UDK 621.9.01:621.9.025.71

RESEARCH

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Materials Machinability in Relation to the Cutting Temperature

Measurement of cutting temperature methods and analysis of problems associated to it, are shown, in this paper. Artificial thermocouple for investigation of material machinability from the cutting temperature aspect was made and placed just below the cutting edge of the tool bit. This way, the simple, reliable, economical and satisfyingly precise method for determining the material machinability by cutting, has been obtained. Machinability analysis have been realized through experimental investigation of machining of number of semi-manufactured products, made of various materials, in combination with tool bits with various coatings.

Keywords: *material machinability, cutting temperature*

1. INTRODUCTION

Lathe machining is a very common type of machining in a metal-cutting industry. It is realized in a very complex environment and up till today not completely investigated. Tribological phenomenon occurring at the cutting wedge directly influences the cost of the machining process.

Wear, which is the main cause for decrease of the working life for tools, occurs as a consequence of the complex phenomena at cutting tools. Defining the wear process can be based on: changes of tool, workpiece, change of resistance, or cutting temperature. Many physical and chemical reactions that are developed during the cutting process are directly connected with the tool wear and with the cutting temperature. Well known regularities of derivation and distribution of thermal energy during metal cutting significantly helps in solving many problems that occur during the cutting process and points to procedures for improving the cutting ability of tool, for optimal machining regime, as well as for improvement of quality and of accuracy.

This paper deals with application of appropriate temperature measurement method in areas close to the cutting zone and setting up of the reliable measuring chain in order to collect data that is necessary for investigation of material machinability. Developed model can also serve for development of adaptive methods of control for turning process, on the cutting temperature basis.

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2. INFLUENCE OF THE CUTTING TEMPERATURE ON MACHINING EFFECTS

Heat phenomena that occur in the narrow and in the broad area of the cutting zone, are directly related to wear rate of tool, to the machinability rate of workpiece material, to the tool stability and related to many other characteristics of the machining process. Almost all work of cutting forces are turned into the thermal energy, as experimental investigations show. Generated heat goes from the cutting zone into the chips, tool, workpiece and into the environment, during which, the decrease of the hardness of tool's cutting elements, cutting wedge deformations, the loss of the tool cutting ability and its bluntness occur.

Generated heat distribution in workpiece, in tool and in chips, that is, the temperature level at working elements of the tool, at processed surface and at chips depends on: workpiece material (its mechanical and chemical characteristics), cutting speed, pace, cutting depth, tool geometry, lubricants type and many other relevant parameters.

Beside the influence on tool stability, heat generated in the cutting process has influence on: the machining process productiveness, processed surface quality, accuracy of machining and other output parameters of the machining process. Due to this, the investigation, measurement and knowledge of levels and distributions of the cutting temperature within the tool and workpiece are of the utmost importance from aspects of practice. Optimum conditions, working regimes, quality, productiveness and economy of process and tool stability can be determined on basis of this knowledge.

3. MEASURING CHAINS FOR MEASUREMENT OF TEMPERATURE

Measurement of the cutting temperature at lathe (by natural or artificial thermocouple) is solved according to the measuring chain shown in Figure 1.

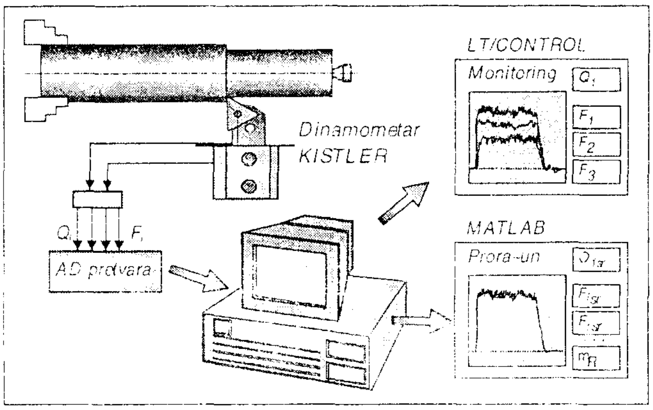

Figure 1. Measuring chain for measurement of the cutting temperature

Artificial thermocouple, specially made, is placed between the backing plate and the tool bit, below the cutting zone. Thermocouple is made from thermoelements of type 2AB AC 15 from "Termocoax", "PHILIPS" series. Thermoelements are wires made of NiCr(+) and Ni(-).

