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USING THERMOVISION FOR MACHINING PROCESSES INSPECTION

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Abstract

During metal cutting process, an increase of the tool and workpiece temperatures can be observed. The heat generated has a negative influence on the tool life and performance. It causes rapid tool wear, plastic deformation of the cutting edge, built-up-edge formation and others. Therefore, the control of cutting temperature is required to achieve the desired tool performance. Temperature is the most frequently measured physical quantity, second only to time. Accurate temperature monitoring improves product quality and increases productivity. Downtimes are decreased, since the manufacturing processes can proceed without interruption and under optimal conditions.

In this work, authors propose noncontact infrared method for determining temperature of machining processes. This was mainly due to thermography ability to catching moving targets in real time, to measure temperatures over some area not only in point. As a result of measurement, it is obtained a data set that is presented in a form of a colourful map: a thermogram. Getting an accurate temperature of an object using this method is difficult because of numerous errors, which researchers could done during experiments.

This work presents some results of research done during turning and drilling realized on conventional lathe CDS 6250 BX-1000. These demonstrate the usefulness of proposed method to study the machining processes temperature.

Keywords: *turning, infrared measurement, drilling, machining processes temperature*

1. Introduction

During the metal cutting process, a considerable amount of the machine energy is transferred into heat through:
1 – plastic deformation of the work piece surface,
2 – the friction of the chip on the tool face, and
3 – the friction between the tool and the work piece (Fig. 1).

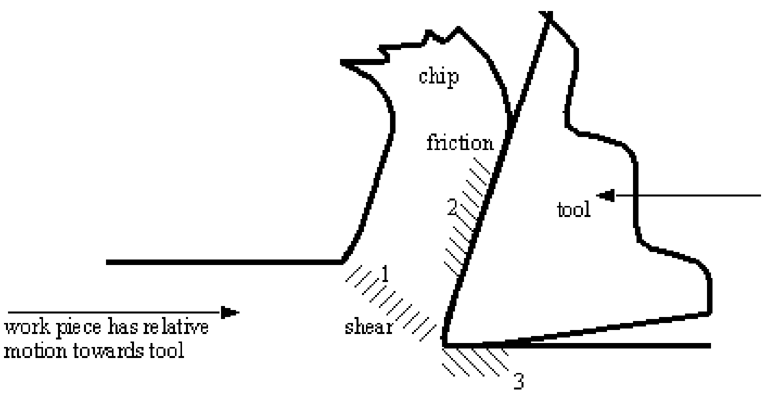

Fig. 1. Chip formation process during turning [2]

This results in an increase of the tool and workpiece temperatures. It is significant enough to cause local ductility of the workpiece material as well as of the cutting edge. Although softening and local ductility are required for machining hard material, the heat generated has a negative

influence on the tool life and performance. The possible detrimental effects of high temperature on cutting tool (edges) are:
- rapid tool wear, which reduces tool life,
- plastic deformation of the cutting edges if the tool material is not enough hot-hard and hot-strong,
- thermal flaking and fracturing of the cutting edges due to thermal shocks,
- built-up-edge formation.

The possible detrimental effects of cutting temperature on the workpiece are:
- dimensional inaccuracy of the workpiece due to thermal distortion and expansion contraction during and after cutting,
- surface damage by oxidation, rapid corrosion, burning etc.,
- induction of tensile residual stresses and micro cracks at the surface/subsurface.

These problems can be avoided by using coolant. It is necessary that cooling must be very intensive to protect workpiece and tool material against rapid changes of temperature and thus large thermal stresses. Therefore, the control of cutting temperature is required to achieve the desired tool performance [4, 6].

2. Temperature measurements method

Since that at the interface there is a moving contact between the tool and chip, not every experimental techniques can be used to measure the interface temperature. In this work, infrared technology is proposed. Thermography is not a new phenomenon – it has been utilized successfully in industrial and research settings for decades – but new innovations have reduced costs, increased reliability and resulted in noncontact infrared sensors offering smaller units of measurement [6, 7, 9].

