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THE EFFECT OF CONVECTIVE COOLING ON THE SOLUTION TO THERMOELASTIC CONTACT PROBLEMS WITH THE FRICTION HEAT GENERATION

ALEKSANDER YEVTUSHENKO

ROMAN KULTCHYTSKY-ZHYHAILO

Department of Mechanics and Mathematics, University of Lviv, Ukraine

The effect of the convective heat exchange in the separated region during the sliding contact with frictional heat generation of two elastic bodies is studied. It is assumed that only one of the bodies is a heat conductor and the shear stresses at the interface do not affect the normal tractions. The role of heat exchange is dual. Distribution of the contact pressure and size of the contact region are the same as in the corresponding contact problem with perfect insulation of the conducting body surface. On the other hand, the contact temperature distribution depends mainly on the surface thermal conditions.

Key words: convective cooling, thermoelasticity, contact problem

1. Introduction

The contact problems of stationary thermoelasticity involving frictional heating are usually solved on the assumption that the heat flux occurs on one part of the boundary (on the contact area), while the other part is thermoinsulated (see, e.g., Barber (1976); Barber and Comninou (1989); Yevtushenko and Kultchytsky-Zhyhailo (1995)). This assumption is made to simplify the calculations. However, these boundary conditions are idealisations of the physical problem, since there will always be some amount of heat lost from the unloaded surfaces of contacting bodies. More realistic it therefore the radiation condition, defined by Gladwell and Barber (1983) for the axi-symmetric stationary thermoelastic contact of heated or cooled bodies, on to which the heat flux outside the contact area is proportional to difference between the local surface temperature and that of surrounding medium.

This paper formulates the axi-symmetric and plane static thermoelasticity problems in which the heat is generated due to friction at the interface between two semi-infinite solids. It is assumed that:

- The contact area is remains at rest relative to the solid, in which a steady flow of heat is assumed. Outside the heating region the convective cooling from the surface of the body is considered
- The other solid is a non-conductor
- The coupling between tangential and normal tractions at the interface can be neglected
- Both bodies are elastic.

The third assumption reflects the fact that the shear stress has a negligible effect on the contact pressure distribution, and hence that the mechanical boundary-value problem is the same as that in which the contact is frictionless, except for the inclusion of the appropriate heat input to the thermally conducting solid.

2. Formulation of the axi-symmetric contact problem

On these assumptions the boundary conditions can be stated as follows (see Fig.1)

— mechanical

$$\sigma_{zz}^{(1)} = \sigma_{zz}^{(2)} = -p(r) \qquad r \leq a \qquad z = 0 \tag{2.1}$$

$$\sigma_{zz}^{(1)} = \sigma_{zz}^{(2)} = 0 \qquad r > a \qquad z = 0 \tag{2.2}$$

$$\sigma_{rz}^{(1)} = \sigma_{rz}^{(2)} = 0 \qquad r \geq 0 \qquad z = 0 \tag{2.3}$$

$$u_z^{(1)} - u_z^{(2)} = d - g(r) \qquad r \leq a \qquad z = 0 \tag{2.4}$$

— thermal

$$-\kappa\frac{\partial T}{\partial z} = fvp(r) \qquad r \leq a \qquad z = 0 \tag{2.5}$$

$$\kappa\frac{\partial T}{\partial z} - hT = 0 \qquad r > a \qquad z = 0 \tag{2.6}$$

where

$\sigma_{kj}^{(i)}$	–	stresses
$u_z^{(i)}$	–	normal displacements on the surface
T	–	temperature
$g(r)$	–	known function representing the surface of the contacting solids
d	–	parameter of mutual penetration
$p(r)$	–	contact pressure
f	–	coefficient of friction
v	–	sliding speed
κ	–	conductivity
h	–	coefficient of surface heat transfer
a	–	unknown contact circle radius
r, z	–	cylindrical coordinates (the conducting solid occupies the space $z \geq 0$).

The superscripts $i = 1, 2$ denote the values which correspond to conducting and insulated bodies, respectively.

