Pergamon

Int. J. Heat Mass Transfer. Vol. 38, No. 13, pp. 2395–2401, 1995

0017–9310/95 $9.50+0.00

0017–9310(94)00361–0

The transitive temperature processes in local friction contact

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(*Received* 23 *February* 1994 *and in final form* 28 *November* 1994)

Abstract—The nonstationary temperatures on the peaks of asperity of contacting rough surfaces have been determined for the sliding contact. Assuming that there exists circular source of heat on the surface of semi-limited body modelled by a half-space and a layer of finite thickness, the influence of the boundary conditions on the temperature distribution resulting from friction is investigated.

1. INTRODUCTION

The processes of physical–chemical mechanics related to the creation and the fracture of axidized films, structural transformations and the wear of the surface of friction take place in the frictional contact [1]. The intensity of these processes to a considerable extent is defined by the temperature in the frictional contact zone. As real surfaces are always rough, the load between them is transferred by the tops of asperities in contact which create a factual contact area. The friction heat is generated on these small areas, and the temperature on a single spot of contact is called the flash temperature [2]. The quantity of factual spots of contact depends on both the load and the surface roughness [3]. To compute the temperature conditions of contact surfaces a model is suggested in refs. [4, 5] which provides the presence of heat sources on the boundary plane. The heat sources are conditioned by a probable process of interaction of separate asperities of contiguous bodies. The contact asperities are modelled by spherical segments, and a single area has a form of a circle. The realization of such a method conforming to the stationary and quasi-stationary thermal contact has been carried out. A non-stationary solution for a single immovable source on the thermo-insulated surface of a half-space is given in the monograph [6]. It is shown that the maximum value of the temperature, when there is such heating, is inversely proportional to the magnitude of the conductivity coefficient, and the velocity of the achievement of this maximum is higher the larger the thermal diffusivity coefficient. These conclusions are corroborated by experimental data of the work [7]. The values of the time of duration of local heating transitional processes from 0.1 to 1 ms measured in [7] conform to the estimations based on the real diapasons of contact spots size.

The analysis of the kinematics of the processes of heat generation in the contact area [8] shows that all the periods of the hot spots' existence in dependence on their size may be changed from milliseconds to some seconds. When the load P and the velocity of sliding V grow, the intensity of the wear of contacting bodies increases and a faster change of the contact points coordinates occurs. This leads to a decrease in the time of the hot spots' existence. Such small duration of the contact hot spots' existence means that the local values of the temperature fall as well as grow.

2. STATEMENT OF PROBLEMS

Now consider the sliding of a single asperity of circular plan form placed on the surface of a heat conductivity body about the other, smooth surface. The subject of the investigation of this work will be two types of the base: a semi-limited body modelled by a half-space and a layer of a finite thickness l. Owing to friction a heat generation occurs in the contact area. It creates a heat flow for the warming-up of the asperity [9]

$$Q(r) = \gamma f V p(r) \quad 0 \leqslant r \leqslant R \tag{1}$$

where $p(r)$ is the contact pressure in the contact region $0 \leqslant r \leqslant R$ [10]

NOMENCLATURE

a	thermal diffusivity	r	radial coordinate
Bi	Biot number $(\alpha \cdot R/\lambda)$	R	radius of contact area
$\mathrm{erf}\,\zeta$	probability integral	t	temperature
$\mathrm{erfc}\,\zeta$	additional probability integral $(1-\mathrm{erf}\,\zeta)$	T	dimensionless temperature (t/Q_0)
Fo	Fourier number $(a\tau/R^2)$	V	velocity sliding
f	friction coefficient	z	axial coordinate
H	α/λ	Z	dimensionless axial coordinate (z/R)
$J_0(\cdot)$	Bessel function of the first kind null order	Z_1	z/l.
l	layer thickness		Greek symbols
L	l/R	α	coefficient of heat exchange
p_0	$3P/(2\pi R^2)$	γ	fraction of total frictional heat input to the stationary body
P	load	λ	thermal conductivity
q_0	fVp_0	τ	time
Q_0	$\gamma\, q_0\, R/\lambda$	ρ	dimensionless radial coordinate (r/R).

