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THERMAL ASPECTS OF PRODUCTION TECHNOLOGY OF AMORPHOUS STRUCTURES

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Introduction. In the technology of the hardening from the liquid state layer of melted metal is contacted with the surface of the massive body (a body-fridge) and cooled by means of heat removal in the internal layers. In this case, the processes of formation of the primary structure of alloys, as well as subsequent solid phase transformations are accompanied by the formation of different structural types of metastable states (amorphous structure). For the formation of the amorphous structure of the metal was performed surfacing of the samples with a low-alloy steel Figure 1.

Structure of deposited metal is determined by the cooling conditions which affect the processes of solidification the metal and diffusion processes. Therefore, on the experimental equipment installed system a forced cooling of the surface layer of the melt.

For the study regularities of formation of structure and effect of the structure on the mechanical, electrical and other properties of the metal after surfacing have been performed metallophysical research, resulting in the found that deposited layer has a crystal a, mainly ferritic structure.

When the layer is cooled down (Figure 1) crystals grow in the direction opposite heat removal deep into the liquid bath and the metal acquires a columnar structure. At higher cooling rates, in the deposited metal of these steels besides ferrite and pearlite present as martensite, bainite and residual austenite. The number of structural components is changed depending on the temperature cycle of surfacing. Since the structure of the samples shown in Figure 1, has a crystalline structure, we can conclude that, without the use of process techniques during surfacing, which are aimed at increasing the cooling rate of the melt with a view to rapid heat removal, receive amorphous structure deposited metal is not possible.

In the process of surfacing the cooling rate of the melt directly depends on the heat input of the process, with a decrease of heat input rate of cooling increases. With increasing deposition rate, decreases heat input, which in turn increases the speed of the cooling process [5]. Surfacing of subsequent samples was carried with increasing deposition rate V_d, 16...18 m/s, the other mode parameters have left unchanged. The results of metallophysical studies are presented in figure 2, from which it follows that increasing the deposition rate has led to grain refinement and improvement of the structure of the metal.

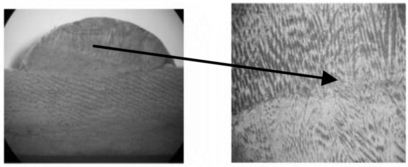


Figure 1 - Structure of the deposited metal

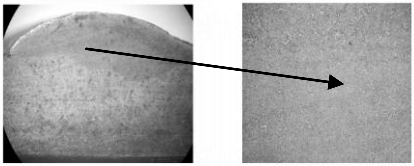


Figure 2 - Structure of the deposited metal

To produce the amorphous structure deposited metal should be applied technological techniques that will ensure cooling rate of 10^4 ... 10^5 K/s and above. With increasing rate of heat removal metallophysical studies fixed the amorphous structure of deposited metal (figure 3).

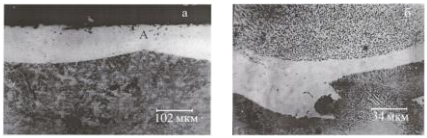


Figure 3 – Amorphous structure of the deposited metal

The rate of cooling alloys calculated by numerically solving the problem of heat transfer between a thin layer the melt and of a solid metal plate with high heat conductivity. During the cooling process of the layer melt metal temperature of the upper layers of the array increasing and corresponds to the condition the heat transfer from the melt while at a large distance from the working surface, its temperature does not change [6-7] (figure 4) . A simplified scheme heat removal on the condition that the melt temperature is changed in a direction perpendicular to the contact surface can be represented as a heat conduction equation [8]:

$$c_1\rho_1 \cdot \frac{\partial T_1(x_1,t)}{\partial t} = k_1 \cdot \frac{\partial^2 T_1(x_1,t)}{\partial x_1^2}, \tag{1}$$

where - $T_1(x_1,t)$, c_1, ρ_1, k_1 - temperature, heat capacity, density and thermal conductivity of the melt; t - time.

The initial condition

$$T_1(x_1,0) = T_m + \Delta T, \tag{2}$$

where T_m - the melting temperature investigated metal;
ΔT - the degree of the previous melt overheating.

Boundary conditions:

at $x1$=0: $$-k_1 \cdot \frac{\partial T_1(0,t)}{\partial x_1} = 0 \tag{3}$$

at $x1=l$: $$-k_1 \cdot \frac{\partial T_1(l,t)}{\partial x_1} = \alpha[T_1(l,t) - T_2(0,t)], \tag{4}$$

where α - coefficient of heat transfer at the melt-array;
$T_2(x_2,t)$ - the temperature of the array.

For the formalization process of heat removal to the array using the general equation of heat conduction for the relevant material, as well as the conditions that reflect the physical aspects of the thermal problem:

$$c_2\rho_2 \cdot \frac{\partial T_2(x_2,t)}{\partial t} = k \cdot \frac{\partial^2 T_2(x_2,t)}{\partial x_2^2}; \tag{5}$$

$$T_2(x_2,0) = T_0; \tag{6}$$

$$-k_2 \cdot \frac{\partial T_2(0,t)}{\partial x_2} = -\alpha[T_2(0,t) - T_1(l,t)]; \tag{7}$$

where c_2, ρ_2, k_2 - heat capacity, density and thermal conductivity of the substrate;

T_0 - the initial temperature of the array (x=0).