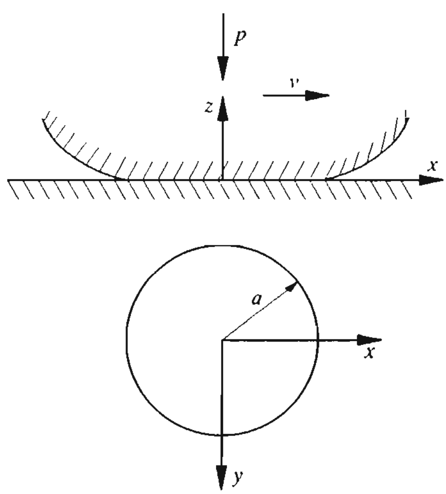

Fig. 1. The scheme of the contacting bodies in the axi-symmetrical case

The load P, applied to the solids will also be given and hence

$$2\pi \int\limits_0^a rp(r)\, dr = P \tag{2.7}$$

3. Reduction to a dual integral equations

Normal displacements and the state of stress in an elastic half-space with a steady-state temperature distribution by Generalov et al. (1976) can be expressed in terms of the Hankel transform

$$
\begin{aligned}
u_z^{(1)}(r,z) = &-\int\limits_0^\infty [-A_1(\alpha) + B_1(\alpha)(3 - 4\nu_1 + \alpha z)]\mathrm{e}^{-\alpha z} J_0(\alpha r)\, d\alpha + \\
&-\alpha_t(1+\nu_1)\int\limits_0^\infty \frac{1}{\alpha} C(\alpha)\mathrm{e}^{-\alpha z} J_0(\alpha r)\, d\alpha
\end{aligned}
\tag{3.1}
$$

$$
u_z^{(2)}(r,z) = \int\limits_0^\infty [-A_2(\alpha) + B_2(\alpha)(3 - 4\nu_2 - \alpha z)]\mathrm{e}^{\alpha z} J_0(\alpha r)\, d\alpha
\tag{3.2}
$$

$$
\sigma_{zz}^{(i)}(r,z) = 2\mu_i \int\limits_0^\infty [-A_i(\alpha) + B_i(\alpha)(2 - 2\nu_i - \eta_i \alpha z)]\mathrm{e}^{\eta_i \alpha z} J_0(\alpha r)\alpha\, d\alpha
\tag{3.3}
$$

$$
\sigma_{rz}^{(i)}(r,z) = 2\mu_i \eta_i \int\limits_0^\infty [A_i(\alpha) - B_i(\alpha)(1 - 2\nu_i - \eta_i \alpha z)]\mathrm{e}^{\eta_i \alpha z} J_0(\alpha r)\alpha\, d\alpha
\tag{3.4}
$$

$$
T(r,z) = \int\limits_0^\infty C(\alpha)\mathrm{e}^{-\alpha z} J_0(\alpha r)\, d\alpha
\tag{3.5}
$$

where $\eta_i = (-1)^i$, $i = 1,2$ and

μ_i, ν_i – shear modulus and the Poisson ratio for the materials of the two contacting bodies, respectively

α_t – coefficient of thermal expansion of the conducting solid

$J_m(\cdot)$ – Bessel functions of the first kind.

Eqs (2.1) and (2.3) imply

$$
\begin{aligned}
A_i(\alpha) &= (1 - 2\nu_i)B_i(\alpha) \\
2\mu_1 B_1(\alpha) &= 2\mu_2 B_2(\alpha) = B(\alpha)
\end{aligned}
\tag{3.6}
$$

Substituting Eqs (3.1)÷(3.3) and (3.5) into the boundary conditions (2.2) and (2.4)÷(2.6) and taking into account Eq (3.6) we obtain the two pairs of dual integral equations

$$\gamma \int_0^\infty B(\alpha) J_0(\alpha r)\, d\alpha + \alpha_t(1+\nu_1) \int_0^\infty \frac{1}{\alpha} C(\alpha) J_0(\alpha r)\, d\alpha = g(r) - d \qquad r \le a \tag{3.7}$$

$$\int_0^\infty \alpha B(\alpha) J_0(\alpha r)\, d\alpha = 0 \qquad r > a$$

$$\int_0^\infty \alpha C(\alpha) J_0(\alpha r)\, d\alpha = \frac{fv}{K} p(r) \qquad r \le a$$

$$\int_0^\infty \left(\alpha + \frac{h}{K}\right) C(\alpha) J_0(\alpha r)\, d\alpha = 0 \qquad r > a \tag{3.8}$$

