UDC 621.91.02

METHODS OF EXPERIMENTAL DETERMINATION OF HEAT AND TEMPERATURE ELEMENTS OF THE TECHNOLOGICAL SYSTEM

KONSTANTIN TULEI, NIKOLAI POPOK
Polotsk State University, Belarus

Experimental determination of heat and temperature in the technological system is necessary to solve heat problems empirically and to test theoretical calculations of temperature.

Methods of determining temperature are divided into *direct* and *indirect* [1]. To use *indirect* methods of estimation of temperature values for some of its indirect manifestations. For example, to change the component of the cutting force P_Z, because the amount of heat is determined by the formula $Q = P_Z \cdot \upsilon$. *Direct methods* are based on a relatively more accurate determination of temperature using temperature sensors. Direct methods further are divided into *contact* and *contactless*. The *contact methods* include methods and devices where there is no direct contact between the temperature sensor and the measurement object. The *contactless* methods are those ones in which the measuring sensor devices are located at some distance from the object which temperature is to be determined.

Contact methods

Thermometers, heat indicators, thermocouple are used for contact methods; radiation and other devices, optical, acoustic and pneumatic sensors are used for contactless methods. Due to the nature of the temperature measuring elements of the processing system thermometers (mercury gauge and mechanical) are mainly used to determine the temperature of liquids, melts and when calibrating. The use of heat indicators, which are further divided into chemical, thermal and melting, are also limited. Heat indicators are produced in the form of heat pencils, thermoablation, termotronic, heat-sealing and thermal paper. Heat indicators have a temperature measuring range from 20°C to 1500°C and a few color changes (from 1 to 6). Each color indicates a certain temperature. For example, a fluoride of cobalt in $CoO2$ is orange in colour, and at the temperature of 85°C it becomes light pink.

Heat indicators in the form of fusible inserts are substances which in a certain temperature range, turn into the liquid crystalline state. Tin (θm = 231,9 °C), cadmium (θm = 320,9 °C), zinc (θm = 419,5 °C), silver (θm = 960 °C), copper (θm = 1083 °C) are often used as such substances.

Direct methods are the most widely applied methods with using thermocouples, calorimeters and radiation pyrometers.

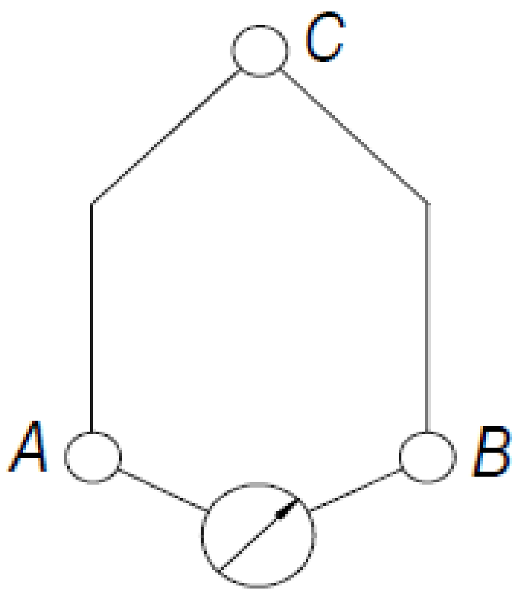

Fig. 1. Schematic diagram of the thermocouple

A thermocouple is the junction of two dissimilar metals, a common point called the hot junction, and all other dissimilar metals A and B in the circuit of the thermocouple, called cold junctions (figure 1).

Thermocouples are based on the phenomenon that in the closed circuit of two dissimilar metallic conductors an electric current or so-called thermal electromotive force (thermal EMF) is caused by heating one of the junctions. The thermocouple records the temperature difference between the hot and cold junctions. The cold junctions can be maintained at room temperature or zero temperature, which is achieved by locating the cold junctions in a vessel with melting ice.

Non-contact methods

Calorimetric method is the use of containers with liquid (water) and 1 for trapping flying off the chips 2, which are installed under the treatment area (figure 2, a).

