DETERMINATION OF CUTTING TEMPERATURE WHEN TURNING ON THE LATHE MODEL 1K62

PURPOSE OF THE LABORATORY WORK

Mastery of skills to determine the average contact temperature of the cutting zone during turning, processing of experimental data and obtaining empirical dependences of the cutting temperature on cutting conditions.

1K62 LATHE MACHINE SPECIFICATIONS

- the largest diameter of the product installed above the bed – 400 mm;
- the largest diameter of the processed bar – 45 mm;
- the distance between centers – 1000 mm;
- the number of spindle speeds – 23 (from 12.5 to 2000 rpm);
- the number of working feeds – 42 (from 0.07 to 4.16 mm/rev).

BRIEF THEORETICAL PART

In the process of cutting, the heat source is the mechanical work spent on shaping the chips. The amount of heat generated is equivalent to the perfect work that is spent on plastic and elastic deformation of the cut layer (A_{def}), friction of the chips on the front ($A_{\text{fr.f.s.}}$) and on the back surface ($A_{\text{fr.b.s}}$) of the cutter. The heat (θ) generated during the cutting process is carried away by the chips (θ_{c}), spreads into the part (θ_{p}), the cutter (θ_{cut}) and the environment (θ_{env}). The heat balance equation during cutting will take the following form:

$$\theta = A_{\text{def}} + A_{\text{fr.f.s}} + A_{\text{fr.b.s}} = \theta_{\text{c}} + \theta_{\text{p}} + \theta_{\text{cut}} + \theta_{\text{env}} \qquad (1)$$

Empirically established the percentage ratio of the components of the heat balance equation, which is expressed as follows:

$$100\% = 55\% + 35\% + 10\% = (60 \div 70)\% + (30 \div 40)\% + 3\%$$

The degree of concentration of heat in different parts of the product, shavings and tools are different and sometimes reaches several hundred degrees. Temperature fields are formed that have different effects on chip formation, outgrowth, shrinkage, the magnitude of the cutting forces, the dullness of the tool and its durability. Therefore, it is important to know what temperatures occur under different cutting conditions and what is the nature of their distribution when changing operating conditions.

The following methods are used to determine the temperature in the cutting zone: thermocouples, photoelectric, thermosensitive paints, calorimetric, discoloration colors.

The photoelectric temperature measurement method is non-contact and is based on the principle of optical collection of thermal radiation from a portion of a heated surface, and directing it to a photocell that generates a current equivalent to the value of thermal radiation.

Method of thermal paints – special compositions are used that change their color under the influence of a certain temperature.

Calorimetric method – allows you to determine the amount of heat passing into the chips. Hot chips are placed in the calorimeter and, knowing the mass of chips and water, the change in water temperature, the average temperature of the chips and the temperature in the cutting zone are determined.

The most widely used methods of measuring temperature using thermocouples. It is known that if the junction of two conductors of different metals is heated, leaving the free ends at a lower temperature, then a thermo-electromotive force arises on the latter, the magnitude of which is directly proportional to the temperature difference between the junction and the colder ends. The thermoelectric measurement method has several varieties:

a) artificial thermocouple method – a small diameter hole is drilled in the tool, not reaching the test surface by 0.2...0.5 mm, into which an insulated thermocouple is inserted;

b) semi-artificial thermocouple method – one of its elements (tool or part) is present during machining, and the second does not participate in this process, but is introduced into the processing zone in order to create a thermocouple and measure temperature;

c) natural thermocouple method – the elements and thermocouples are the part and tool, which, being dissimilar conductors, have a very hot contact during cutting, which is a junction of the thermocouple. This thermocouple measures some average temperature of the contact zone between the cutter and the part.

Most of the temperature measurement methods discussed above do not record the direct temperature values, but some parameters (voltage, mV), therefore calibration of measuring devices with recordings is necessary. Calibration - establishing the relationship (graphical, mathematical) between the measured and measured value (for example, temperature versus voltage).

In the process of experimental studies, the following power dependence of the cutting temperature on the cutting conditions was established:

$$\theta = C_\theta \cdot V^m \cdot S^n \cdot t^q \qquad (2)$$

where C_θ – coefficient taking into account the influence on the cutting temperature of all possible factors except cutting conditions (for example: material of the workpiece and cutter, its geometry); m, n, q – exponents indicating the intensity of the influence of the cutting speed V, feed S and the cutting depth t on the temperature.

The greatest influence on the increase in cutting temperature has an increase in speed, which leads to an increase in cutting work per unit time. On the other hand, the higher the cutting speed, the greater the proportion of heat carried away by the chips, not having time, will spread to the tool and part. As a result, the higher the cutting speed, the less the cutting temperature rises.