$$p(r) = p_0\sqrt{\left[1-\left(\frac{r}{R}\right)^2\right]}. \tag{2}$$

The temperature field of the examined system is described by a conductivity equation

$$\frac{\partial^2 t}{\partial Z^2}+\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial t}{\partial r}\right)=\frac{1}{a}\cdot\frac{\partial t}{\partial \tau}$$
$$r \geqslant 0 \quad z>0 \quad \tau>0 \tag{3}$$

at initial

$$t|_{\tau=0}=0 \tag{4}$$

and boundary conditions (using (1) and (2)):

a half-space

$$\lambda\frac{\partial t}{\partial Z}\bigg|_{Z=0} = -Q(r)U_-(R-r)U_+(\tau) \quad t|_{r^2+z^2\to\infty}=0 \tag{5}$$

a layer

$$\lambda\frac{\partial t}{\partial z}\bigg|_{z=0} = -Q(r)U_-(R-r)U_+(\tau) \quad \lambda\frac{\partial t}{\partial z_0}\bigg|_{z=l}=0. \tag{6}$$

Here $U_\pm(\xi)$ are asymmetrical single functions [11]:

$$U_\pm(\xi)=\begin{cases}1 & \xi>0\\ 0.5\mp 0.5 & \xi=0\\ 0 & \xi<0.\end{cases} \tag{7}$$

3. NON-STATIONARY SOLUTION FOR A BODY WITH AN INSULATED BOUNDARY

The solution to a boundary-value problem determined by equations (3)–(5) which has been obtained in [12] by using the Hankel integral transform with respect to radial coordinate and Laplace's with respect to time has the form

$$t(\rho,Z,\tau) = Q_0\int_0^\infty \varphi(\xi)\Phi(\xi,Z,Fo)\,J_0(\xi\rho)\,\mathrm{d}\xi \tag{8}$$

where

$$\varphi(\xi)=\frac{1}{\xi^2}\left(\frac{\sin\xi}{\xi}-\cos\xi\right)$$

$$\Phi(\xi,Z,Fo)=0.5\left[\mathrm{e}^{-\xi Z}\,\mathrm{erfc}\left(\frac{Z}{2\sqrt{Fo}}-\xi\sqrt{Fo}\right)-\mathrm{e}^{\xi Z}\,\mathrm{erfc}\left(\frac{Z}{2\sqrt{Fo}}+\xi\sqrt{Fo}\right)\right].$$

Equation (8) determines the temperature for every point of the half-space during the transitional processes. On the steady state ($\tau\to\infty$, $Fo\to\infty$) we have

$$t(\rho,Z)=Q_0\int_0^\infty\varphi(\xi)\,\mathrm{e}^{-\xi Z}J_0(\xi\rho)\,\mathrm{d}\xi. \tag{9}$$

The maximum value of the temperature is reached at a point $\rho=0$ on the surface $Z=0$ and is

$$t_{\max}=Q_0\frac{\pi}{4}. \tag{10}$$

We will find the solution to a stationary conductivity equation (in the differential equation (3) we neglect the right-hand side (RHS)) under a mixed boundary condition

$$\frac{\partial t}{\partial Z}\bigg|_{Z=0} = -Q_0\sqrt{(1-\rho^2)}U_-(1-\rho)+Bi\cdot t\cdot U_+(\rho-1). \tag{11}$$

Applying Hankel integral transforms of zero order with respect to ρ to equation (3) and boundary condition (11) gives

$$t(\rho, Z) = \int_0^\infty \frac{\xi e^{-\xi Z} J_0(\xi\rho)}{\xi + Bi} \int_0^1 \rho_0 J_0(\xi\rho_0) \times [Q_0\sqrt{(1-\rho^2)} + Bi \cdot t(\rho_0, 0)]\, d\rho_0\, d\xi. \quad (12)$$

Supposing $Bi \ll 1$, we have instead of equation (12)

$$t(\rho, Z) \cong Q_0 \int_0^\infty \varphi(\xi)\, e^{-\xi Z} \frac{\xi \cdot J_0(\xi\rho)}{\xi + Bi} d\xi. \quad (13)$$