The advantages offered by noncontact temperature measurement are:
1. It is fast (in the ms range) – time is saved, allowing for more measurements and accumulation of data (determination of temperature field).
2. It facilitates measurement of moving targets (conveyor processes).
3. Measurements can be taken of hazardous or physically inaccessible objects (high-voltage parts, great measurement distance).
4. Measurements of high temperatures (greater than 1300°C) present no problems. In similar cases, contact thermometers cannot be used, or have a limited life.
5. There is no interference – no energy is lost from the target. For example, in the case of a poor heat conductor such as plastic or wood, measurements are extremely accurate with no distortion of measured values, as compared to measurements with contact thermometers.
6. There is no risk of contamination and no mechanical effect on the surface of the object; thus wear-free. Lacquered surfaces, for example, are not scratched and soft surfaces can also be measured.

All of these factors have led infrared technology to become an area of interest for new kinds of applications and users, including machining processes observations [6, 7, 9].

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 based on 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 [4, 8, 10].

Fig. 2. Emissivity and ambient calibration setting in Thermo Gear G100 [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 affect measurement error is 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 [4, 7, 8].

4. Infrared camera

For measuring the temperature, infrared camera ThermoGear G100 (Fig. 3) produced by NEC Avio Infrared Technologies CO., Ltd. was used. The camera does not need computer to be controlled. It employs a gun grip design with a rotatable monitor similar to that of video cameras, which enables one-hand operation. Two measuring ranges are defined: -40 – 120 and 0 – 500ºC. The measurement accuracy is ±2ºC or 2% of reading, whichever is greater. The thermogram consists of 76800 measuring points 320 points in 240 lines. The image capture support functions of a 2-megapixel visible camera. Images that have been made can be presented as thermal (Fig. 4a), visible (Fig. 4b), parallel (Fig. 4c) or as a mix of both (Fig. 4d) [5, 10].

Fig. 3. Thermo Gear G100 [10]

