ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0012.4803

USING THERMOVISION FOR TEMPERATURE MEASUREMENTS DURING TURNING PROCESS

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Abstract

In metal cutting industries, machining processing, especially turning operation is very basic type of machining. For certain processes in manufacturing, it is favourable and necessary to have certain knowledge about heat generation and temperature rise (including average and maximum temperature) during machining process. Increment in maximum temperature at clearance face or at rake face of cutting tool causes the reduction in life of tool. Similarly, the quality of machined surface, a metallurgical structural alteration in tool and workpiece material also depends on the maximum temperature, temperature gradient and cooling rate of both tool and workpiece. Certain physical and chemical reactions that are developed during the cutting process are directly connected with tool wear, power consumption, surface roughness on work piece material and cutting temperature. The natural low of thermal energy gives significant relationship between cutting temperature and cutting parameters in order to improvement of cutting tool's wok efficiency, quality and accuracy. The heat distribution in cutting tool, in formed chip and in workpiece material strongly depends on (mechanical and chemical) properties of cutting tool and workpiece material, cutting speed, depth of cut, feed rate, nose radius, geometry of tool, type of coolant used and other parameters. This work presents some results of research done during turning steel 235JR realized on conventional lathe CDS 6250 BX-1000 with severe parameters. These demonstrate the necessity of further, more detailed research on turning process temperature, realized for different materials.

Keywords: *lapping, infrared measurement, lapping plate temperature, lapped surface quality*

1. Introduction

Temperature at the cutting point of the tool is a crucial parameter in the control of the machining process. Due to advancement in the machining processes, a special attention has been given on the life of a tool.

Interfacial temperatures in turning play a major role in tool wear, and can also result in modifications to the properties of the workpiece and tool materials. As there is a general move towards dry machining, for environmental reasons, it is increasingly important to understand how machining temperatures are affected by the process parameters: cutting speed, feed rate, tool geometry, and by other factors such as tool wear.

During machining heat is generated at the cutting point from three sources i.e. primary, secondary and tertiary zones (Fig. 1):
1) the shear zone – plastic deformation of the workpiece surface,
2) the friction of the chip on the tool face, and
3) the friction between the tool and the workpiece [4, 7].

The total work done by a cutting tool in removing metal can be determined from the force components on the cutting tool. Approximately, all of this work or energy is converted into heat, which is dissipated into the chip, tool and workpiece material. Fig. 1 schematically shows this dissipation of heat. The chip, tool and workpiece help to remove this heat from the cutting zones (Fig. 2). Studies have shown that maximum amount of heat is carried away by the flowing chip.

From 10 to 20% of the total heat goes into the tool and some heat is absorbed in the workpiece [1, 6, 8].

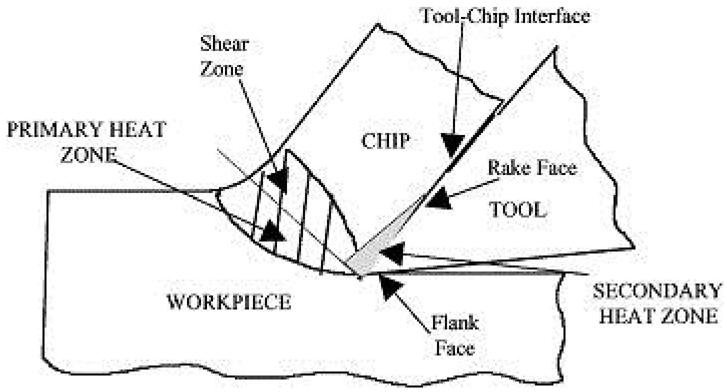

Fig. 1. Regions of heat generation in turning [3, 7]