Here

$$\gamma = \frac{1-\nu_1}{\mu_1} + \frac{1-\nu_2}{\mu_2} \tag{3.9}$$

$$p(r) \equiv -\int_0^\infty \alpha B(\alpha) J_0(\alpha r)\, d\alpha \qquad r \le a \tag{3.10}$$

The solution of Eqs (3.7) may be written as

$$B(\alpha) = -\frac{2}{\pi} \int_0^a \cos(\alpha t) \frac{d}{dt} \int_0^t \frac{x f(x)\, dx}{\sqrt{t^2 - x^2}}\, dt \tag{3.11}$$

where

$$\gamma F(x) = d - g(x) + \alpha_t(1+\nu_1) \int_0^\infty \frac{1}{\alpha} C(\alpha) J_0(\alpha r)\, d\alpha \tag{3.12}$$

Now substitute Eq (3.12) for F(x) in Eq (3.11). We have

$$B(\alpha) = -\frac{2\sin(a\alpha)}{\pi\gamma\alpha}\Big[d - a\int_0^a \frac{g'(x)\, dx}{\sqrt{a^2 - x^2}} + \alpha_t(1+\nu_1)\int_0^\infty \frac{1}{\eta} C(\eta)\cos(\eta a)\, d\eta\Big] + \tag{3.13}$$

$$-\frac{2}{\pi\gamma\alpha}\int_0^a \sin(\alpha t)\, dt \int_0^t \frac{[x g'(x)]'\, dx}{\sqrt{t^2 - x^2}} - \frac{2fv\delta}{\pi\gamma}\int_0^a \sin(\alpha t)\, dt \int_0^t \frac{x p(x)\, dx}{\sqrt{t^2 - x^2}}$$

where $\delta = \alpha_t(1+\nu_1)/K$ is the distortion coefficient and $(\cdot)'$ denotes differentiation with respect to x.

Using representation (3.13) we may rewrite Eq (3.10) as

$$p(r) = -\frac{2}{\pi\gamma\sqrt{a^2-x^2}}\Big[d - a\int\limits_0^a \frac{g'(x)\,dx}{\sqrt{a^2-x^2}} + \alpha_t(1+\nu_1)\int\limits_0^\infty \frac{1}{\eta}C(\eta)\cos(\eta a)\,d\eta\Big] + \tag{3.14}$$
$$+\frac{2}{\pi\gamma}\int\limits_r^a \frac{dt}{\sqrt{t^2-r^2}}\int\limits_0^t \frac{[xg'(x)]'\,dx}{\sqrt{t^2-x^2}} + \frac{2fv\delta}{\pi\gamma}\int\limits_r^a \frac{dt}{\sqrt{t^2-r^2}}\int\limits_0^t \frac{xp(x)\,dx}{\sqrt{t^2-x^2}}$$

In the case of the continuously curved solids, applying the condition that the contact pressure is limited at $r \le a$ from Eq (3.14) it follows

$$d = a\int\limits_0^a \frac{g'(x)\,dx}{\sqrt{a^2-x^2}} - \alpha_t(1+\nu_1)\int\limits_0^\infty \frac{1}{\eta}C(\eta)\cos(\eta a)\,d\eta \tag{3.15}$$

Finally, by virtue of Eqs (3.14) and (3.15) the pressure distribution is given by the following integral equation

$$p(r) = \frac{2}{\pi\gamma}\int\limits_r^a \frac{dt}{\sqrt{t^2-r^2}}\int\limits_0^t \frac{[xg'(x)]'\,dx}{\sqrt{t^2-x^2}} + \tag{3.16}$$
$$+\frac{2fv\delta}{\pi\gamma}\int\limits_r^a \frac{dt}{\sqrt{t^2-r^2}}\int\limits_0^t \frac{xp(x)\,dx}{\sqrt{t^2-x^2}} \qquad r \le a$$

An unknown value of the contact radius a can be found from Eq (2.7).