Going on to the limit $\rho \to 0$, $Bi \to 0$ in the RHS of equation (13), we find

$$t(0, Z) \cong Q_0 \int_0^\infty \varphi(\xi)\, e^{-\xi Z} d\xi. \quad (14)$$

Using the value of integral 6.621.1 [13], we obtain from equation (14)

$$t(0, Z) \cong \frac{Q_0}{2}\sqrt{(1+Z^2)}\left[\sqrt{(1+Z^2)} \times \arccos\left(\frac{Z}{\sqrt{(1+Z^2)}}\right)\frac{Z}{\sqrt{(1+Z^2)}}\right]. \quad (15)$$

Putting $\rho \to 0$, $Bi \to 0$, from equation (13) we find the following expression for the temperature of the boundary surface $Z = 0$

$$t(\rho, 0) \cong Q_0 \int_0^\infty \varphi(\xi) J_0(\xi\rho)\, d\xi. \quad (16)$$

The integral of Veber–Shafheitlin type in the RHS of equation (16) will be represented by the hypergeometrical function ${}_2F_1$ [14]

$$t(\rho, 0) \cong \begin{cases} \dfrac{Q_0\pi}{4}\, {}_2F_1\left(\frac{1}{2}, -1; 1; \rho^2\right) & 0 \leqslant \rho \leqslant 1 \\ \dfrac{Q_0}{3\rho}\, {}_2F_1\left(\frac{1}{2}, \frac{1}{2}; \frac{5}{2}; \dfrac{1}{\rho^2}\right) & \rho > 1. \end{cases} \quad (17)$$

Expressed in dimensionless variables the solution to a corresponding boundary-value problem from equations (3), (4) and (6) can be written by using the Laplace's integral transforms with respect to time τ and Hankel's ones with respect to radial coordinate ρ

$$t(\rho, Z_1, Fo) = Q_0 L \int_0^\infty \zeta^2 \varphi(\zeta) F(\zeta, Z_1, Fo) J_0(\zeta\rho)\, d\zeta \quad (18)$$

where

$$F(\zeta, Z_1, Fo) = \sum_{k=0}^{\infty} (2-\delta_{k0})\beta_k^{-1} \cos(\pi k Z_1)(1 - e^{-\beta_k Fo})$$

$$\beta_k = \pi^2 k^2 + \zeta^2 L^2$$

$$\delta_{k0} = \begin{cases} 1, k = 0 \\ 0, k \neq 0 \end{cases} \text{ is Kroneker symbol.}$$

From equation (18) we obtain for a steady state ($Fo \to \infty$)

$$t(\rho, Z_1) = Q_0 L \int_0^\infty \zeta^2 \varphi(\zeta) J_0(\zeta\rho) \times \sum_{k=0}^{\infty} (2-\delta_{k0})\beta_k^{-1} \cos(\pi k Z_1)\, d\zeta. \quad (19)$$

4. CONVECTIVE COOLING OF ASPERITY AFTER EXIT OUT OF THE CONTACT

We estimate the duration of cooling process after the exit of a single asperity of a rough surface out of the contact. The time of the cooling is defined by an instant of a new contact rise as a result of the asperity pairs' collision over the limits of nominal contact area. As an initial condition of the considered process of heat conductivity it is naturally to take the stationary temperature distribution found above equation (9) in the case half-space and equation (19) for the layer. Therefore, the problem comes to a construction of the solution to conductivity equation (3) with a boundary

$$\left.\frac{\partial t}{\partial Z}\right|_{Z=0} = Bi t \quad \rho \geqslant 0 \quad \rho > 0 \quad (20)$$

and initial condition:

the half-space

$$t(\rho, Z, 0) = Q_0 \int_0^\infty \varphi(\xi)\, e^{-\xi Z} J_0(\xi\rho)\, d\xi \quad \rho \geqslant 0 \quad Z \geqslant 0 \quad (21)$$

the layer

$$t(\rho, Z_1, 0) = Q_0 L \int_0^\infty \zeta^2 \varphi(\zeta) J_0(\zeta\rho) \times \sum_{k=0}^{\infty} (2-\delta_{k0})\beta_k^{-1} \cos(\pi k Z_1)\, d\zeta. \quad (22)$$

