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Lishchenko N., Larshin V. (2020) **Temperature Field Analysis in Grinding.** In: Ivanov V. et al. (eds) Advances in Design, Simulation and Manufacturing II. DSMIE 2019. Lecture Notes in Mechanical Engineering. Springer, Cham: 199-208.
https://doi.org/10.1007/978-3-030-22365-6_20
https://link.springer.com/chapter/10.1007%2F978-3-030-22365-6_20

Abstract

The paper is devoted to solving an important scientific problem of determining the profile grinding temperature based on the choice of a not complex but at the same time adequate solution from the available analytical ones. The initial prerequisite for the paper developing concept is that of a moving heat source. In engineering applications, the moving heat source is often represented in the form of a moving contact zone between the grinding wheel and the workpiece surface. The source forms around itself a three-, two- or one-dimensional temperature field in the Cartesian coordinate system with (three-dimensional) and without (two- or one-dimensional) taking into account the influence of the source length in the direction, which is perpendicular to the direction of the source moving, respectively. There is another possibility to simplify the determination of grinding temperature by choosing a one-dimensional solution of the differential equation of heat conduction in which the moving heat source is absent and replaced by the time of action of an unmoving heat source. This time is equal to the ratio of the contact length (in the direction of moving) to the velocity of its movement. Due to the high speeds of the discontinuous profile grinding process, the replacement of the moving source with the unmoving (stationary) one often does not affect the accuracy of determining the profile grinding temperature on the surface and in a thin surface layer.

Keywords

Grinding wheel Grinding temperature Moving heat source

The proposed research methodology [27] is based on the use of related scientific categories of modeling, optimization and control to create appropriate technological preconditions and subsystems for the designing, monitoring and diagnosing of the grinding operation similar to how it was done previously for the drilling operation [28].

The determination of temperature on the basis of moving strip source mathematical model with the restriction of this source along the y axis (Fig. 1, a) is a complex task of mathematical thermophysics. The solution of this problem for the determination of the temperature at a constant density of the heat flux on the surface in the contact zone has the following form obtained on the appropriate decision of H.S. Carslaw and J.C. Jaeger [25] when the initial temperature of the part to be grinded is equal to zero.

where q is the density of the heat flux, W / m^2; a, λ are coefficients of temperature in m^2/s and thermal conductivity in W/(m·°C); V is velocity of the source in the direction of the z axis (see Fig. 1), m/s; X, Y, Z are dimensionless or relative coordinates, which correspond to dimensional coordinates x, y, z; H, L are dimensionless half-width (Peclet number) and dimensionless half-length of the source of heat, which correspond to the same dimensional parameters h and l.

Here is indicated: $\xi = \frac{V(z-z')}{2a}$; $X = \frac{V \cdot x}{2a}$; $Y = \frac{V \cdot y}{2a}$; $Z = \frac{V \cdot z}{2a}$; $L = \frac{V \cdot l}{2a}$; $H = \frac{V \cdot h}{2a}$. Besides: $-h < z < h$, $-l < y < l$ (Fig. 1). In formula (1) the following notation for the Gauss error function is used: $\operatorname{erf}(s) = \frac{2}{\sqrt{\pi}} \int_0^s \exp\left(-\xi^2\right) d\xi$.

The purpose of the paper is to investigate the continuity of the solutions of three-, two- and one-dimensional differential heat equations to establish the criteria for continuity and the ranges of their changes for the grinding conditions. The solution (1) with a rectangular source (Fig. 1, *a*) is investigated here by comparing it with the solution for a two-dimensional temperature field from a moving strip source (Fig. 1, *b*), which is infinite in the direction of the axis $0y$ ($-\infty < y < \infty$) and having the form in the adopted notation

where $K_0(s)$ stands for the zeroth order modified Bessel function of the second kind.

The corresponding one-dimensional solution for an unmoving half-space medium heat source on the heating time interval $\tau_0 = 4aH_0/V^2$ has the following form obtained under the previous notations.

When X = 0 from equation (3) we get the maximum temperature on the surface to be grinded.

To obtain the dimensional temperature for the cases considered the equations (1) - (5) must be multiplied by a factor $\frac{2qa}{\pi\lambda V}$. As an example, let's calculate the temperature on the surface by the equation (1) multiplied by $2qa/\pi\lambda V$ with the following output data: q = 22.7 · 10^6 W/m^2; a = 5.683 · 10^{-6} m^2 / s; λ = 24 W/(m·° C); V = 0.2 m / s (12 m / min); z = 0; h = 2.72 · 10^{-2} m ($h = \sqrt{Dt_v}/2$; D is diameter of the grinding wheel, D = 0.4 m; t_v is vertical grinding depth, t_v = 0.074 · 10^{-3} m); l = 3.469 ·10^{-3} m; $-5H \le Z \le 5H$; X = 0 (on the surface); H = 47.869; L = 17.597. The coordinates along the y axis are the following: y = 0, i.e. Y = 0; $y = l/2$, i.e. Y = 8.799; $y = 3l/4$, i.e. Y = 13.198; $y = 7l/8$, i.e. Y = 15.397; $y = l$, i.e. Y = 17,597. The maximum temperatures are located about at the rear edge of the source at the point $Z = -0,95H$.

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