Note, that integral equation (3.16) coincide with the integral equation of the corresponding contact problem in the case of insulated surfaces outside the contact area (see, e.q., Yevtushenko and Kultchytsky-Zhyhailo (1995)). Thus, the pressure distribution and the contact radius in the considered problem are independent of the convective heat exchange between the conducting solid and surrounding medium.

The case in which the surface of conducting solid is slightly curved in the contact zone and perfectly insulated in the separated region was studied by Barber (1976), Yevtushenko and Kultchytsky-Zhyhailo (1995). It was shown that at a constant sliding speed there existed the limiting value of the contact circle radius for the increasing of the total force P. This limit value is

$$a_{cr} = \frac{2}{\beta^*} \qquad \beta^* = \frac{\delta fv}{\gamma} \tag{3.17}$$

In the paper of Yevtushenko and Kultchytsky-Zhyhailo (1996) was shown that if the input parameter $b = a_H/a_{cr}$, where a_H was the contact circle radius in the corresponding Hertz problem, satisfying the inequality $b > 2.5$, then $a \approx a_{cr}$ and the pressure distribution was nearly parabolic

$$p(r) \approx p_0\sqrt{1 - \Big(\frac{r}{a_{cr}}\Big)} \qquad\qquad p_0 = \frac{3P}{2\pi a_{cr}^2} \tag{3.18}$$

Using the representation

$$C(\alpha) = \frac{\alpha}{\alpha + \frac{h}{K}} \int\limits_0^a xJ_0(\alpha x)\Big[\frac{fv}{K}p(x) + \frac{h}{K}T(x)\Big]\, dx \tag{3.19}$$

for $C(\alpha)$ and substituting Eq (3.19) into Eq (3.8), we find

$$\begin{aligned} T(r) - \frac{h}{K}\int\limits_0^\infty \frac{\alpha J_0(\alpha r)\, d\alpha}{\alpha + \frac{h}{K}} \int\limits_0^a xJ_0(\alpha x)T(x)\, dx = \\ = \frac{fv}{K}\int\limits_0^\infty \frac{\alpha J_0(\alpha r)\, d\alpha}{\alpha + \frac{h}{K}} \int\limits_0^a xJ_0(\alpha x)p(x)\, dx \qquad r \geq a \end{aligned} \tag{3.20}$$

Substituting Eq (3.18) into Eq (3.20), we obtain

$$\begin{aligned} T^*(\rho) - \mathrm{Bi}\int\limits_0^\infty \frac{\alpha J_0(\alpha\rho)\, d\alpha}{\alpha + \mathrm{Bi}} \int\limits_0^1 xJ_0(\alpha x)T^*(x)\, dx = \\ = 2\sqrt{\frac{2}{\pi}}\int\limits_0^\infty \frac{J_0(\alpha\rho)J_{3/2}(\alpha)\, d\alpha}{\sqrt{\alpha}(\alpha + \mathrm{Bi})} \qquad \rho \geq a \end{aligned} \tag{3.21}$$

where

$$\begin{aligned} T^* &= \frac{T}{T_0} & T_0 &= \frac{3fvP}{8Ka_{cr}} \\ \mathrm{Bi} &= \frac{ha_{cr}}{K} & \rho &= \frac{r}{a_{cr}} \end{aligned} \tag{3.22}$$

Figure 2 shows distributions of the temperature T^* at several values of Biot's number Bi. Note that approximately $T^*(\rho) \approx 1 - \rho^2/2 - t_0$, where t_0 is the constant, depending on Biot's number Bi ($t_0 = 0$ at $\mathrm{Bi} = 0$).

