Heating of metal surface layer with partial melting

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The highest heat treatment temperatures, in many cases often bordering on the melting temperature, are used in local heat treatment of targeted metal surface areas in order to increase the process intensity and the concomitant chemical action on the metal [1].

To expand capabilities of control of the phase and chemical structure of the treated surface metal layer, a possibility of partial penetration of the surface layer to a given controlled value of 0.1-0.5 mm was investigated. Thus the degree of diffusion saturation of the treated layer can be increased by an order of magnitude while maintaining the original processing time intervals.

The modeling object is a one-dimensional metallic (low-carbon steel) sample of a given finite length l oriented along the *"x"* axis and bounded by two infinite planes $x = 0$ and $x = l$. Thermal parameters of the model corresponded to the actual processing conditions.

The problem was to find the sample surface heating time t^*, at which a melt front will be located at a given distance from the heating surface x^*, and conditions for its further stabilization.

The heat-conduction equation in the context of the phase transition problem was solved in one-dimensional approximation using the finite-difference method, taking into account the latent heat of phase transition during metal melting and a thermal diffusivity jump in the liquid and solid phases.

To calculate temperature T at the node points (x_i, t_j), an implicit scheme for determination of temperatures $T_{i,\ j}$ on a new (after layer j) time layer $t_{j\ +\ 1}$ (lead scheme) was applied as a stable scheme with arbitrary time τ and spatial h steps of calculations. In this case, the differential operator $L\ (T)$ is associated with the difference operator $L_{h\tau}\ (T_{i,\ j\ +\ 1})$:

$$L(T) = \frac{1}{a^2}\frac{\partial T}{\partial t} - \frac{\partial^2 T}{\partial x^2} \quad \rightarrow \quad L_{h\tau}(T_{i,j+1}) = \frac{1}{a^2}\frac{T_{i,j+1} - T_{i,j}}{\tau} - \frac{T_{i-1,j+1} - 2T_{i,j+1} + T_{i+1,j+1}}{h^2},$$

defined on a four-point pattern (x_{i-1},t_{j+1}), (x_i,t_{j+1}), (x_{i+1},t_{j+1}), (x_i,t_j), where i and j are the numbers of nodes of respectively spatial and temporal variables and a^2 is the thermal diffusivity coefficient of the phase [2, p. 557]. The system of algebraic equations for the values of the sought-for function $T_{i,j+1}$ on the new layer $t = t_{j+1}$ was solved using factorization method [2, p. 591].

As a result of our investigation, the dependence of movement of the melt front x^* on the time t for model samples of different length was found. Fig. 1 shows the said dependence for a sample of l_i = 2 mm in length. The time was counted from the beginning of melting of the metal surface. The surface temperature was T_s = 1600ºC.

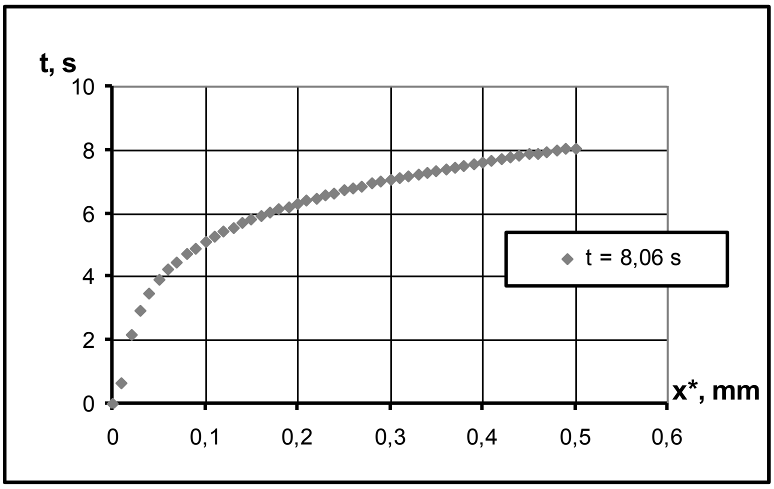

Fig. 1. Movement of melt front in sample l_i = 2 mm at surface temperature 1600ºC

Fig. 2 shows interpolation curves of the dependence of time of penetration of the sample surface layer to a given depth *x** = 0.1 mm and *x** = 0.5 mm on the sample length.

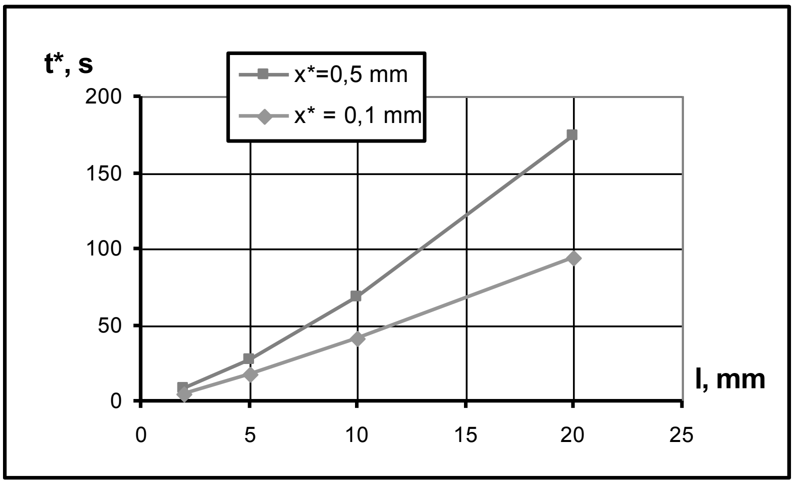

Fig. 2. Dependence of the sample surface penetration time *t** to a given depth *x** on the sample length *l*

The obtained data on the melting rate of the surface layer of model samples determine the duration of energy exposure of the metal surface during penetration to a given depth, which makes it possible to control the processes of thermal and diffusion transformations of the metal surface layer under conditions of local energy exposure on its surface.

1. Method of thermochemical treatment of steel products: a. c. № 1436527 USSR, IC P 23 P 8/24, P 21 D 1/08, IB (1988), № 42.
2. Tikhonov A.N., Samarskiy A.A. Equations of mathematical physics. – M.: Nauka. - 1972. – 736 p.