Applying Hankel integral transform of zero order with respect to ρ and Fourier modified transform with respect to Z [15] in consecutive order

$$\bar{t}(\xi, Z, \tau) = \int_0^\infty \rho t(\rho, Z, \tau) J_0(\xi\rho)\, d\rho$$

$$\bar{\bar{t}}(\xi, \beta, \tau) = \int_0^\infty (\beta \cos \beta Z + Bi \sin \beta Z)\, \bar{t}(\xi, Z, \tau)\, dZ$$

we obtain the solution to the boundary-value problem equations (3), (20) and (21) in the following form

$$t(\rho, Z, \tau) = \frac{2}{\pi} Q_0 \int_0^\infty \int_0^\infty \varphi(\xi) \Psi(\xi, \beta, Z, Bi)$$

$$\times \mathrm{e}^{-(\xi^2+\beta^2)Fo}\xi \cdot J_0(\xi\rho)\,\mathrm{d}\beta\,\mathrm{d}\xi \quad (23)$$

where

$$\Psi(\xi,\beta,Z,Bi) = \frac{\beta(\xi+Bi)(\beta\cdot\cos\beta Z+Bi\cdot\sin\beta Z)}{\xi(\xi^2+Bi^2)(\beta^2+Bi^2)}.$$

At $\rho = 0$, $Z = 0$ equation (23) will be slightly simplified

$$t(0,0,\tau) = Q_0\int_0^\infty \frac{\varphi(\xi)}{\xi - Bi}[\xi\,\mathrm{erfc}\,(\xi\sqrt{Fo}) - Bi\cdot \mathrm{e}^{Fo(Bi^2-\xi^2)}\,\mathrm{erfc}\,(Bi\sqrt{Fo})]\,\mathrm{d}\xi. \quad (24)$$

Equation (24) gives the cooling temperature at the centre of the hot spot in dependence on Fourier criterion after removing the frictional source. It is not difficult to make sure that at $Fo \to 0$ from equation (24), equation (9) follows, and at $Fo \to \infty$ we obtain $t \to 0$ (the approach to steady state).

Finding the solution to the conductivity problem for a layer, we use Hankel integral transform of zero order with respect to r and the transforms with respect to z

$$\bar{t}(\xi,\beta_m,\tau) = \int_0^\infty\int_0^l t(r,z,\tau)K(\beta_m,z)rJ_0(\xi r)\,\mathrm{d}z\,\mathrm{d}r$$

where the kernel $K(\beta_m, z)$ and β_m are defined according to the formulae

$$K(\beta_m,z) = A_c\cos\beta_m z + A_s\sin\beta_m z$$

$$\beta_m\sin\beta_m l - H\cos\beta_m l = 0.$$

Here

$$A_c = \frac{\beta_m\sqrt{2}}{\sqrt{(l(\beta_m^2+H^2)+H)}}\, A_s = \frac{H\sqrt{2}}{\sqrt{(l(\beta_m^2+H^2)+H)}}.$$

The solution to the boundary-value problem equations (3), (20) and (22) is given by

$$t(r,z,\tau) = Q_0\sum_{m=1}^\infty K(\beta_m,z) \times\int_0^\infty \xi G(\xi,\beta_m)\,\mathrm{e}^{-a(\xi^2+\beta_m^2)\tau}J_0(\xi r)\,\mathrm{d}\xi \quad (25)$$

where

$$G(\xi,\beta_m) = g(\xi)[(\xi l)^{-2}\int_0^l K(\beta_m,z)\,\mathrm{d}z + \sum_{k=1}^\infty 2\beta_k^{-1}\int_0^l K(\beta_m,z)\cos(\pi k Z)\,\mathrm{d}z\Bigg]$$

