TEMPERATURE DISTRIBUTION WITHIN A MOVING STRIP HEAT SOURCE

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The temperature within a strip heat source moving at different speeds has been investigated. The results of the experiments are compared with the results of the theoretical analyses of other authors.

Various engineering problems involving the calculation of thermal stresses reduce to finding temperature fields and temperature gradients that cannot be determined without a knowledge of the temperature variation within a moving strip heat source, for example, in metal grinding.

Because of their simplifications, existing theoretical methods do not make it possible to determine the temperature variation along the contact arc. Thus, most such methods are based on the assumption that the density of the heat flux entering the ground part is constant along the length of the contact arc. However, an analysis of the grinding process shows that at any point on the ground part different thermal conditions exist during contact with the grinding wheel. For example, in countergrinding the cold grains of the grinding wheel enter into contact with the heated layer of the part. At the rear edge of the source the abrasive grains, having been heated to the maximum temperature, come into contact with the cold region of the part. Consequently, the heat flux density cannot be constant along the contact arc and depends on the contact time.

One of the principal methods of theoretical investigation of contact temperatures is the method of sources [1–3].

All the formulas for calculating temperatures obtained by the method of sources are based on Kelvin's equation [1]

$$\theta_{(x,y,z,t)} = \frac{q}{\lambda \sqrt{a}\,(4\pi t)^{3/2}} \exp \frac{(x_s - x)^2 + (y_s - y)^2 + (z_s - z)^2}{4at},$$

which describes the process of heat propagation after the heat source has ceased to act, i.e., the cooling process. When the temperature field created in an infinite body by a continuously acting source is described, its action is represented as a rapid pulsation with very short intervals between successive pulses. Thus, the process of heat propagation in the presence of a constantly acting source is described by superimposing (summing) the temperature fields created by an infinitely large number of successive heat pulses.

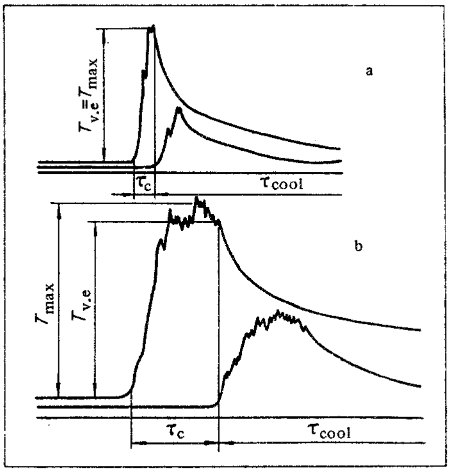
This, however, violates one of the conditions of validity of Kelvin's equation, namely, that all points on the body must be at the same temperature before the process begins. At the same time, in solving the problem by the superposition method, a situation is created in which each successive source acts on a body nonuniformly heated by the preceding pulse. No one has determined the extent to which this distorts the true picture of the temperature field.

The curves for the variation of temperature along the contact are obtained by Silin [2] from formulas derived using the method of sources have not been experimentally verified.

In [4], the variation of heat flux density along the contact arc was experimentally determined for the case of grinding when the part is not displaced relative to the contact zone and the resulting field is quasi-stationary. The applicability of the solutions obtained to the temperature field created by a moving strip source was not determined by the authors.

We have experimentally studied the variation of temperature along the contact arc in grinding, when the surface points of the grinding wheel and the part are displaced relative to the contact zone and a nonstationary temperature field is created in the part.

For this purpose, we introduced between the two halves of the specimen two thermocouples, one of which served for investigating the contact temperature, while the other acted as a thermocouple-time marker.



Oscillograms showing the variation of contact temperature along the contact arc in the grinding of ZhS-6k alloy: a) velocity of part 0.2 m/sec, grinding depth 0.01 mm; b) 0.05 m/sec and 0.01 mm.

The distance between the thermoelectrodes was equal to the length of the contact arc. Consequently, the moment the working thermocouple left the zone of action of the heat source the thermocouple-time marker entered it and began supplying current to the oscillograph loop.

This arrangement made it possible to establish the moment at which the working thermocouple left the contact zone and to determine the dwell time of its hot junction in that zone.

The oscillograms obtained are presented in the figure. An analysis of these oscillograms indicates that the nature of the temperature distribution along the contact arc depends on the velocity of the source. The maximum on the temperature curve lies within the source. At a velocity $v_g \geq 0.1$ m/sec, for the grinding conditions investigated, this maximum is located at the rear edge.

Increasing the velocity of the source at constant contact arc length leads to a decrease in contact temperature. As the velocity decreases, the contact temperature increases and its maximum is displaced from the rear edge of the source toward the front edge, without, however, passing the center of the contact arc. The lower the velocity of the source, the nearer the temperature maximum moves to the center and the lower the temperature at the rear edge of the source. In the case of a stationary heat source (notch grinding), the maximum on the temperature curve is located in the middle of the contact arc, as shown in [4].

The fall in temperature before the point leaves the contact zone (within the source) can be attributed to an increase in the cooling action of the grinding wheel and also to the fact that at the rear edge the abrasive grains cut heated metal, which produces lower heat fluxes and reduces the contact temperature.

The conclusion of [4] concerning a normal distribution of heat flux density along the contact arc is valid only for a stationary heat source.

The results of these experiments confirm the theoretical analysis of Silin [2].

NOTATION

$\theta_{(x,y,z,t)}$ —temperature of some point of a body with coordinates x, y, z, which develops t sec after the point heat pulse;

q—quantity of heat released by the source;

λ and a —thermophysical characteristics.

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