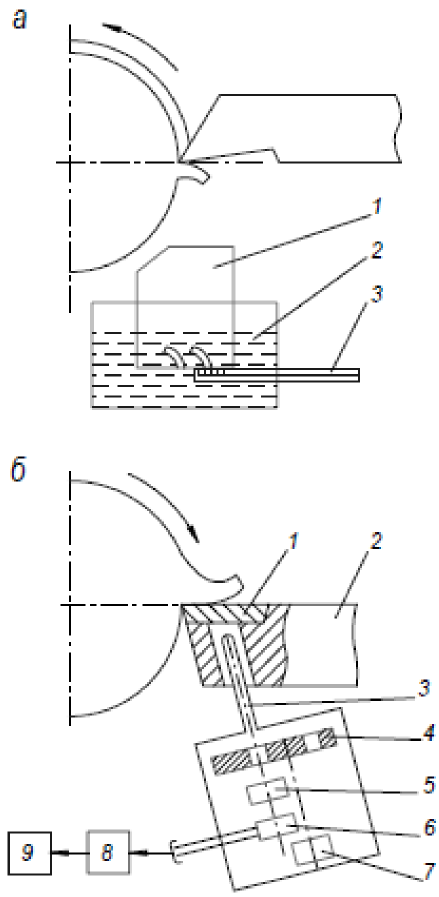

Fig. 2. Scheme of temperature measurement
of cutting with a calorimeter (a) and radiation thermometer (b)

After getting chips in a calorimeter, the water is stirred to equalize the temperature. After stirring, the water temperature is measured, then the chips are weighed on an analytical balance, the temperature of the water in the calorimeter is calculated enthalpy of chips in calories and its volumetric average temperature:

$$\theta = \theta_{см} + \frac{G_B(\theta_{см} + \theta_B)}{c \cdot G}. \quad (1)$$

where $\theta_{см}$ – the temperature of the mixture (water after being hit by a chip);

θ_B – initial temperature of water;

G_B – the mass of water in calorimeter;

G – the mass of the chip or of the cutter;

c – the heat capacity of the shavings or cutter.

The radiation method is based on measurement of infrared radiation in the cutting zone radiation pyrometers (figure 2, b). Insert 1 cutter 2 needs to be transparent, for example, diamond, for the infrared rays, which through the light guide pads 3 fall to the modulator 4 and then through the filter on the radiation receiver 6. To drive the modulator 4 the micro 7 is used. Infrared radiation is amplified by an amplifier 8 and is recorded by the device 9. This method is effective, but its use during cutting is restricted to small areas of the zone of heat radiation and its closeness.

The results of experimental studies in determining the temperature of chips by calorimetric method have shown that at the stages of cutting and nursing its values are in the range of 410-460°C. When exceeding the permissible values of the blade wear chamfer (above 0,4 mm) and the tool speed of 12,000 min^{-1}, the chip temperature rises sharply up to the melting point of the processed material and is formed in the form of drops [2].

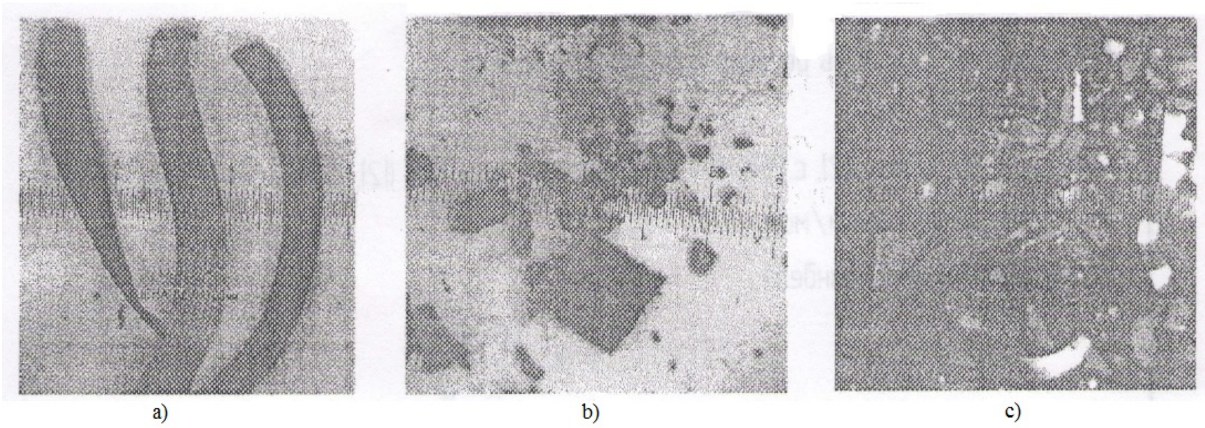

Fig. 3. a) at the stage of cutting; b) at the stage of nursing;
c) when working a blunt tool and the tool rotation frequency of n_1 = 12,000 min^{-1}

The temperature of the part measured by the pyrometer varies depending on the rotation frequency of the tool and the work piece and their diameters from 30 to 120°C. A typical graph of the part temperature change from the processing time is shown in figure 4.

