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TEMPERATURE MONITORING OF THE DRILLING PROCESS USING THERMOVISION METHOD

Lis Krzysztof
Kosmol Jan
Department of Machine Technology of the Silesian University of Technology
Gliwice
Poland

ABSTRACT
The main goal of that article is to show the research conception of identification of temperature field in the cutting zone during drilling process, using a modern thermovision technique. During the research the attention was focused on method, which directly does not interfere the cutting process. The main criterion of the analysis was the possibility of the utilization of the method in temperature monitoring system of the drilling process.
During the first stage, the work was focused on the research of the emissivity coefficient, which permits to solve the basic problem concerning the non-contact measurements. The surface of drilling process components i.e. tool, workpiece and chip was studied. The next stage concerned on the principle research. The investigations results were analyzed by working out a module of software to process sequence of thermovision image. Program was worked out in LabView.
Keywords: monitoring of drilling, cutting process, thermovision, emissivity coefficient

1. INTRODUCTION
A general assumptions of monitoring methods of a tool temperature relies on question: to use a tool or a workpiece or a chip as a heat sensor, so as to do not interfere in the cutting process, when access to cutting zone is difficult (i.e. drilling process). The temperature measurements carries out for the separate components of cutting process.
The measurements method, which determine a body temperature on the basis of his energy state requires precise identification of a body properties concerning a capable of radiation emission. Temperature radiation, which is emitted by separate components of the cutting process, will give information about temperature of components if the body properties are determined. Problems associated with them and the way of solution them is described in article [1], whereas in regarding to components of drilling process in article [2].

2. TWO DIMENSIONS MEASURE OF TEMPERATURE (THERMOVISION) OF DRILLING PROCESS
The investigations were conducted using IR camera with spectred range 8-14 μm and image resolution of 320x240 pixels. The maximum speed of this camera is 30fps. The experimental research were conducted using ϕ5mm diameter of drillers type XWMC by DIN338 HSCO GÜEHRING using the numerically controlled milling machine TRIAC VMC DENFORD. During the research using the steel st3 workpiece (100x70x20mm) was used.

2.1. Concept of the experiment
The idea of temperature measurements applying thermovision camera relies on using the radiation reflector IR to measure tool temperature of the end of drill while the reboring drilled workpiece. That solution permits to realize the measurement from two points of view in the same time using one pyrometer equipment (Figure 1).

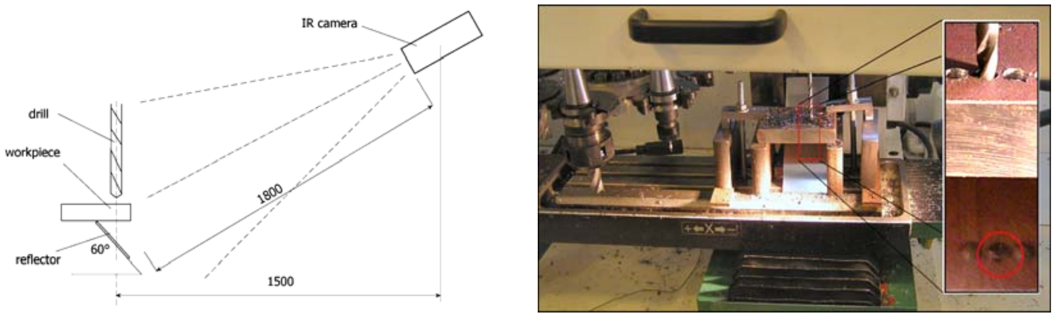

Figure 1. The temperature measuring stand

The Camera IR was positioned within the distance of 1800 mm from workpiece. Under workpiece was positioned the radiation reflector IR, which had been polished to reflexivity about E_r=0,965. The slope angle of reflector was positioned so as to the incidence and reflected angle of radiation IR had got the least angle relatively normal to surface of reflector. The position angle of reflector was equaled 60° relatively horizontal. Acquisition of data was realized by using the software environment NI LabView. The velocity of canvassing was equal to 25 frame per minute. On the basis of tool producer catalog data [4] and preliminary test of cutting, parameters were determined. The research was performed for the followings parameters: cutting speed V_c=28m/min and feed rate f=0,06mm/min. In article [2], was presented the stab and software system where problem of emissivity during the temperature pyrometric measurements was described. The additionally research were conducted where emisivity coefficient values for separates components of the cutting process and used reflector IR stand were determined.