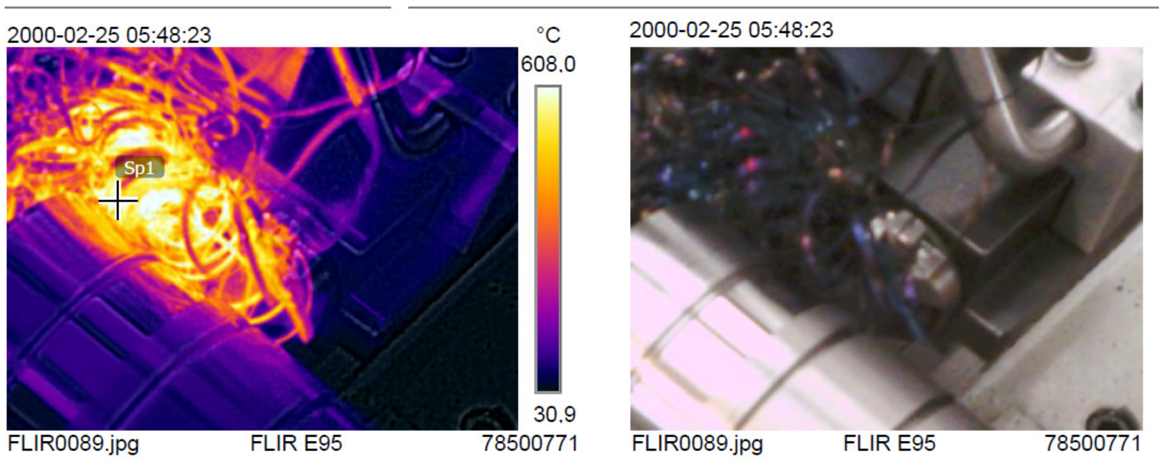

Fig. 2. Temperature distribution in cutting zone during turning

2. Turning temperatures

The increase in temperature at cutting point of the tool is mainly due to secondary shear zone, but primary shear zone also contribute towards the temperature rise of the cutting tool and indirectly affects the temperature distribution on the tool rake face. The primary shear zone temperatures affect the mechanical properties of the workpiece – chip material and temperatures at the tool – chip and tool – workpiece interfaces influence tool wear [7].

The temperature in the cutting zone depends on contact length between tool and chip, cutting forces and friction between tool and workpiece material. Its distribution depends on the heat conductivity and specific heat capacity of the tool and the work piece and finally the amount of heat loss based on radiation and convection [1, 2, 8].

It is well known that the temperature of the cutting tool, the chip and the work piece can be significantly increased during machining and that it can reach for steel levels typically of 750ºC. The temperature level depends on several machining parameters (such as the speed of cutting, depth of cut and feed rate) and the characteristics of steel (e.g. thermal diffusivity and hardness). An example of a typical temperature distribution in the cutting zone is shown in Fig. 3, where f_n is the feed direction [2, 6].

Much research has been taken into measuring the temperatures generated during cutting operations. Investigators have attempted to measure these cutting temperatures with various techniques (Fig. 4).