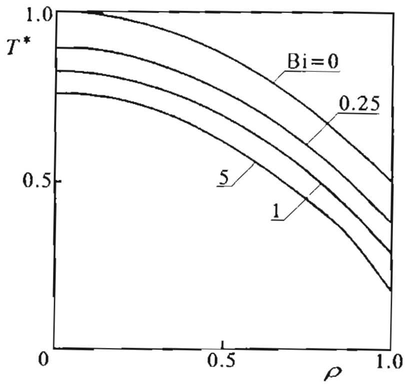

Fig. 2. Distributions of the contact themperature in the axi-symmetric case

4. The two-dimensional problem

The two-dimensional (plane strain) problem corresponding to the above considered one is that in which a conducting body sliding with speed v in the positive x-direction over the insulated surface of the half-plane (see Fig.3). Two bodies contact over the strip $-a \leq x \leq a$.

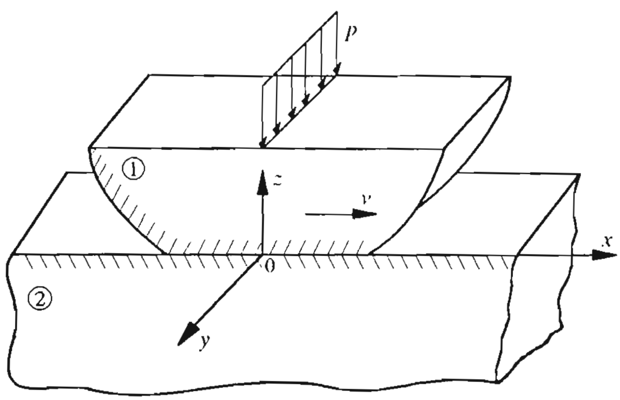

Fig. 3. The scheme of the contacting bodies in the plane case

A convective cooling between the surface conducting body and surrounding medium is assumed.

The solution of the two-dimensional problem can be obtained using the similar approach as in the previous axi-symmetric case. The integral representation can be obtained from Eqs (3.1) ÷ (3.5) by the Fourier transform replace $\alpha \rightarrow |\alpha|$, $J_0(\alpha r) \rightarrow \exp(i\alpha x)/\sqrt{2\pi}$ and $J_1(\alpha r) \rightarrow \mathrm{isign}(\alpha)\exp(i\alpha x)/\sqrt{\pi}$.

Finally, we obtain the two systems of the dual integral equations

$$\gamma \int_0^\infty \alpha B(\alpha)\sin(\alpha x)\, d\alpha + \alpha_t(1+\nu_1)\int_0^\infty C(\alpha)\sin(\alpha x)\, d\alpha = -\sqrt{\frac{\pi}{2}}g'(x) \qquad 0 \le x \le a \qquad (4.1)$$

$$\int_0^\infty \alpha B(\alpha)\cos(\alpha x)\, d\alpha = 0 \qquad x > a$$

$$\int_0^\infty \alpha C(\alpha)\cos(\alpha x)\, d\alpha = \sqrt{\frac{\pi}{2}}\frac{fv}{K}p(x) \qquad 0 \le x \le a$$

$$\int_0^\infty \Big(\alpha + \frac{h}{K}\Big) C(\alpha)\cos(\alpha x)\, d\alpha = 0 \qquad x > a \qquad (4.2)$$

where

$$p(x) \equiv -\sqrt{\frac{2}{\pi}}\int_0^\infty \alpha B(\alpha)\cos(\alpha x)\, d\alpha \qquad -a \le x \le a \qquad (4.3)$$

The general solution of a first pair of dual integral equations (4.1) can be written in the form

$$\alpha B(\alpha) = -\frac{2}{\pi}\int_0^a J_0(\alpha t)\frac{d}{dt}\int_0^t \frac{xF)x)\, dh}{\sqrt{t^2-x^2}}\, dt + \varphi_0 J_0(\alpha a) \qquad (4.4)$$

where

$$\gamma F(x) = \sqrt{\frac{2}{\pi}}g'(x) + \alpha_t(1+\nu_1)\int_0^\infty C(\alpha)\sin(\alpha x)\, d\alpha \qquad (4.5)$$