A result of solving the equations obtained diagrams of relation the cooling rate for aluminum and nickel on the thickness of the melt at different values of the heat transfer coefficient α (figure 5).

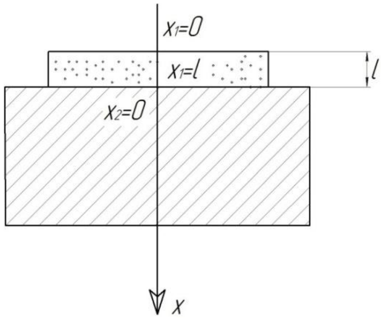
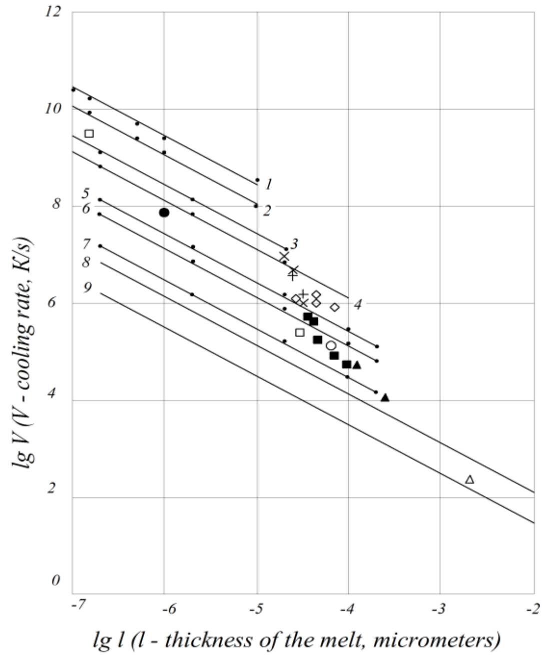


Figure 4 - Scheme of cooling:
l – thickness of the melt layer; x_1 – coordinate in the direction of heat transfer within the boundaries of melt layer ($0\leq x_1\leq l$);
x_2 – the coordinate in the direction of heat removal within the boundaries of substrate ($0\leq x_2\leq \infty$).

For the formalization concepts of the structure the materials we introduce index - the degree of amorphization (the ratio of volume metal to the volume of the crystals). Figure 6 shows a diagram characterizing relation of the degree amorphization of the thickness of the melted layer and the mass of deposited metal at a cooling rate of 10^4 K/s.

Conclusions

As seen from the graphs of cooling rates significantly progresses with decreasing thickness of the melt. Other technological factors, by which to control the mode of rapid cooling of the melt it is degree of overheating of the melt and the initial temperature of the array. When changing the substrate temperature from -200 to 200 ° C decrease the cooling rate, so it can be concluded, the lower the temperature substrate the higher cooling rate. Theoretical calculations even under the simplified mathematical models make it possible to estimate the rate of cooling of the melt and the probability of obtaining the amorphous structure of the metal.



1) $\alpha = 10^7$ Вт/(м^2×К); 2) $\alpha = 5 \cdot 10^6$ Вт/(м^2×К); 3) $\alpha = 10^6$ Вт/(м^2×К);

4) α=5·10^5 Вт/(м^2×К); 5) α=10^5 Вт/(м^2×К); 6) α=5·10^4 Вт/(м^2×К);

7) $\alpha = 10^4$ Вт/(м^2×К); 8) $\alpha = 5 \cdot 10^3$ Вт/(м^2×К); 9) $\alpha = 10^3$ Вт/(м^2×К);

Figure 5 - Relation cooling rate of aluminum and nickel on the thickness of the melt at different values of the heat transfer coefficient α

Summary

In this paper, developed an algorithm solving the problem of high-speed thermal cooling of molten metals and alloys in order to form an amorphous structure. The rate of cooling alloys calculated by numerically solving the problem of heat transfer between the melt and a thin layer of a solid metal plate with high heat conductivity.

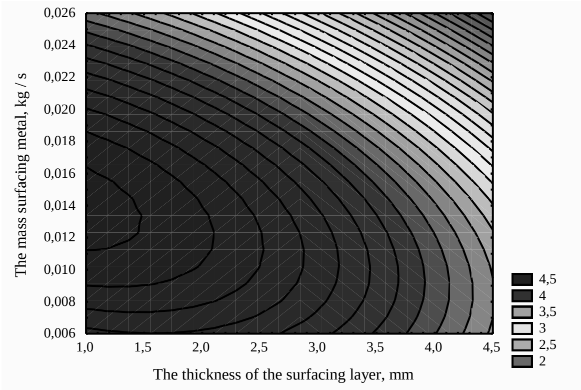


Figure 6 - Graph relation of the degree of amorphization on the thickness of the deposited layer and the mass of deposited metal

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