The average emissivity band magnitude of working part of driller was equaled to E=0,82. The emissivity of reflector was equaled to E_r=0,035 and the emissivity of workpiece was equaled to E_0=0,74.

2.2. Results of research

In the first step, the picture of research object using the thermovision camera was performed to make identification possibility of thermovision screen separate elements of the drilling process (chip, tool, workpiece). Comparison of thermal-picture with photo-picture in the range of visible radiation is showed on fig. 2.

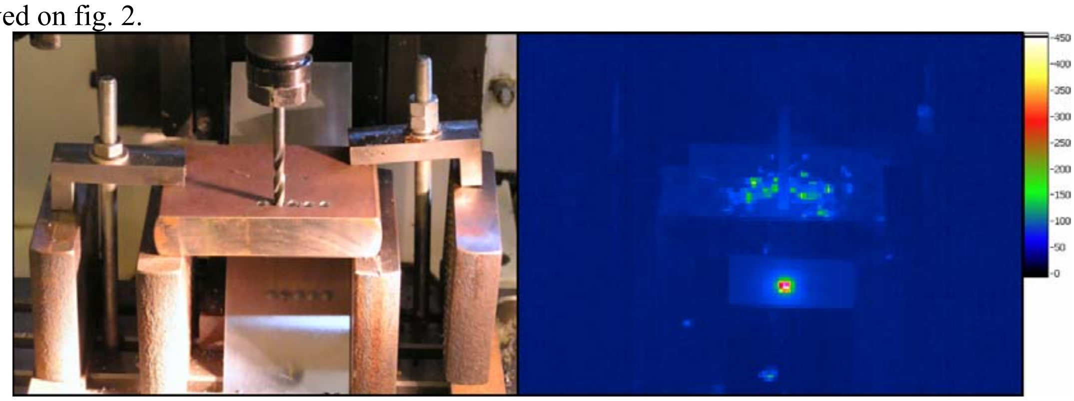

Figure 2. Images statement in visible range and IR range for example frame obtained during the research

During the analysis of temeratures matrix, on the basis of pyrometric properties separater considered visible surface on photo-picture in the range of visible radiation can determine emissivity coefficients treating them as homogenous. The theoretical bases were showed in articles [1] and [2], where was recalculated the temperature at E=1 for real temperature i.e. corrected temperature at real emissivity coefficient for measured surface.

It is noticed that application IR reflector gives additionally damping into the measurements system. If the reflexivity coefficient R_r for applied reflector is known, we can obtain virtual emissivity of system E_z from relationship:

$$E_z = (1 - R_R) \cdot E_O \tag{1}$$

for: R_R – reflective coefficient of reflector
E_O – real emissivity coefficient for measure object
E_z – equivalent (using in measure) emissivity coefficient for measure object

The analysis of thermographic image were performed in LabView software as is shown on fig. 3a.