φ is a constant, which in the case of slightly curved surface of the conducting body is equal to zero. From Eqs (4.4) and (4.5) after some transformations we have

$$\alpha B(\alpha) = -\frac{2}{\pi}\int\limits_0^a J_0(\alpha t)\,dt\Big[F(0) + t\int\limits_0^t \frac{F'(x)\,dx}{\sqrt{t^2-x^2}}\Big] =$$

$$= -\frac{1}{\gamma}\sqrt{\frac{2}{\pi}}\int\limits_0^a tJ_0(\alpha t)\,dt\int\limits_0^t \frac{g''(x)\,dx}{\sqrt{t^2-x^2}} +$$

$$-\frac{2}{\pi\gamma}\alpha_t(1+\nu_1)\int\limits_0^a tJ_0(\alpha t)\,dt\int\limits_0^t \frac{dx}{\sqrt{t^2-x^2}}\int\limits_0^\infty \eta C(\eta)\cos(\eta x)\,d\eta = \tag{4.6}$$

$$= -\frac{1}{\gamma}\sqrt{\frac{2}{\pi}}\int\limits_0^a tJ_0(\alpha t)\,dt\int\limits_0^t \frac{g''(x)\,dx}{\sqrt{t^2-x^2}} - \sqrt{\frac{2}{\pi}}\beta^*\int\limits_0^a tJ_0(\alpha t)\,dt\int\limits_0^t \frac{p(x)\,dx}{\sqrt{t^2-x^2}}$$

The contact pressure can be now obtained from Eqs (4.3) and (4.6)

$$p(x) = \frac{2}{\pi\gamma}\int\limits_x^a \frac{t\,dt}{\sqrt{t^2-x^2}}\int\limits_0^t \frac{g''(y)\,dy}{\sqrt{t^2-y^2}} +$$

$$+\frac{2}{\pi}\beta^*\int\limits_x^a \frac{t\,dt}{\sqrt{t^2-x^2}}\int\limits_0^t \frac{p(y)\,dy}{\sqrt{t^2-y^2}} \qquad a \le x \le a \tag{4.7}$$

The Fredholm integral equation (4.7) can be reduced by defining $\xi = x/a$. We obtain

$$p(\xi) = \frac{2a}{\pi\gamma}\int\limits_\xi^1 \frac{t\,dt}{\sqrt{t^2-\xi^2}}\int\limits_0^t \frac{g''(y)\,dy}{\sqrt{t^2-y^2}} +$$

$$+\frac{2}{\pi}\beta^* a\int\limits_\xi^1 \frac{t\,dt}{\sqrt{t^2-\xi^2}}\int\limits_0^t \frac{p(y)\,dy}{\sqrt{t^2-y^2}} \tag{4.8}$$

By virtue of the geometric series theorem by Atkinson (1976) Eq (4.8) has a unique solution $p(\xi)$ for any $g(\xi) \in C[-1,1]$, provided that

$$-\frac{2}{\pi}\beta^* a\int\limits_0^1 d\xi\int\limits_0^1 |K(\xi,y)|\,dy < 1 \tag{4.9}$$

where $K(\xi, y)$ is the kernel of Eq (37). The integrals in Eq (4.9) are

$$\int\limits_0^1 d\xi \int\limits_0^1 |K(\xi,y)|\,dy = \int\limits_0^1 d\xi \int\limits_0^\xi dy \int\limits_\xi^1 \frac{t\,dt}{\sqrt{(t^2-\xi^2)(t^2-y^2)}} +$$

$$+\int\limits_0^1 d\xi \int\limits_\xi^1 dy \int\limits_y^1 \frac{t\,dt}{\sqrt{(t^2-\xi^2)(t^2-y^2)}} = \int\limits_0^1 d\xi \int\limits_\xi^1 \frac{t\,dt}{\sqrt{t^2-\xi^2}} \int\limits_0^t \frac{dy}{\sqrt{t^2-y^2}} = \tag{4.10}$$

$$= \frac{\pi}{2}\int\limits_0^1 t\,dt \int\limits_0^t \frac{d\xi}{\sqrt{t^2-\xi^2}} = \frac{\pi^2}{4}\int\limits_0^1 t\,dt = \frac{\pi^2}{8}$$