$$g(\xi) = \frac{\sin\xi R}{\xi^2} - \cos\xi R.$$

Putting $z = 0$ in equation (25) we obtain

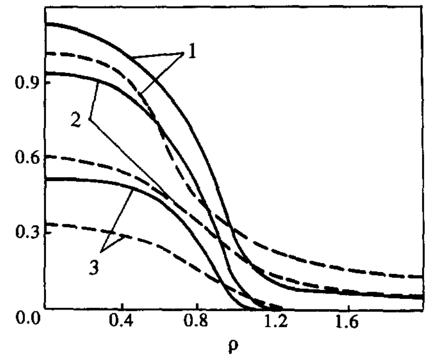

Fig. 1. Transient distribution of dimensionless non-stationary temperature of surface $Z = 0$ along radius: 1, $Fo = 10$; 2, $Fo = 1$; 3, $Fo = 0.1$.

$$t(\rho,0,Fo) = Q_0\sum_{m=1}^\infty\sum_{k=1}^\infty C_k(\alpha_m)I_2^{(k)}(\rho,Fo) + I_1(\rho,Fo)\sum_{m=1}^\infty B(\alpha_m)\,\mathrm{e}^{-\alpha_m^2 Fo} \quad (26)$$

where

$$B(\alpha_m) = \frac{2\sin^2\alpha_m}{\sin^2\alpha_m + Bi}C_k(\alpha_m) = -B(\alpha_m)\,\mathrm{e}^{-\alpha_m^2 Fo}(\pi^2k^2-\alpha_m^2)^{-1}$$

$$I_1(\rho,Fo) = L^{-1}\int_0^\infty \zeta^{-2}\varphi(\zeta)\,\mathrm{e}^{-\zeta^2 Fo}J_0(\zeta\rho)\,\mathrm{d}\zeta$$

$$I_2^{(k)}(\rho,Fo) = 2L\int_0^\infty \varphi(\zeta)\,\mathrm{e}^{-\zeta^2 Fo}\beta_k^{-1}J_0(\zeta\rho)\,\mathrm{d}\zeta$$

where α_m are the roots of the transcendental equation

$$\alpha_m\sin\alpha_m - Bi\cos\alpha_m = 0.$$

In the analysis of heat processes the integrals are determined numerically.

5. NUMERICAL ANALYSIS OF THE RESULTS

The integrals in the RHS of equations (8), (9), (12)–(14), (18), (19) and (24) were estimated numerically by procedures QAGS and QAWS of the QUADPACK package [19]. The graphs represented in Figs. 1–8 show the behaviour of dimensionless temperature $T = t/Q_0$ in dependence on dimensionless values of spatial coordinates and time (continuous lines correspond to the case of a layer and broken lines correspond to the half-space).

In Fig. 1 one can see the non-stationary distribution of dimensionless surface temperature T calculated by equations (7) and (16) along the radius ρ at different values of Fourier criterion Fo. Equations (8) and (18) are the solutions to the conductivity problems (3)–(6) for a body with an insulated boundary. Therefore we shall judge that the stationary state near a hot spot of the contact is shown by a small rise in temperature

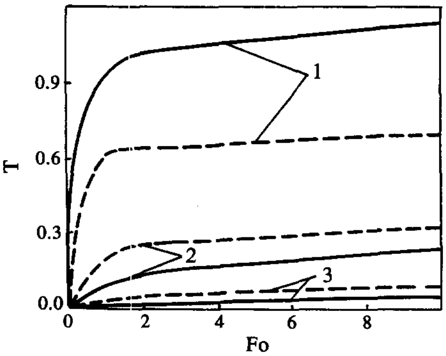

Fig. 2. Dependence of dimensionless non-stationary temperature of surface $Z = 0$ from criterion Fourier: 1, $\rho = 0$; 2, $\rho = 1$; 3, $\rho = 2$.