The position of the measuring spot and the way of placing the thermocouple is shown in Figure 2. The groove was formed at the backing plate, by grinding and the thermocouple had been placed inside it.

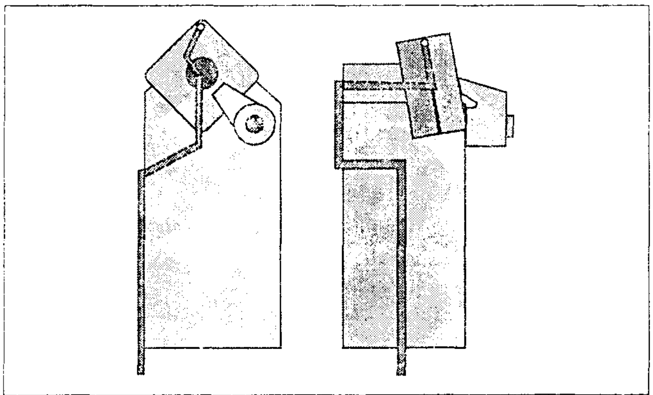

Figure 2. Position and measuring spot for artificial thermocouple

Four-canal recording instrument of type "RUKADENKI R-54" (position 3 in Figure 1.) was used for recording the signal. Dynamometer of type KISTLER-9441 (position 2 in Figure 1.), with appropriate amplifier (position 2 in Figure 1.), was used for tool carrier.

The tool and the workpiece were separated from the machine for measurement of the temperature with natural thermocouple. The natural thermocouple was not calibrated, because of its complexity, therefore causing the results of the temperature measuring being in mV units (thermo voltage).

The tool used was CSDNR 2020K12 lathe tool with replaceable SPMX 12T3AP-75 plate. Tool bits with TiN, TiAlN, TiZrN and ZrN coatings were used for investigation.

All investigations were done at universal lathe of 10 kW power in Laboratory for Metal Cutting at Mechanical Engineering Faculty, Kragujevac.

4. MEASURING RESULTS

Experimental investigations were aimed at determining of the cutting temperature change within the body of the lathe tool, depending on the following parameters:

a - cutting speed, v (m/min), that is, the relevant number of revolutions, n (rpm), (355, 450, 560, 710 rpm),

b - pace s (mm/o) (0.14, 0.2, 0.25),

c - cutting depth δ (mm) (0.3, 0.5, 0.7),

d - workpiece material.

- Č4730 steel in improved state of 273-300HB hardness (semi-lining),
- Č4731.6 steel in improved state of 230-280HB hardness (axle shaft),
- Č5421 steel isothermally annealed of HB-120 hardness (forging),

e - cutting bit coating (TiN, TiAlN, TiZrN, ZrN).

Some of the results obtained are given in Figure 3. and in Figure 4. Influence of the workpiece material type on the measurement of the temperature is presented in Figure 3. and the influence of the tool bit coating type is presented in Figure 4.

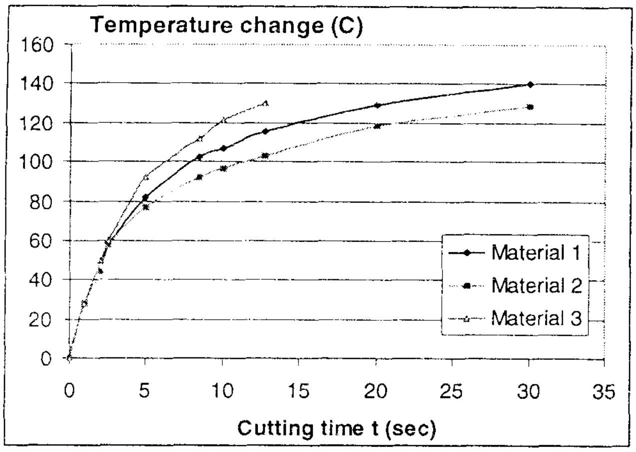

Figure 3.