With an increase in the width of the cut layer (cutting depth), the cutting force, as well as the amount of work and the heat generated, increases in direct proportion. The width of the contact of the tool with the chips and the part grows to the same extent, that is, the load per unit length of the cutting edge does not increase. Heat dissipation conditions are improving. In this regard, the cutting temperature with increasing width of the cut layer increases slightly.

With increasing thickness of the cut layer (feed), the cutting force increases slightly. Therefore, the increase in cutting work and the amount of heat generated lags behind the increase in the thickness of the cut. On the other hand, with an increase in the thickness of the cut layer, the center of the chip pressure on the cutter shifts, the contact area of the chip with the front surface of the cutter increases slightly, which helps to improve heat dissipation and lower the cutting temperature. But the load per unit length of the cutting edge increases. The heat sink improves to a lesser extent than increasing the width of the cut. Therefore, despite the fact that the amount of heat with an increase in the thickness of the cut increases more slowly than with an increase in the width of the cut, due to the conditions of heat removal, the thickness of the cut affects the cutting temperature much more than the width of the cut.

INTRODUCTION TO THE CUTTING TEMPERATURE MEASUREMENT METHOD

The temperature in the cutting zone is measured using a natural thermocouple method. The natural thermocouple diagram is shown in Fig. 1. The workpiece is isolated from the machine by means of dielectric gaskets and a sleeve on which the back center of the machine rests. The cutter is also insulated from the tool holder by dielectric gaskets. The contact of the rotating workpiece with the cutter is carried out by a brush current collector. The thermo-electromotive force arising during the cutting process is recorded by a galvanometer (mV).