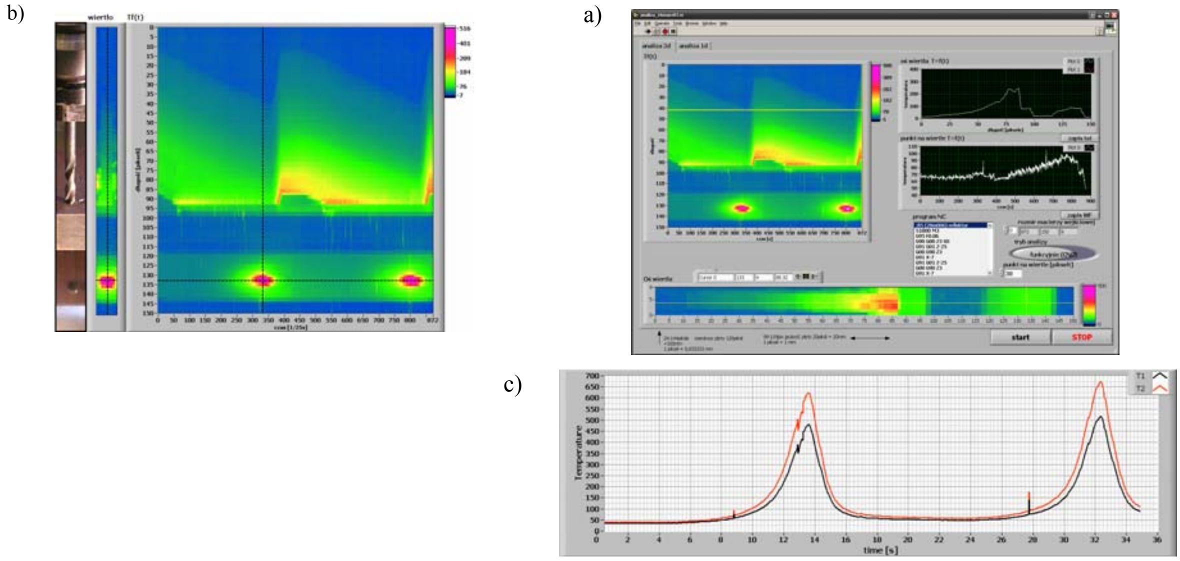

Figure 3. a) main window of application for termovision images sequence analysis; b) view in visible range and IR range of driller top and linear temperature distribution of driller axis with respect to time; c) reflector temperature with respect to time $T_r=f(t)$ during the drilling of two holes: T1 – temperature at E=1, T2 - E=0,71

The first part of analysis was an attempt of determination maximum temperature of the tool during drilling process while to making port. It was realized by analysis of reflected temperature value from tool at reflector IR. The distribution of maximum temperature with respect to time is shown on fig 3c. Symbol T1 concerning the temperature without correction (emissivity coefficient E=1) and symbol T2 is a value of bottom surface of workpiece temperature (emissivity coefficient E=0.74). The virtual emissivity of surface was obtained using the equation (1), which is equal to:

$$E_Z = E_o \cdot R_R = E_o \cdot (1 - E_R) = 0.74 \cdot 0.965 = 0.71 \qquad (2)$$

On the basis of temperature distribution in relative time, the maximum temperatures are equal to T_{r1}=622°C and T_{r2}=672°C adequately. The average temperature is equal to $T_{r\acute{s}r}$=647°C. The dispersion of results is lower than 10%.

The next analysis relied on determination of temperature distribution along the driller axis. That approach required geometrical calibration of thermovision images on the basis of dimension of workpiece.

It was necessary rescaling temperatures for separate elements of tool for measured emissivity coefficients to obtain real temperature along axis of driller. The measured and corrected temperature are showed on figure 4. During the research, the camera was focused on the workpiece.

It was prepared a program to analyze pictures IR (fig. 3a). Transformation of coordinate system from system of camera IR to spindle and tool system (axis Z of machine) was conducted using that program. Transformation of system is performed according to numerical program of CNC machine, which was used during the research.

The noise level caused chips increases when the cutting zone is closed along axis of tool. Those noises resulted of fast changing of temperature values, which were non typically during the heat process. Analysis of signals with respect to time for some points existed on tool axis are shown on fig. 5a. The real values with respect to time and signal after using the low-pass filter were shown.