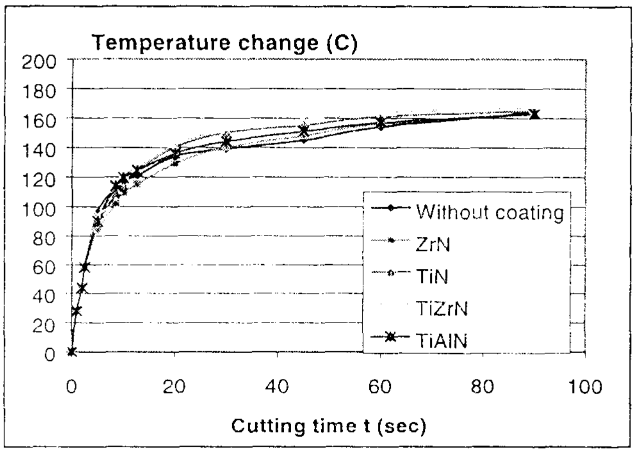

Figure 4.

5. MACHINABILITY INDEX

Without entering the problems of origination and development of the wear process, it can be assumed that by knowing values of the cutting temperature and its dependence from machining conditions and with other relevant parameters, machinability index for certain material can be determined with satisfying accuracy.

Machinability index or machinability coefficient is determined from the following equation:

$$I_O = \frac{\theta_{ref}}{\theta_i}$$

or from the following equation (percent value)

$$I_O = \frac{\theta_{ref}}{\theta_i}(100)\%$$

where:

Θ_{ref} - temperature of the referent material (etalon),

Θ_i - temperature of the investigated material.

For determining of the machinability index for the workpiece material, a part of results obtained during machining of various materials with cutting bits with various coatings were sorted. With referent material being the material of the semi-lining, the machinability index is easy obtained by the previously defined equation.

The machinability indices for materials and tool bits investigated is given in Figure 5.

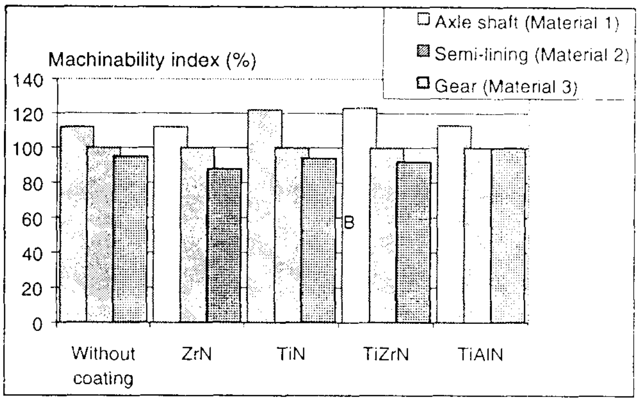

Figure 5.

6. CONCLUSIONS AND ANALYSIS OF THE MEASURING RESULTS

Investigations performed in this paper are part of the larger investigations that were aimed at determining the influence of different coatings on tribological characteristics of the tool bits made of the hard materials, which were conducted in several phases as follows:

- measurement of the cutting resistance and obtaining the appropriate correlative functionalities,
- measurement of the cutting temperature,
- measurement of the tool wear and obtaining the wear curves,
- measurement of the processed surface quality.

Based on the measuring results obtained the following conclusions can be given:

- the method developed for the measurement of the cutting temperature on surface between the backing plate and the tool bit with thermocouple, as a method is: simple, accurate, reliable, cost-effective and sensitive enough.
- the following technological demands are enabled:

- the correct material selection through application of the machinability index depending on the temperature,
- the correct coating selection and application of optimized machining regimes,

- the conditions are obtained for further development of the model for adaptive process control by application of the method developed.

On basis of investigations performed and results obtained the following conclusions can be made:

- results obtained show that for general conclusions to be made, the more detailed investigations are needed, but they confirmed some well-known facts about the dependences between machining regimes and temperature,
- results obtained enable the correct coating selection for tool bit for every operation (material) analyzed,
- with increase in the cutting speed, the cutting temperature raise occur and its influence is the biggest one, while the influence of the cutting pace and the cutting depth is somehow lower,
- the change in temperature until its stagnation was not monitored with all materials, because of the duration time for each operation at certain material,
- high machining regimes influence the instability of the measuring chain,
- applied method for the measurement of the temperature can be successfully used for determining of the material machinability,
- investigations conducted were the preliminary ones and represent the good foundation for further investigations (basically on influence of the lubricants).

Applied method for measurement of the temperature with natural and artificial thermocouple can be used for analysis of the turning process.

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