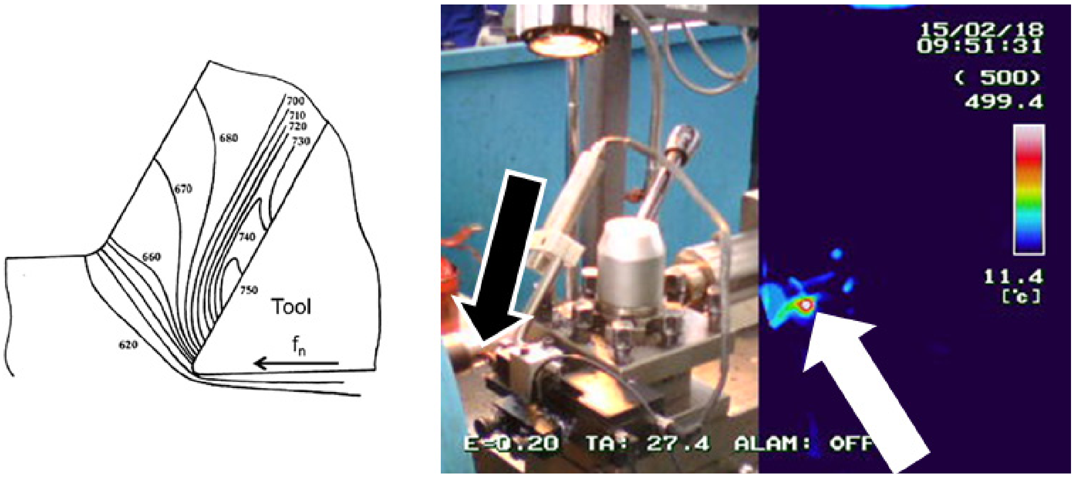

Fig. 3. Typical temperatures near the tool – chip interface (in ºC) [2, 6]

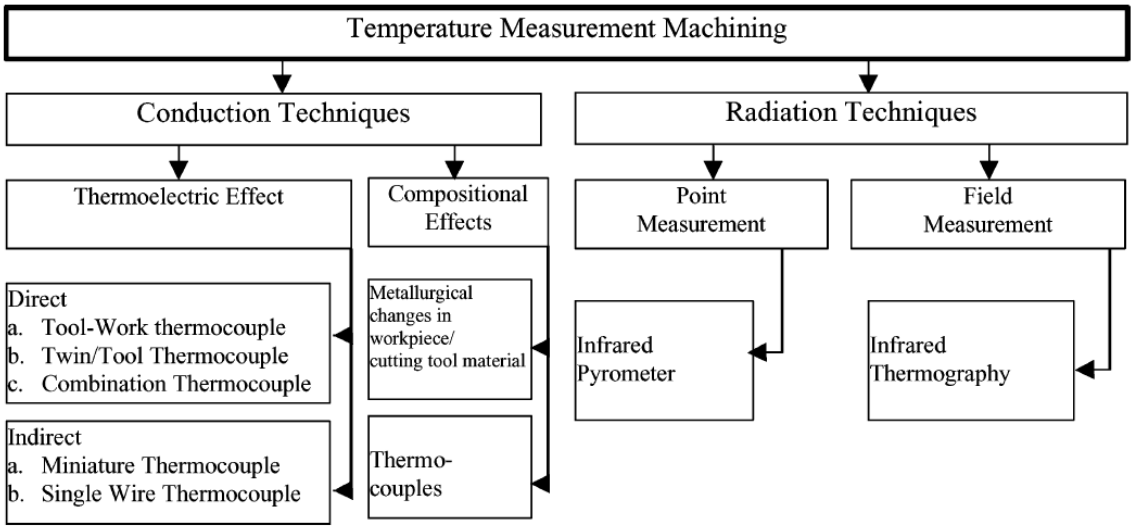

Fig. 4. Temperature measurement in machining [7]

The main techniques used in temperature measurement during machining engaged thermocouples. Thermocouples have always been a popular transducers used in temperature measurements. They are very rugged and inexpensive and can operate over a wide range of temperature values. It is easy to apply those techniques, but measure only the mean temperature over the entire contact area. High local or flash temperatures, which may occur for a short period, cannot be observed [1, 7].

In recent years, the use of infrared thermography for measuring temperature during machining is becoming increasingly popular. Thermography is not a new phenomenon – it has been utilized successfully in industrial and research settings for decades – but innovations have reduced costs, increased reliability, and resulted in noncontact infrared sensors offering smaller units of measurement. This technique has many advantages, the main is that it is non-contact technique and therefore there is no disturbance of the temperature field [5, 6, 10].

