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THE EFFECT OF TOOL-WEAR ON CUTTING TEMPERATURE

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ВПЛИВ ЗНОШУВАННЯ ІНСТРУМЕНТА НА ТЕМПЕРАТУРУ РІЗАННЯ
Точність виробництва відіграє важливу роль у сучасній промисловості. Не тільки провідні галузі світової промисловості, але й інші відповідають вимогам, які дозволять компанії вийти на новий рівень прибутку, виробничих процесів й якісних показників виробництва виробів. Стаття представляє деякі результати експериментальної обробки, які подають інформацію про температуру й зношування інструментів, обмірювані в процесі обробки аустенітної корозійностійкої сталі. Результати порівнювались з результатами моделювання методом кінцевих елементів (FEM). Можна сказати, що вимір максимальної температури стружковідділення дозволяє прогнозувати зношування інструмента, за допомогою FEM можна одержати адекватне керівництво для обробки, у випадку точного планування моделі.
Ключові слова: зношування інструмента, температура різання, FEM

Точность производства играет важную роль в современной промышленности. Не только ведущие отрасли мировой промышленности, но и другие отвечают требованиям, которые позволят компании выйти на новый уровень прибыли, производственных процессов и качественных показателей производства изделий. Статья представляет некоторые результаты экспериментальной обработки, которые дают информацию о температуре и износе инструментов, измеренные в процессе обработки аустенитной коррозионностойкой стали. Результаты сравнивались с результатами моделирования методом конечных элементов (FEM). Можно сказать, что измерение максимальной температуры стружкоотделения позволяет прогнозировать износ инструмента, с помощью FEM можно получить адекватное руководство для обработки, в случае точного планирования модели.
Ключевые слова: износ инструмента, температура резания, FEM

Precision manufacturing plays an important role in modern manufacturing. Not only leading industry branches of the world but any other meet the profit requirements that encourage companies to think over their manufacturing processes and quality indicators of the produced components. The paper introduces some results of a machining experiment which gave information about temperature and tool-wear measured during turning of austenitic corrosion resistant steel. The results were compared with the results of a finite element modeling (FEM). It can be stated that measuring maximum temperature of the leaving chip is able to predict tool-wear and FEM can give a usable guide to cutting phenomena in case of exact model planning.
***Keywords:** tool-wear, cutting temperature, FEM*

INTRODUCTION

The increasing customer needs for higher quality enlarge the significance of precision machining. It is a relatively new area of machine industry and requires intensive experimental and practical investigation activity referring to technological parameters and circumstances, e.g. [1]. One part of the research activity of our department is the scope of precision machining and the applicability of our results in the industry. The monitoring of cutting processes predestinates the investigation on the major technological variables determining the shape and dimensional accuracy of the machined parts. Among several influences cutting temperature and tool-wear plays an important role in metal cutting.

To investigate these technological parameters, we turned austenitic steel with tungsten carbide insert and measured the temperature of leaving chip, tool-wear, roughness and cutting force. The results gave us a reliable base to continue the experiments in case of the special conditions of precision machining.

1. CONDITIONS OF MACHINING AND MEASUREMENT

Table 1 includes the data of the machined workpiece, the used tool and the major technological conditions. The experiment was performed by dry cutting and minimal quantity lubrication too. The paper introduces only the first one. Temperature and tool-wear was measured in predetermined cutting times, which required the interrupted cutting. Thereby cutting was started with cold insert in every period. The workpiece was held in chuck and leaned with the lathe-centre. In the beginning of the experiment the edge of the inserts was sharp. In figure 1 the temperature measuring system can be seen.

Table 1 – Technological data of the experiment

Workpiece	Dimension	Ø168×600 mm
	Material	X6CrNiTi 18-10 (austenitic steel)
Tool	Insert	SNMM 120408FN
	Cutting tool	PSBNR 2525 M12
	Material	P20 tungsten carbide
	Coating material	titan carbide
	Rake angle	γ = -6°
	Relief angle	α = +6°
Technological conditions	Cutting speed	v_c = 147 m/min
	Feed	f = 0.25 mm/rev
	Depth of cut	a_p = 1 mm
	Coolant	Dry cutting

There are several methods to measure temperature during machining and numerous publications detail the results of experiments performed with using infrared camera [2, 3] and optic fibre method [4, 5]. A more complicated method is measuring with built-in thin film thermocouple sensors [6] but it works very well if we have to monitor the temperature continuously. We have chosen the infrared (IR) camera because it provides temperature values in large resolution. But in case of precision manufacturing, resolution of the objective has to be relatively larger. The technique of measuring temperature by the detection of radiation is sometimes very useful in obtaining the surface temperature of the workpiece, the chip and the tool [7].