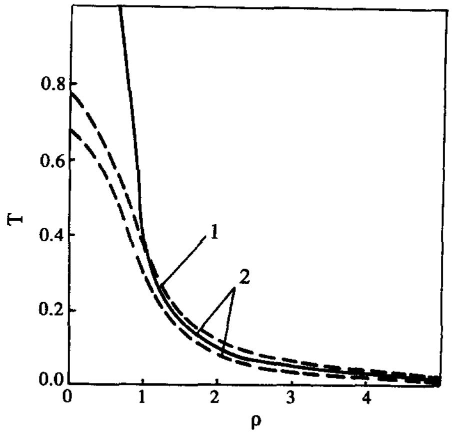

Fig. 3. Distribution of dimensionless steady temperature of surface $Z = 0$ along radius: 1, $Bi = 0$; 2, $Bi = 0.1$.

growth when the heating time increases by an order of magnitude. It is clear that near the hot spot a sharp temperature gradient (at $Fo \cong 1$) is set in a short interval of time while in the region $\rho > 3$ the temperature field is at the zero level. As the temperature reaches a steady state near the heating region, the large temperature gradients remain, though their levels fall during the time. So, for example, for the half-space at $Fo = 0.1, 1, 10, 50$ values of the relation $T(0, 0, Fo)/T(2, 0, Fo)$ are 2759.6, 18.6, 6.4, 5.7, respectively; at $Fo = 2$ the temperature at the centre of the contact spot is 83.4% and at the point $\rho = 3$ is only 19.3% of the stationary value. At the points which are the nearest to the centre of the hot spot the transitional process is not so long. We note that in the heating region ($\rho \leqslant 1$) for the fixed values of time the surface temperature of the layer is higher than in the half-space. If $\rho > 1$ an inverse picture is observed.

Mentioned properties of the transitional processes in frictional heating of the roughness are confirmed by the data represented in Fig. 2. The dependence of the non-stationary surface temperature at the points $\rho = 0, 1, 2$ and 5 on the magnitude of Fourier criterion is represented here. The value $Fo = 50$ almost exactly corresponds to the steady state in the vicinity of the asperity. The results of the experimental investigations [8] show that the mean size of hot spots is in the interval 17–21 mkm. The majority of metals have $a \simeq 10^{-5}$ m^2 s^{-1}, thus the characteristic times of the transitional process will be 1.4 and 2.2 ms, respectively.

The distribution of the dimensionless steady surface temperature T (13) and (19) ($L = 1$) of a micro-asperity along the radius at two values of the number Bi is shown in Fig. 3. At $Bi \to 0$ the temperature coincides with the stationary distribution obtained by (8) at $Fo = 50$ (Fig. 1). The number Bi which contains a multiplier R according to the takes small (about 0.1) values. The comparison of stationary temperatures in Fig. 3 at $Bi = 0$ and $Bi = 0.1$ shows that convective heat transfer is not an essential factor.

The distribution of the steady temperature T (13) for some values of the number Bi along the axis $\rho = 0$ is plotted in Fig. 4 Near the surface $Z = 0$ at $Bi = 0$ the temperature gradient $\mathrm{d}T/\mathrm{d}Z$ reaches its maximum value which is $-\pi/4$ as it needs to be in accordance with the formula (15).

The maximum value of the dimensionless temperature $T_{\max}$ in the half-space is $\pi/4$ at $\rho = 0$, $Z = 0$, $Bi \to 0$, $Fo \to \infty$. This follows from equations (10), (15) and (17). Thus, $t_{\max} = \pi \gamma q_0 R/4\lambda$ and, consequently, at a constant power of heat generation $q_0 = fVp_0$ and increase of the hot spot radius the maximum temperature grows. The localized temperature rise occurs over the limits $0 \leqslant \rho \leqslant 3$, $Z = 0$ and lasts, as it is noted above $\simeq 2.2$ ms.

In Fig. 5 one can see the graphs of dependence of the dimensionless temperature $T(0, 0, Fo)$ calculated by equations (24) and (26) on the magnitude of Fourier criterion in the transitional process of purely convective cooling for three different values of the number Bi. It is evident that the temperature falls rapidly and it does not almost depend of the number Bi, i.e. in cooling heat pipe-bend by heat conductivity into a semi-infinite body plays a principal part and not the convective exchange with the surroundings. Thus, in the case of the half-space at $Fo = 1$ the temperature is only $\cong 23\%$ of its initial value which is $\pi/4$. The state