3. Errors of non-contact temperature measurement

All methods of non-contact temperature measurement employed by the radiation thermometers are indirect methods. Output temperature is determined on the basis of the power of thermal radiation emitted by the tested object and measured in one or more spectral bands using different mathematical models. Parameters of the model are emissivity of tested object, atmospheric temperature, relative humidity, object distance. All those parameters values are entered into the camera by the operator (Fig. 2). They should be estimated properly. Incorrect values will cause measurement error [5, 6, 10].

The factor with the greatest impact is emissivity ε – the relation between the real emissive power and that of a blackbody. The second most influencing is atmospheric temperature, especially important when testing object with lower emissivity value. The others parameters impact on measurement error are far smaller, but not negligible.

Thus, to perform correct temperature measurement, special attention should be paid to determining emissivity value. Emissivity of many frequently used materials can be found in a table. Particularly in the case of metals, the values in such tables should only be used for orientation purposes since the condition of the surface (e.g. polished, oxidized or scaled) can influence emissivity more than *the* various materials themselves. The emissivity of a particular material should be determined by experimental methods [5, 6, 10].

4. Experimental setup

Experiments were carried out on a conventional lathe CDS 6250 BX-1000 without using any coolant. A commercially available turning insert CCMT 09T304 was used. The machining was performed using workpiece of S235JR steel (250 mm long and 40 mm diameter) (Fig. 5).

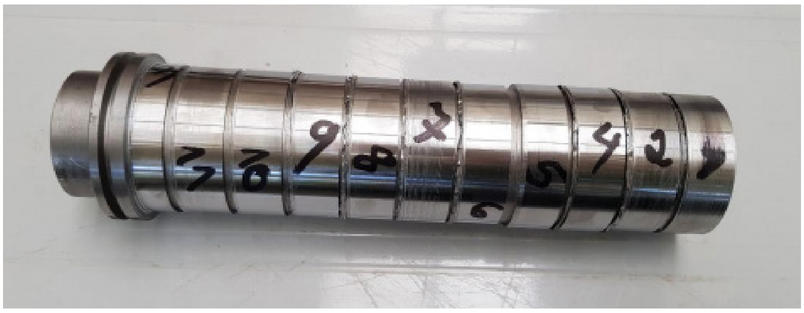

Fig. 5. S235JR steel workpiece

Temperature was measured by infrared camera E95 produced by FLIR® Systems, Inc. (Fig. 6).

Fig. 5. E95 thermographic camera [9]

The camera serves for contact-less, remote temperature measurement and visualization of its distribution. As a result of a measurement, it is obtained a data set that is presented in a form of a colour map: a thermogram. The thermogram consists of 161 472 measuring points (464 points in 348 lines). The camera views and measures highest temperatures are from -20 to +1800ºC with thermal sensivity ±0.03ºC. The camera employs a gun grip design with multi touch monitor similar to that of a smartphone or tablet, which enables one-hand operation. The image capture support functions of a 5-megapixel digital camera.

Tests were conducted for different turning parameters: feed rate differentiated from 0.1 to 0.2 mm/rev, cutting speed v_c between 200 and 300 m/min, and depth of cut a_p = 0.5-1.5 mm. Some examples thermograms are presented in Fig. 6.