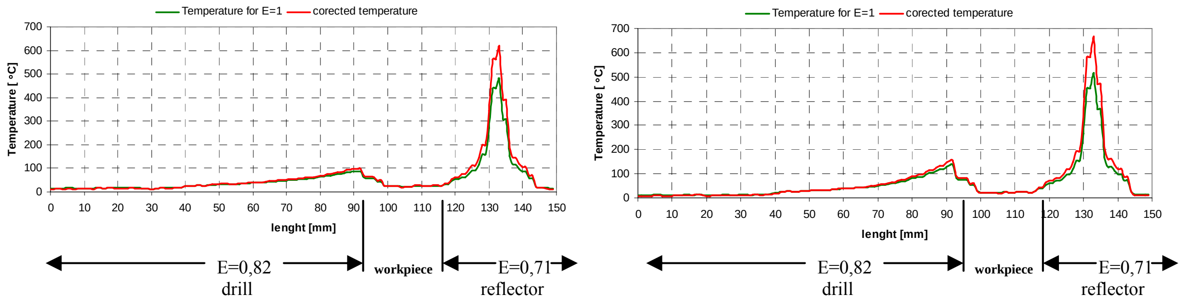

Figure 4. Temperature distribution along axis of driller for working data (E=1) and corrected data for first and second hole

The limit frequency was equal to f_{gr} = 1 Hz. The noises with respect to time is shown on fig. 5b. The relative noises level value with respect to the absolute signal values expressed by function of distance from top of chipper.

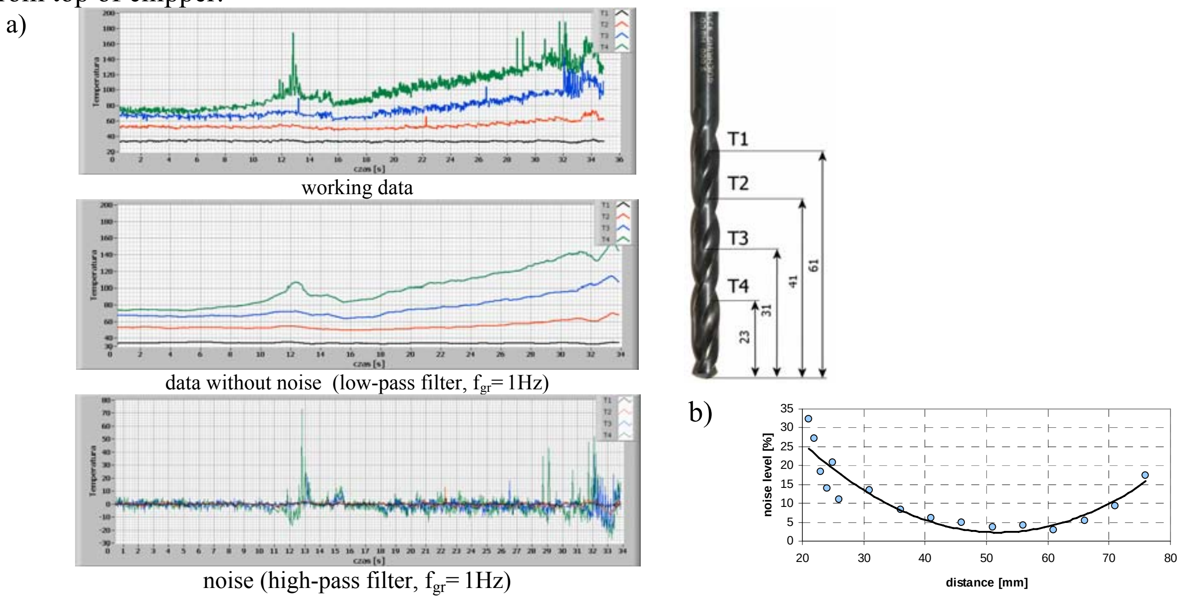

Figure 5. a) measured temperature with respect to time (E=1) for some points on tool axis; b) relative noises level of temperature value measured at specified point of tool axis as a function of points distance from top of tool.

On the basis of the noise level, the optimal measure point exists in the middle of tool axis as is shown on fig 5b.

3. CONCLUSION

The techniques development in the field of temperature measurements by the non-contact methods, which uses energy of heat radiation, suggests the possibility of application those methods to identification of temperatures field in the cutting process. Presented results are only examples of application of termovision devices for the measurements of temperature field during the drilling process. In the future its can be used as effective system to monitor of temperature during the drilling process.

4. REFERENCES

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