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MATHEMATICAL MODELLING OF HEATING AND SMELTING OF HARD LIGUIDS OF FRICTION

1. Introduction

Heavy development of tribology-the science on friction of hard liguids is accompanied by the formation of new fields of tribotechnology. Constructions and methods which applied in various fields of machine-building including welding of hard steams, braking construction of various purpose, termfrictional seizures in drilling of wells and e.t.

There is considered two solving of problem on heating and smelting of hard liquid out of friction. General organisation and analysis methods of decisions of similar problems applied to welding of friction in hardphase are stated in work [1]. Works [2,3,4] are devoted to solving of concrete problems on technological processes of term-frictional heating of hard liquids. In all these work there are considered cases of two cylindrical liquids, which one of them is turned constant corner velocity. Unlike these, in present work there is investigated term-frictional heating and smelting of two liquids in changeable progressive motion one of them relatively other. There are considered two problems. One of these decisions is on friction of two hard liquids. The second is on streamline of one hard liquid of squelch non-compressed liquid in smelting of others.

2.Organisation of problems.

In friction of two liquids in moment of achievement in some places of surface of temperature contact of several significance equally temperature of smelting (T_{pl}) one of these points there will be began take root the front of smelting to the deep of liquid as a surface, in which there is occurred smelting and which differs the liquid and hard phases of material. Considering that, the liquid is in relatively motion but liquid phase have a squelch one, ir will be drawn in motion.That is why, it is necessary to solve first of all, un-stationary problem of heat conduction in known initial and bordering terms of fourth kind [6]. The problem is un-linear and there is used iteration method of decision with using on times Laplas's integral formation. The basis of this method applied to such kind of problems stated [2,6]. If in this decision the temperature is increased $T \geq T_{pl}$ in several points of surface of joint or in line it is important to solve the problem with considering the beginnigs of liquid phase from indicated moment.

Inside of this phase the material is situated in smelting situation and flows. There is necessary to find distribution of temperature in liquid phase in this case using equation of heat conduction for flowing liquid. The motion of liquid is modelled by Navye-Stox equation for non-compressed liquid. In this case the smelting material is being as dropping liquid and may be considered non-compressed. Border between liquid and hard phases (smelting front) is roused in point or on line surface of contact ant and unknown before. It mutst be found in solving of problem. So this problem with physical point of view is Stefan's complicated version of classical one on smelting or freezing of chamber surroundings. Complication is that, here the liquid phase comes to motion and for solving the problem there is necessary to attract hydrodynamics of squelch liquid. Let's consider the autofashion organisation of problem, which allows to find decision in ended view and reveal more essential qualified properties of process.

In front of smelting there should be satisfied the laws on keeping of mass, energy and quantity of motion and there is two types of surfaces of gap [7] in which there is taken place the smelting. The first-surface of stress gap, where is formed blowing waves differing from ordinary ones that in these the material is smelting, the temperature on these surfaces has patience to gap. In the second surface only heat stream has patience to gap and perhaps, the density. We will call such kind of gap as weak waves of smelting.

Let in the border of liquid, occupying some parts of area and having given initial temperature $T_0 = const$ there is pressed the hard plate in view of density, which begins to move with velocity of $V_0 = const$. Border of inside of liquid comes heat equally through square unit into one:

$$Q = fpv_0 \tag{1}$$

where f-coefficient of friction: p –pressure of plate on liquid.

We suppose that, all force of friction will be taken only by liquid, i.e. the plate is obstacle for heat. If there is supposed that $p = At^{-1/2}$, then the problem will be auto-fashion and the temperature of hard phase (T_1) is determined by equation:

$$\partial T_1 / \partial t = a_1(T_1)\partial^2 T_1 / \partial x^2 \tag{2}$$

in following initial and limited conditions:

$$T_1(x,0) = T_0$$

$$\partial T_1 / \partial x|_{x=0} = [-Q / K_1(T_1)]_{x=0} \tag{3}$$

$a_1(T_1)$ and $K_1(T_1)$-coefficients of heat conduction and temperature conduction.

Calculation of dependencies of heat-physical characteristics of liquid don't breaches the autofashion of problem [6].

The decision of problem (2)-(3) is

$$T_1 = T_0\left\{\left[\delta\sqrt{\pi}/2\right]\left[1 - \Phi(\xi)\right] - 1\right\} \tag{4}$$

where

$$\Phi(\xi) = \frac{1}{2\sqrt{\pi}}\int_0^{\xi_1} e^{-\xi^2} d\xi, \quad \delta = b\sqrt{a_1^*}$$

$$\xi = 0{,}5x / \left[a_1^*(T_1)t\right]$$
$$b = fAv_0\sqrt{a_1^*}/(K_1^* T_0)$$

Methods on solving of this problem for n iteration is stated in [2].

