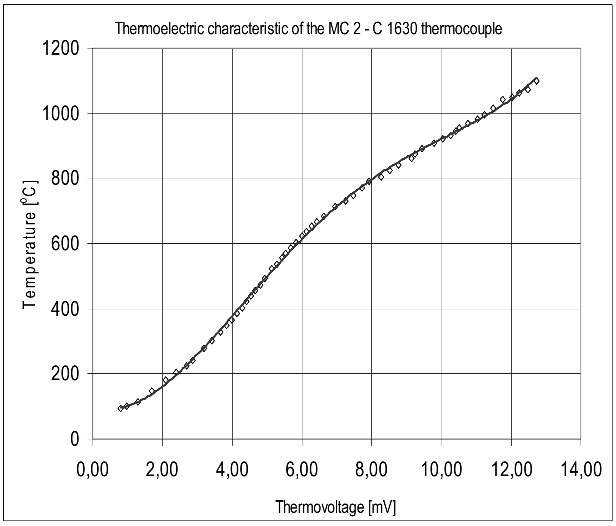

Figure 6: Thermoelectric characteristics of the nature thermocouple MC 2 – C 1630

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 ±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.

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[7] ISO100, Datasheet, Burr-Brown

[8] PIC16F87X, Datasheet, Microchip

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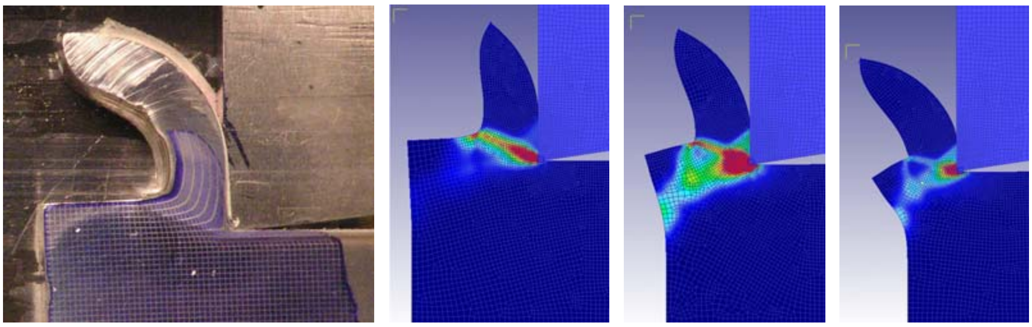

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Foreword

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)

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- 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.

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