To use a technique which detects infrared radiation we have to consider several environmental variables. In case of IR camera the next important parameters

had to be measured in our experimentsbefore data collection: specific emission, reflected temperature, temperature of environment, specific humidity and distance between the chip and measuring device. Table 2 includes some important parameters referring to the used measuring instruments.

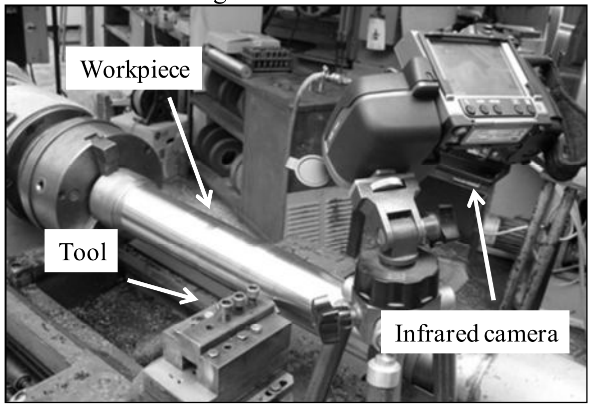

Figure 1 – Temperature measuring system

Table 2 – Measuring instruments

Measured variable		Instrument	Type	Accuracy
Temperature	θ_{max}, [C°]	Infrared camera	FLIR T-360	0,1 °C
Tool-wear	VB_{max}	Microscope with CCD-camera	Mitutoyo QVE 200	X, Y: 2 μm Z: 4 μm

2. RESULTS OF THE EXPERIMENT

The tool-wear diagram is shown on figure 2. The VB_{max} was measured only in every 52[nd] seconds, thereby the first phase of the theoretical diagram (degressive increasing) is not seen. Besides the regression line fitted to the data shows good linearity (equation 1). It corresponds to the data introduced by numerous literature. Wear-criteria was not appointed, that is why the leaving chip was continuous in the end of cutting.

$$VB_{max} = 0.03 + 0.0019\,t_c \qquad (1)$$

R^2=0,95

Maximum temperature diagram of leaving chip corresponds to the typical cutting temperature diagram. We could not measure cutting temperature with this method because the chip covers the largest temperature point of the edge. In this case the best regression curve is logarithmical (equation 2), the goodness of fit is almost 100 percent.