Temperature of border of liquid will be:

$$T_1(0,t) = T_0\left(\delta\sqrt{\pi}/2 - 1\right)$$

that is why, if, $\delta \le \delta_* = 2/\sqrt{\pi}$ there is will be not smelting.

In $\delta > \delta_*$ inside of border of liquid there is provided the weak of smelting, law on motion of front which is unknown: $(x = x_0(t))$. In the field $0 < x < x_0(t)$ have:

$$\partial V/\partial t = v\partial^2 V/\partial x^2 \qquad (5)$$
$$\partial T_2/\partial t = a_2(T_2)\partial^2 T_2/\partial x_2 + \left(v/c_p\right)\left(\partial V/\partial x\right)^2$$

where the first-Navye-Stox's equation; the second-equation of energy; C_p – heat apacity of smelting mass.

In the field $x_0(t) < x < \infty$ the temperature satisfied equation (2) in additional conditions [1]:

$$V(0,t) = V_0; \quad V(x_0,t) = 0$$
$$\left[\partial T_2/\partial x\right]_{x=0} = 0 \qquad (6)$$
$$T_2(x_0,t) = T_1(x_0,t)$$
$$T_1(x,0) = T_0;$$
$$K_1\frac{\partial T_1}{\partial x}\Big|_{x=x_0} - K_2\frac{\partial T_2}{\partial x}\Big|_{x=x_0} = q\rho\frac{dx_0}{dt}$$

where q-heating of smelting of unit mass:

Applying analysis by sizes to (5)-(6) reduced to conclusion on its auto-fashion./ After some reformation the sizeless quantity reduced to dependencies according to π – theory on analysis of sizes [5]:

$$\xi = 0{,}5x/\sqrt{a_1^* t}; \quad \lambda = v/a_1^*$$
$$\alpha = a_2^*/a_1^*; \quad n = 2q\rho a_1^*/\left(K_1^* T_0\right),$$
$$m = \vartheta_0^2/\left(T_0 C_p\right), \quad \chi = K_2^*/K_1^*; \quad (\rho_1 = \rho_2 = \rho)$$

Law on motion of weak wave is determined with exactness till constant φ_0 by formula:

$$x_0(t) = 2\varphi_0\sqrt{a_1^* t}$$

φ_0 defined from transcendental equation:

$$\frac{\chi m}{\alpha}\left[\exp\left(-\varphi_0^2/a_1^*\right)\right]\cdot\Phi_0(\varphi_0)\cdot\left[\Phi_0\left(\varphi_0/\sqrt{\lambda}\right)\right]^{-2} -$$
$$-\exp(\varphi_0^2)/(1-\Phi(\varphi_0)) = 0{,}5n\varphi_0\sqrt{\pi}$$

where

$$\Phi_0(\varphi_0) = \frac{2}{\sqrt{\pi}} \int_0^{\varphi_0} \exp\left[\left(\frac{1}{\alpha} - \frac{2}{\lambda}\right)\tau^2\right] d\tau$$

In $\chi > 0, \alpha > 0, \lambda > 0, m > 0, n > 0$ the last equation has only positive root. If this root few, then it may approximately exressed by formula:

$$\varphi_0 \approx \sqrt{\pi} K_2^* \nu \vartheta_0^2 /(2K_1^* a_2^* C_p T_0)$$

In various version of changes of significance in relatively velocity there is possible analyse got decisions and give mark of influence of different parameters and heat-physical characteristics of material in deep of moving of smelting front. Solving more-criteria problems it is possible to create algorithm of management liquid layer by volume. Calculation of coefficient dependence dry fricition from flowing temperature is quite possible on suggested [2] method of decision of problem.

Literature

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BƏRK CİSİMLƏRİN SÜRTÜNMƏ NƏTİCƏSİNDƏ QIZMASI VƏ ƏRİMƏSİ PROSESİNİN RİYAZİ MODELLƏŞDİRİLMƏSİ

Məqalədə iki bərk cismin qarşılıqlı sürtünmə hərəkəti zamanı qızması və əriməsi proseslərinin riyazi modeli verilmiş, cisimlərin teplofiziki xarakteritikalarının temperaturdan asılılığı nəzərə alınmaqla dəyişən sərhədli məsələ analitik həll olunmuşdur. Dalğa cəbhəsinin yerdəyişməsinin zamandan asılılığı qanunu müəyyən olunmuş, alınmış nəticələrin praktiki tətbiqi məsələləri araşdırılmışdır.