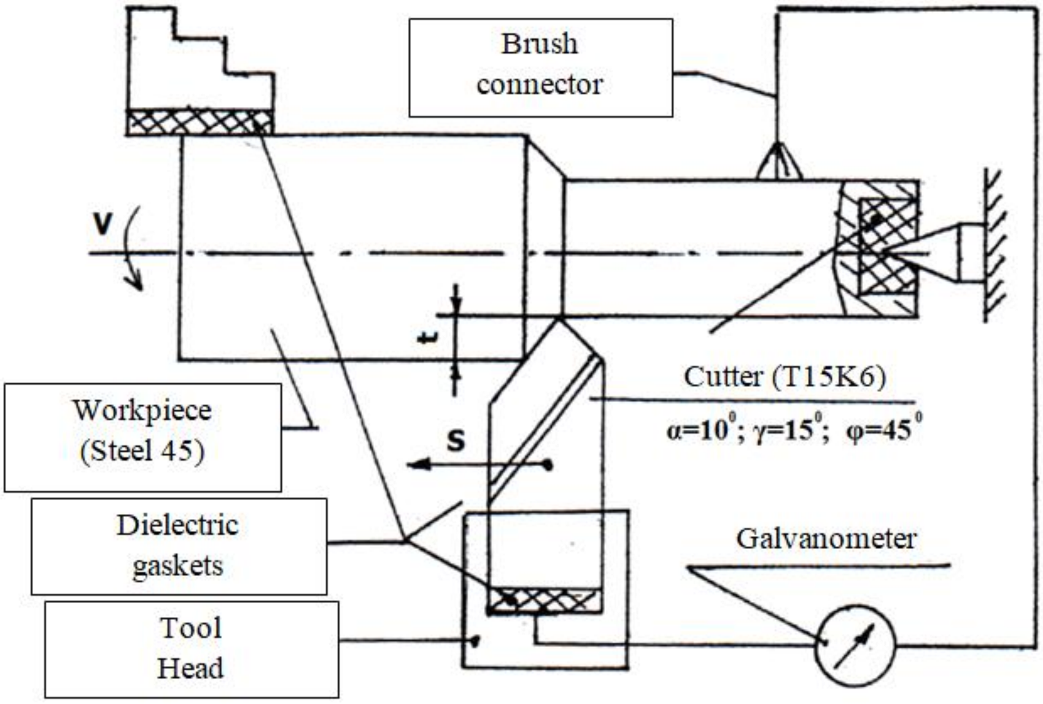


Fig. 1. Natural Thermocouple Diagram

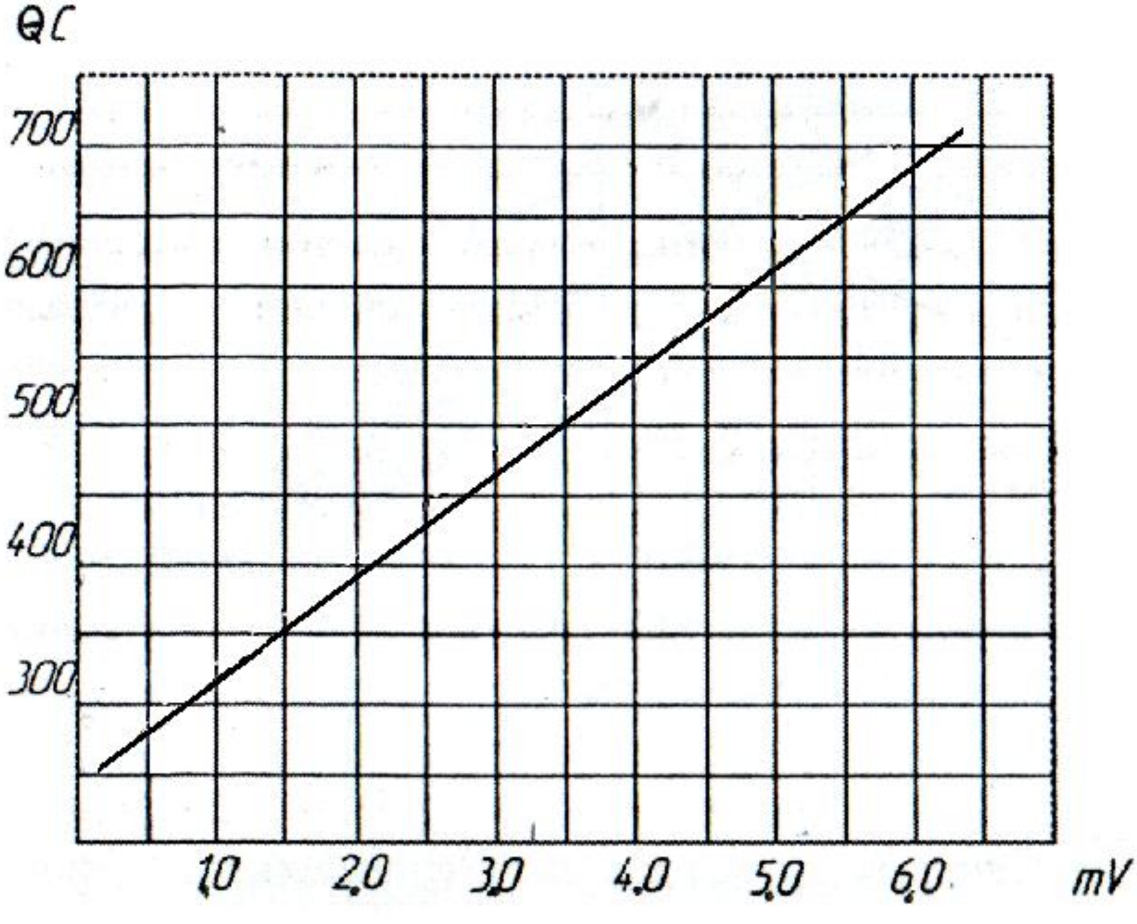


Fig. 2. Calibration Graph

CALIBRATION OF NATURAL THERMOCOUPLES

In order to go from millivolts to degrees, the thermocouple must be calibrated - that is, the correspondence of temperature values to millivoltmeter readings is determined. When calibrating a natural thermocouple in a metal bath (from lead, tin, antimony) heated by some heat source, the cutter and chips from the workpiece used in the experiments are inserted. They do not weld, but have good contact through molten metal. In the same bath in the immediate vicinity of the indicated thermocouple, a «control» thermocouple with a pre-calibrated galvanometer is introduced. When the bath is heated or cooled at certain intervals, its temperature is recorded, indicated by the «control» thermocouple and the readings of the calibrated thermocouple galvanometer. Based on the results obtained, a graph is plotted showing the temperature values corresponding to various indications of a galvanometer of a natural thermocouple. Calibration graph of a natural thermocouple: steel 45 - T15K6 is shown in Fig. 2 and is recommended for use in deriving empirical dependences of cutting temperature on cutting conditions.