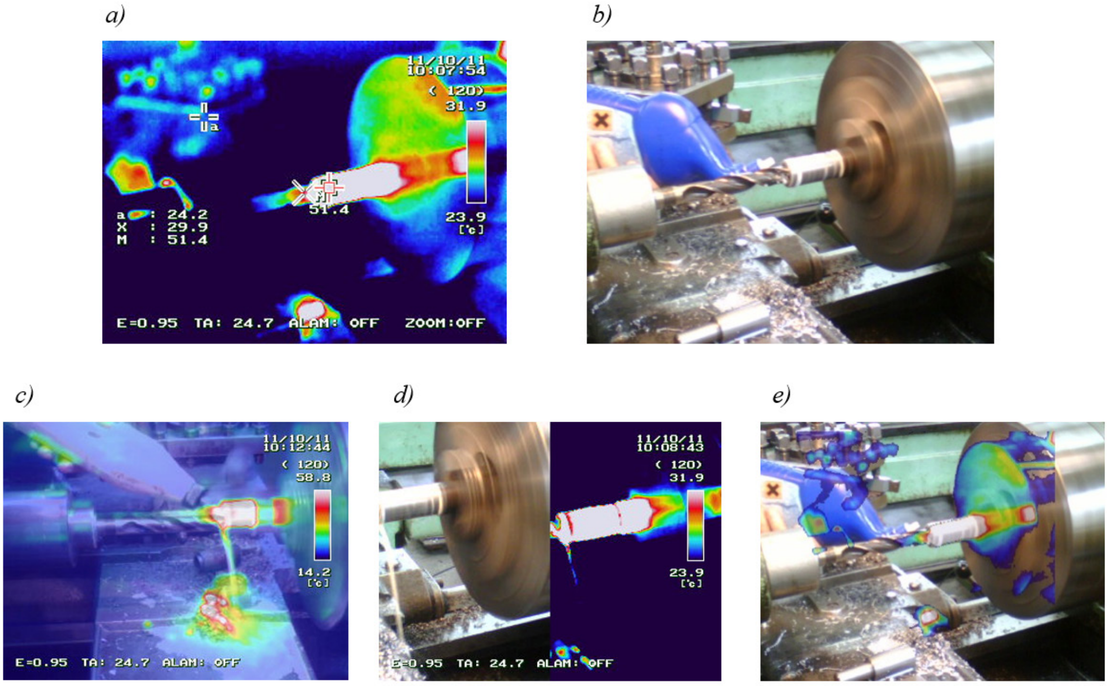

Fig. 4. Displaying images: a) only thermal, b) only visible, c) both parallel, d) mix of both, e) picture-in-picture

When using infrared camera for measuring temperature it is possible to determine its value in any of 76800 points over observed area. To analyse the results, computer software InfReC Analyser NS9500 Lite generate Excel file report with temperature value for each point.

5. Experiments results

The goal of this work is to present possibility of IR technology application in few machining processes like turning and drilling.

Turning is one of the most common of metal cutting operations that produces cylindrical parts. In turning, a workpiece is rotated about its axis as cutting tools are fed into it, shearing away-unwanted material and creating the desired part. Particles of material, the chips, are removed by cutting edge of a tool. The tool has one cutting edge, which is geometrically defined by number, shape and position [1, 3].

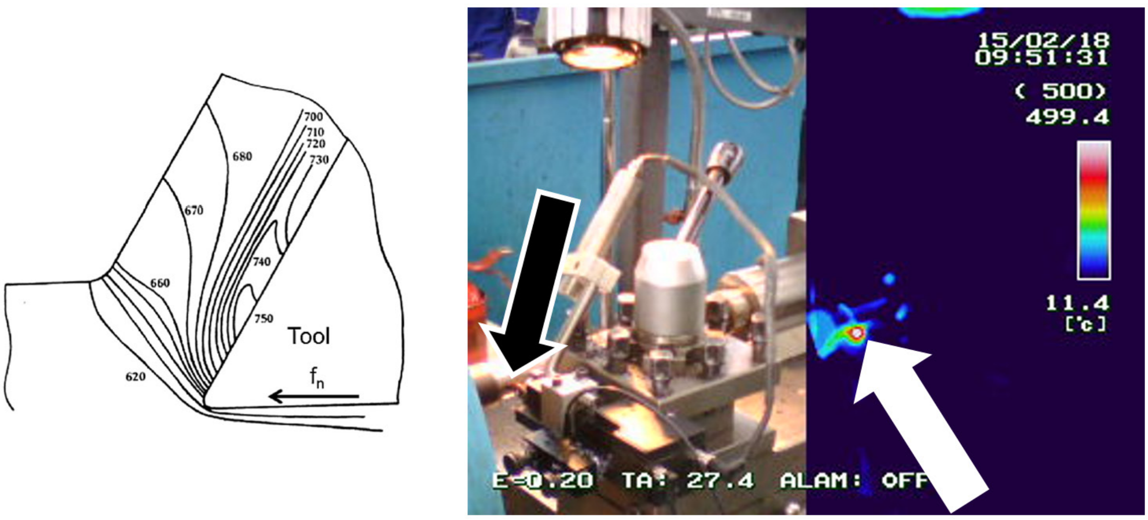

Fig. 5. Typical temperature distribution in the cutting zone (in °C) [2, 8]

The temperature in the cutting zone depends on contact length between tool and chip, cutting forces and friction between tool and work piece 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, 11].

Experiments were carried out on a conventional lathe CDS 6250 BX-1000 without using any coolant. A commercially available turning insert CCMT 09T304 – PF were used. The machining was performed using work piece of S235JR steel (250 mm long and 40 mm diameter). Turning parameters were as follow: feed rate f = 0.114 mm/rev, cutting speed v_c = 166 m/min, depth of cut a_p = 1.2 mm. As shown in Fig. 5 the maximum temperatures occur in the contact zone between the chip and the tool. The heat is shared by the chip, cutting tool and the work piece. Studies have shown that maximum amount of heat is carried away by the flowing chip (Fig. 6). From 10 to 20% of the total heat goes into the tool and some heat is absorbed in the workpiece [1, 8, 11].