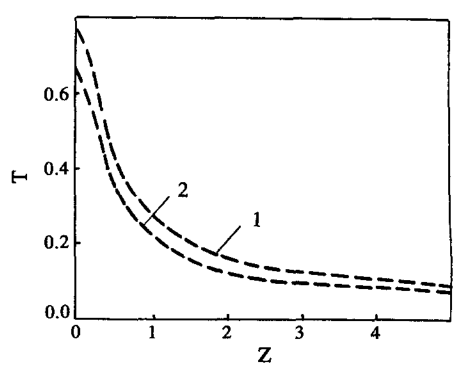

Fig. 4. Distribution of dimensionless steady temperature along axis $\rho = 0$: 1, $Bi = 0$; 2, $Bi = 0.1$.

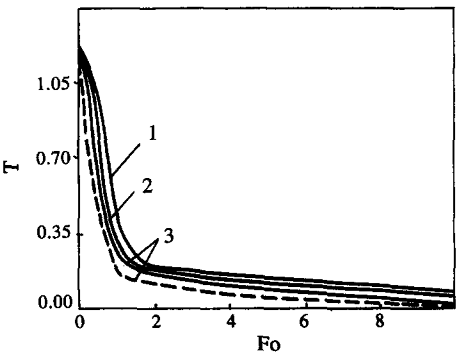

Fig. 5. Dependence of dimensionless temperature at $\rho = 0$ of surface $Z = 0$ from criterion Fourier by transitive process of pure convectivity cooling: 1, $Bi = 0.001$; 2, $Bi = 0.01$; 3, $Bi = 0.1$.

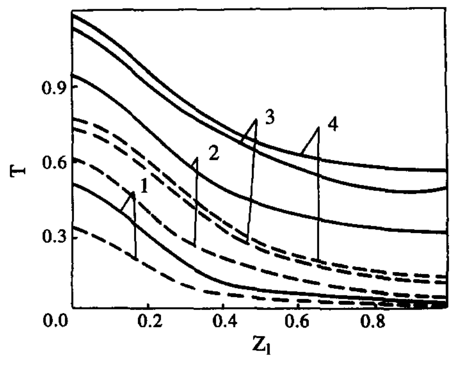

Fig. 7. Distribution of dimensionless non-stationary temperature along axis $\rho = 0$ at $L = 1$: 1, $Fo = 0.1$; 2, $Fo = 1$; 3, $Fo = 10$; 4, $Fo = 50$.

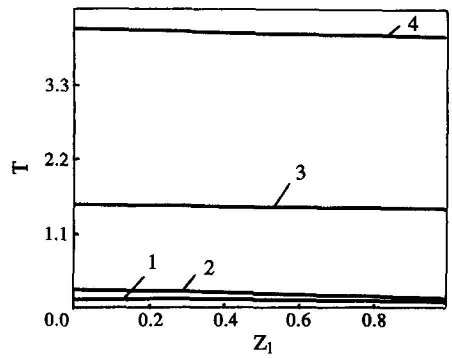

Fig. 6. Distribution of dimensionless non-stationary temperature along axis $\rho = 0$ at $L = 0.1$: 1, $Fo = 0.1$; 2, $Fo = 1$; 3, $Fo = 10$; 4, $Fo = 50$.

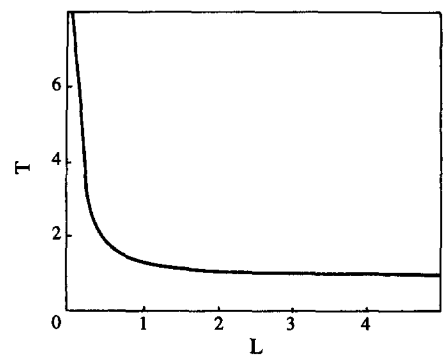

Fig. 8. Distribution of dimensionless stationary temperature of surface $Z_l = 0$ in point $\rho = 0$ from parameter L.