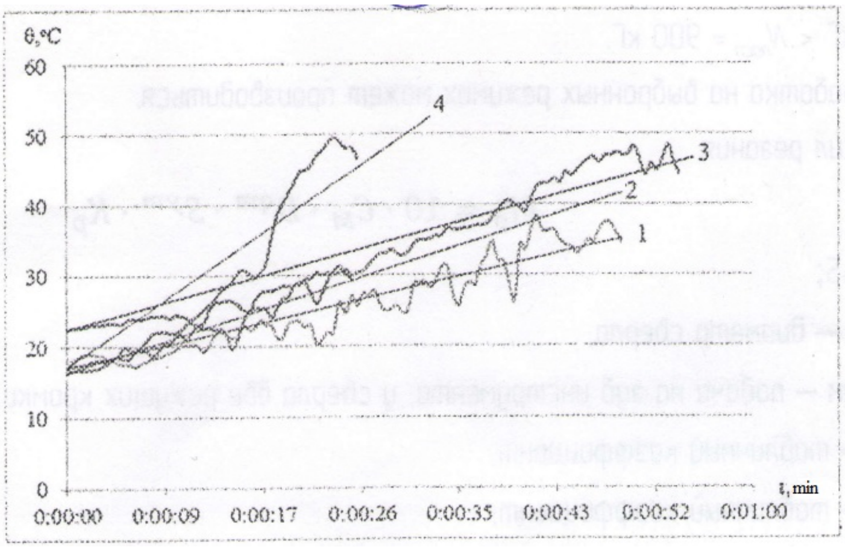

Fig. 4. The variation of the temperature of the work piece surface with a diameter of 35 mm on the time of treatment with the frequency of rotation of the work piece n_2=200 min^{-1} at:
1 - at tool speed n_1=3150 min^{-1} of cross feed *Sn*=1,61 mm/min;
2 - at tool speed n_1=6300 min^{-1} of cross feed *Sn*=2,25 mm/min;
3 - at tool speed n_1=9000 min^{-1} of cross feed *Sn*=0,853 mm/min;
4 – at tool speed n_1=12000 min^{-1} of cross feed *Sn* = 1,543 mm/min

As it can be seen from the graphs, the higher the rotational speed is, the higher the temperature value is. The intensity of heat accumulation in the details is different and depends on the magnitude of the transverse feed - cutting depth. The greater the cross feed and less processing time are, the lower the intensity of heat accumulation in the part is by increasing the heat transfer into the chip.

As the wear chamfer increases on the back of the blade, the heat flows into the tool and the part increases, as evidenced by the increase in the heating temperature of the part to 120 degrees. At the same time, the influence of the transverse feed (cutting depth or section width of the cut layer), as a factor improving heat transfer into the chip, decreases.

Relatively low values of the heating temperature of the part (30–120°C) indicate that there are no significant structural and phase transformations in the surface layers of the part and the tool blade, which ensures high quality of the treated surface of the sphere.

In the study of tool blade wear, mechanical cutting and abrasive abrasion of irregularities on the blade surface with the formation of a wear chamfer of length $l_ф$ and height $h_ф$ along the auxiliary cutting edge and the adjacent back surface are observed. Moreover, the shape of the wear chamfer on the rear surface corresponds to the radius of the treated spherical surface.

Processing data of the measured value of blade wear showed that the permissible length and height of the wear chamfer is respectively $l_ф$ = 2-4 mm and $h_ф$ = 0,1-0,4 mm.

REFERENCES

1. Попок, Н.Н. Теория резания : учеб. пособие для студ. машиностроительных спец / Н.Н. Попок. – Новополоцк : ПГУ, 2006 – 228 с.
2. Комплексные исследования физических и технологических характеристик процесса обработки сферических поверхностей деталей / Н.Н. Попок [и др.]. – Вестник БРУ. – 2017. – № 2(55). – С. 87–97.