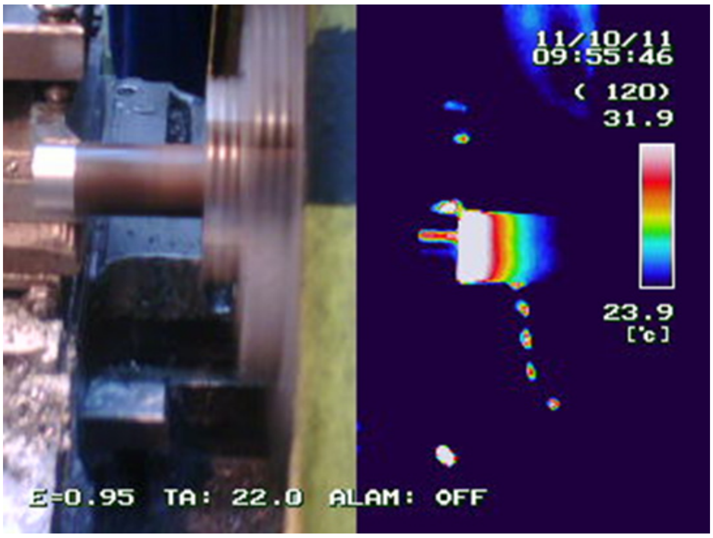

Fig. 6. Thermal and visible view of cutting zone in turning

Summing on, in turning, the heat generated on the tool is important for the performance of the tool and quality of the work piece. Hence, temperatures generated in the cutting zone are an important factor to take into consideration. The machining can be improved by the knowledge of temperature at the tool-chip interface [1, 8].

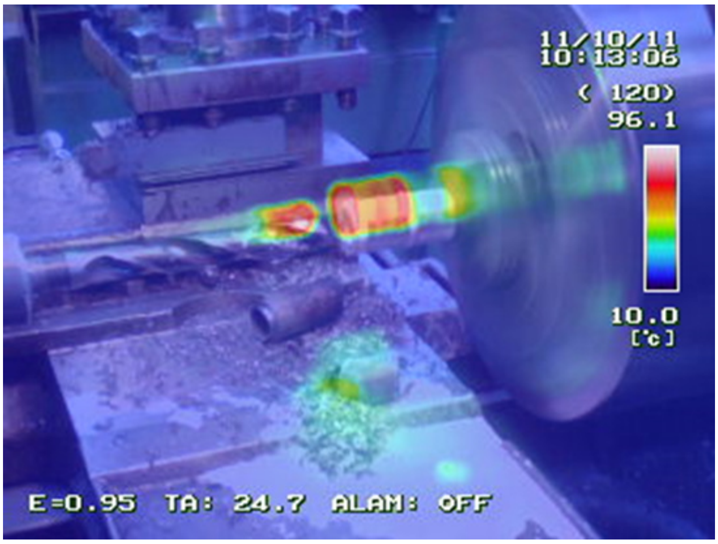

Fig. 7. Mix of thermal and visible view of cutting zone just after drilling

Nearly the same situation exists in drilling. Mechanism of cutting off excess material in drilling is the same as in turning, but machining condition are different. It especially can be seen when long holes are drilling (Fig. 7). There occurs a problem with cooling. Fig. 7 presents workpiece and tool just after drilling the hole with diameter 12 mm and 35 mm long on a conventional lathe CDS 6250 BX-1000 with using the coolant. Application of infrared camera for process inspection results in colourful map – a thermogram. It shows temperature value of 76800 measuring points and thus presents temperature distribution over the area of cutting zone, i.e. workpiece, tool, chips surfaces, machine elements and even the coolant.

6. Conclusions

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. As examples of IR camera applications, two machining processes: turning and drilling were presented.

For those applications, 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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