Taking into account Eq (4.10), from Eq (4.9) we have

$$\beta^* a < \frac{4}{\pi} \approx 1.27 \tag{4.11}$$

hence we obtain the critical value a of half-width of the contact strip, at which the considered problem has the unique solution

$$a_{cr} = \frac{1.27}{\beta^*} = \frac{1.27\gamma K}{\alpha_t(1+\nu_1)fv} \tag{4.12}$$

As in the axi-symmetrical case, the contact pressure distribution can be written in the following approximately form

$$p(x) \approx \frac{2P}{\pi a_{cr}}\sqrt{1-\left(\frac{x}{a}\right)^2} \tag{4.13}$$

where

$$P = \int\limits_{-a}^{a} p(x)\,dx$$

is the total load, a_{cr} is given by Eq (4.12).

The function $C(\alpha)$ in Eq (4.2) can be represented in the form

$$C(\alpha) = \sqrt{\frac{2}{\pi}}\frac{1}{\alpha+\frac{h}{K}}\int\limits_0^a \Big[\frac{fv}{K}p(y) + \frac{\alpha_t}{K}T(y)\Big]\cos(\alpha y)\,dy \tag{4.14}$$

Substituting Eq (4.14) into Eq (4.2), we obtain

$$T(x) = \frac{2}{\pi}\int\limits_0^\infty \frac{\cos(\alpha x)\,d\alpha}{\alpha+\frac{h}{K}}\int\limits_0^a \Big[\frac{fv}{K}p(y) + \frac{\alpha_t}{K}T(y)\Big]\cos(\alpha y)\,dy \tag{4.15}$$

Finally, substituting Eq (4.13) into Eq (4.15), we have

$$T^*(\xi) - \frac{2}{\pi}\mathrm{Bi}\int\limits_0^\infty \frac{\cos(\alpha x)\,d\alpha}{\alpha+\mathrm{Bi}}\int\limits_0^\infty T^*(y)\cos(\alpha y)\,dy = \tag{4.16}$$

$$= \int\limits_0^\infty \frac{J_1(\alpha)\cos(\alpha\xi)\,d\alpha}{\alpha(\alpha+\mathrm{Bi})}$$

where

$$T^* = \frac{T}{T_0} \qquad\qquad T_0 = \frac{2fvP}{\pi K} \tag{4.17}$$

Distributions of the non-dimensional temperature $T^*(\xi)$ at different values of Biot's number is shown in Fig.4. As in the axi-symmetric case the surface temperature can be represented in the form $T^*(\xi) \approx 1.02 - 0.73\xi^2 + t_0$, where the constant depends on Bi ($t_0 = 0$ at Bi=5 and $t_0 \to \infty$ at Bi $\to 0$).

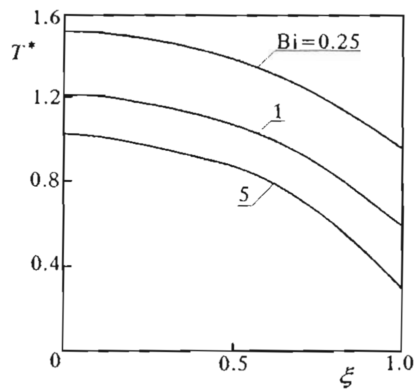

Fig. 4. Distributions of the contact themperature in the two-dimensional case

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Efekt konwekcyjnego chłodzenia na rozwiązania termosprężystych zagadnień kontaktowych z generacją ciepła podczas tarcia

Streszczenie

W pracy zbadano efekt konwekcyjnej wymiany ciepła w wydzielonym obszarze podczas ślizgowego kontaktu dwóch sprężystych ciał z uwzględnieniem generacji ciepła pochodzącego od tarcia. Przyjęto, że tylko jedno z ciał jest przewodnikiem ciepła i naprężenia styczne na powierzchni kontaktu nie oddziaływują na siły prostopadłe. Rozkład ciśnienia kontaktowego i wymiar obszaru kontaktu są takie same jak w odpowiednim zagadnieniu kontaktowym z idealnie izolowaną powierzchnią ciała przewodzącego. Z drugiej strony, rozkład temperatury kontaktowej zależy głównie od powierzchniowych warunków termicznych.

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