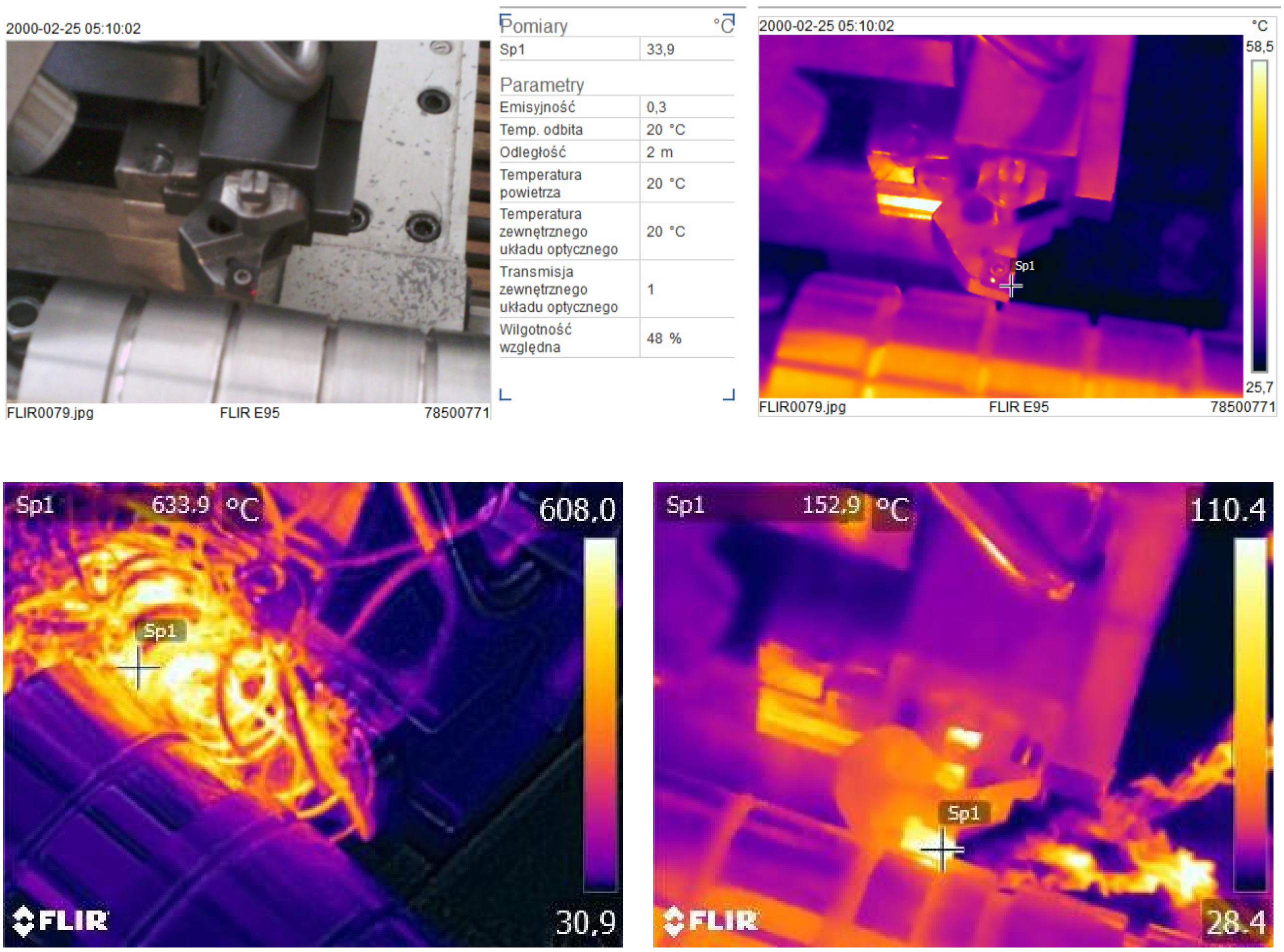

Fig. 6. Thermograms taken during machining with different parameters

5. Conclusions

The present article goal was to check if there is dependence between turning parameters and temperature in cutting zone. The heat generated during metal turning processes affects materials properties and the tool wear. Knowledge of the ways in which the cutting conditions effect the temperature distribution is essential for the study of thermal effects on tool life. To execute such research, temperature in the cutting zone must be obtained. Since at the interface there is a moving contact between the tool and chip in this work authors propose infrared method for temperature measuring.

For this application, infrared methods, which allow for contactless measurements are very useful due to moving contact between the interface of the tool and chip. Moreover, as a result of measurement it is obtained a data set that is presented in a form of a colourful map: a thermogram. It shows temperature distribution over the cutting area.

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Manuscript received 17 July 2018; approved for printing 26 October 2018