PROCESSING THE EXPERIMENTAL RESULTS

From the conditions of a one-factor experiment, expression (2) can be represented by the following particular relationships:

$\theta = C_A \cdot V^m$ (3), where $C_A = C_\theta \cdot S^n \cdot t^q$ (6)

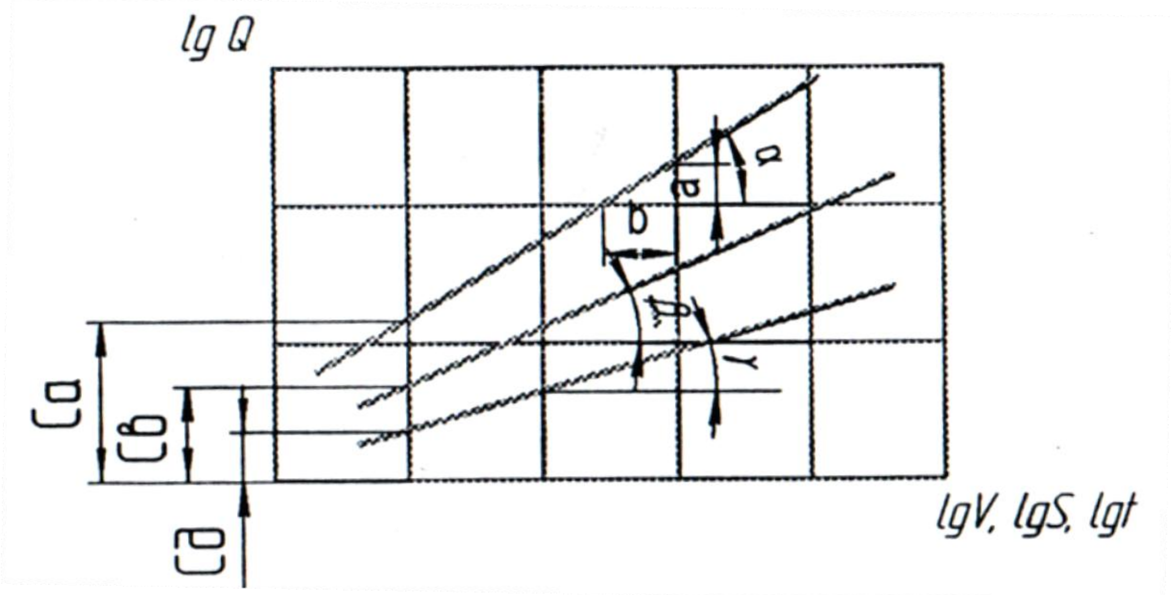
$\theta = C_B \cdot S^n$ (4), where $C_B = C_\theta \cdot V^m \cdot t^q$ (7)

$\theta = C_D \cdot t^q$ (5), where $C_D = C_\theta \cdot V^m \cdot S^n$ (8)

The determination of the parameters of these dependencies is significantly accelerated by the graph-analytical method.

Using double logarithmic coordinates allows you to get a power function in the form of a linear relationship. Moreover, the value of the exponent corresponds to the slope of the straight line and the abscissa axis, and the constant value is equal to the segment cut off by the straight line on the ordinate axis at x=1 (Fig. 3). Having constructed three graphical dependences $\theta = C_A \cdot V^m = C_B \cdot S^n = C_D \cdot t^q$ в in double logarithmic coordinates (the scale grid of which is shown in Fig. 4), having determined the exponents and constant values, we find three values of the coefficient C_θ by solving the dependences (6, 7, 8) with respect to the «common point» (the point at which the cutting temperature is determined under the same cutting conditions, but in different experiments).

The arithmetic mean value C_θ is written into the final empirical dependence of the cutting temperature on the cutting conditions for specific processing conditions of this material.



$$lg\theta = lgC_A + m \cdot lgV; \quad y = A + m \cdot x;$$

$$tg\alpha = \frac{\alpha}{b} = m; \quad tg\beta = n; \quad tg\gamma = q$$

Fig. 3. Power dependences $\theta = C_A \cdot V^m = C_B \cdot S^n = C_D \cdot t^q$ in logarithmic coordinates

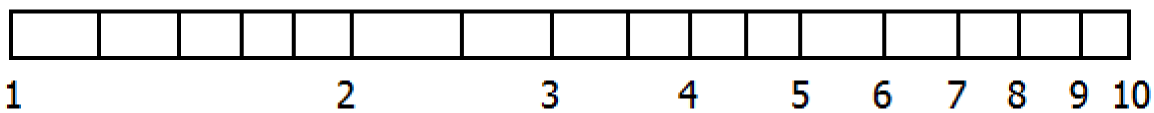


Fig. 4. Scale logarithmic grid

Experiment order	Spindle speed n, rpm	Diameter of the processed product d, mm	Cutting speed V, m/min	Feed S, mm/rev	Depth of cut t, mm	Galvanometer readings h, mV.	Cutting temperature θ, ^{0}C
$\theta=f(t)$							
$\theta=f(S)$							
$\theta=f(V)$							

Fig. 5. Summary table of experimental results