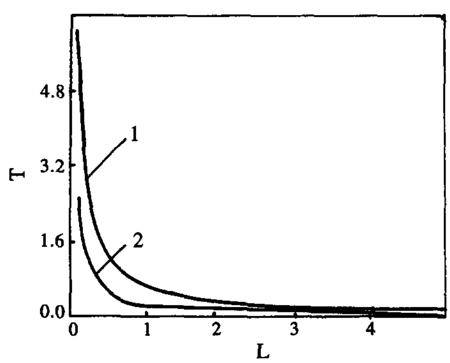

Fig. 9. Dependence of dimensionless temperature of surface $Z_l = 0$ in point $\rho = 0$ from parameter L by transitive process of pure convectivity cooling: 1, $Fo = 0.1$; 2, $Fo = 1$.

will be considered steady when the value of the temperature is only 10% of its initial value. For the half-space it is reached at $Fo = 5$ while for the layer at $L = 1$ the steady state will be reached at $Fo = 3$. For the conditions shown above, that is at $a \simeq 10^{-5}$ m^2 s^{-1} and $R = 17$ or 21 mkm, the stationary state is reached by way of 0.14 and 0.22 ms (half-spaces) and 0.084, 0.132 ms (layer), respectively. This temporal interval is an order smaller than those which were obtained in analysis of the transitional processes of the initial heating of the microasperity.

The graphs represented in Figs. 6 and 7 show the change of the non-stationary temperature (18) ($L = 1$) at the centre of the heating spot along the depth. Moving off the boundary the temperature in the layer decreases, while the character of behaviour and the velocity of its change connects from the parameter L. It is distinctly evident that at $L < 1$ the temperature field along an axial coordinate changes according to the linear law.

The graphs represented in Figs. 8–10 illustrate the dependence of a layer temperature at the centre of the contact spot ($\rho = 0$; $Z_l = 0$) from the parameter L. Figure 8 defines thin dependence for the steady temperature equation (19), Fig. 9 defines the temperature in convective cooling equation (26) and Fig. 10 defines the non-stationary temperature equation (18).

It follows from the graphs in Figs. 8 and 9, that with the increase L, the temperature monotonously decreases. Another characteristic behaviour is the non-stationary temperature. In increasing of the criterion Fo its local extremum relative to the parameter L is reached at points near the zero value. Thus L represents a parameter by selection of which it is possible to reach that at given moment of frictional process the temperature on the contact surface of the friction

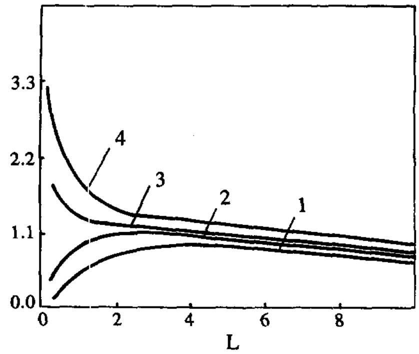

Fig. 10. Distribution of dimensionless non-stationary temperature of surface $Z_1 = 0$ in point $\rho = 0$ from parameter L: 1, $Fo = 0.1$; 2, $Fo = 1$; 3, $Fo = 10$; 4, $Fo = 50$.

couples will not exceed the level at which the destruction begins.

6. CONCLUSIONS

It has been shown that the influence of local heating of the contact spot is localized over the limits $\rho = 5$ and essential temperature rise occurs at $\rho \leqslant 3$.

From Figs. 3 and 4, it follows that the temperature field is strongly localized and has a sharp gradient both in axis and radial directions. Therefore, the heterogeneity of the temperature field is shown in the layer whose thickness is approximately 10 R. For this reason the presence of the rooting of shown thickness from the material with low heat conductivity on the surface of the half-space will lead to the temperature increase. Therefore, the thermophysical properties of this layer will play the principal parts in the calculation of the temperature field and not the base.

It has been established that the cooling of the surface is not essential: this process does not influence strongly the level of the temperature flash or on the length of the region of local heating in radial or axis direction. Thus, in this case we may neglect the heat transfer and thereby simplify essentially the process of the solution finding.

The characteristic durations of the transitional processes in heating and cooling measured during the experiments and given in [7, 8] are approximately 0.1–0.2 mks. This is confirmed by theoretical estimates obtained in the present work.

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