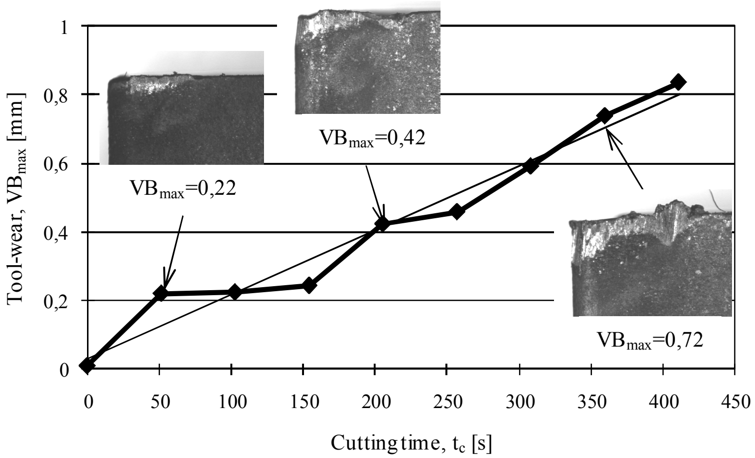

Figure 2 – Tool-wear diagram

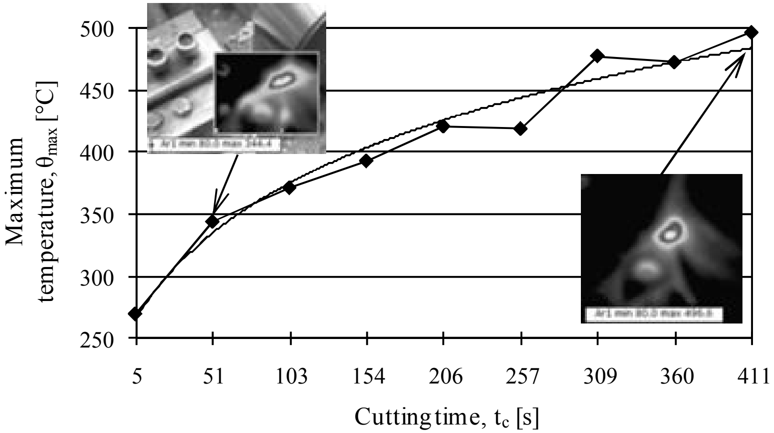

Figure 3 – Maximum temperature of the leaving chip

$$\Theta_{max} = 267 + 99\ln t_c \qquad (2)$$
R^2=0,97

The major goal of the experiment was the investigation on effect of temperature on tool-wear. Figure 4 shows the connection between the two variables. The fitted regression curve is logarithmic.

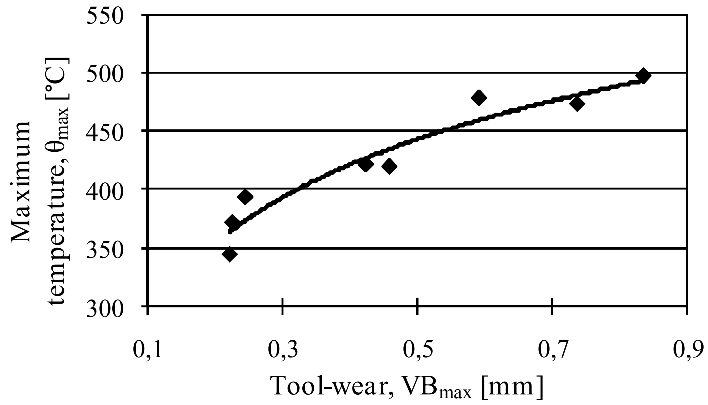

Figure 4 – Connection between tool-wear and temperature

$$\Theta_{max} = 511 + 98\ln VB_{max} \qquad (3)$$
R^2=0,93

Considering the first derivative functions of investigated maximum temperatures (on the basis of equation 2 and 3), they are almost the same. The reason of it is the nearly linear VB_{max} function. This experiment was the repeat of a previous investigation where the temperature measuring was performed be optic fibre method [5]. The connections between tool-wear and temperature were the same in both cases.

Finite element modeling of machining could give some information about several parameters of cutting process. It is used for simulating the machining with defined cutting edge [8], but applicable for simulation of abrasive machining too [9]. Figure 5 shows the simulated cutting temperature diagram besides sharp cutting edge and one that has 1,1 mm tool-wear. The results are similar but the diagrams show the typical logarithmic increasing (equation 4, 5).

The most important data of the standard-mode simulation:

- Minimum element size: 0.03
- Maximum element size: 0.3
- Mesh grade: 0.4
- Modeling of tool-wear: construction of special tool geometry
- Software: 2D Third Wave AdvantEdge V5.6-014.

$$\Theta_{0.0} = 285 + 58\ln t_c \qquad (4)$$
R^2=0,96

$$\Theta_{1.1} = 279 + 64\ln t_c \qquad (5)$$
R^2=0,98

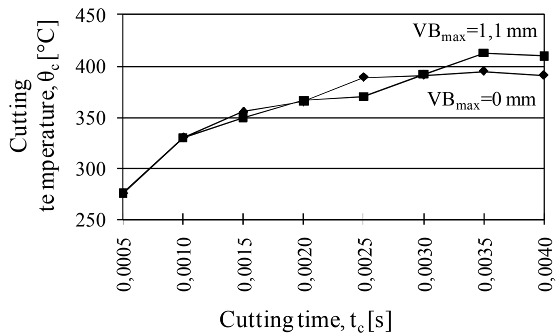

Figure 5 – Cutting temperature diagram by finite element modeling

3. CONCLUDING REMARKS AND FURTHER INVESTIGATION

On the linear part of tool-wear diagram, the connection between tool-wear and temperature is unique. Continuous measuring of tool-wear is complicated but temperature measuring is a good indirect way to get information about the extension of tool-wear. FEM could be a good pretest procedure but it does not substitute the real investigation. Furthermore exact data input is compulsory. During the experiments, force measuring was performed too. It did not give good results because the deviation of data was too large. We have to extend the investigation to special precision cutting circumstances and other, commonly used workpiece materials. It is also important to perform experiments besides more cutting speed levels.

4. ACKNOWLEDGEMENT

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