Influence of multilayer coatings on the operational stability of molds for injection molding

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Annotation. The article examines the main factors affecting the operational stability of molds for injection molding of non-ferrous metals and zinc alloys in particular, and also provides a specific method to increase the index of resistance of molds by coating the molding surface by cathode- ion bombardment. It describes the effect of the proposed coatings on the parameters of pressure, tension and heat in a mold.

1. Introduction

Operational stability tooling increase is a very urgent problem of all foundries and engineering in general. Especially effective solution to this problem is in mass production processes of finished products, which include injection molding. The number of products manufactured in this manner is measured, usually in tens of thousands. The increased operational stability of molds for injection molding, even a small percentage, calculated on the number of manufactured products will have a significant positive result.

There are many factors that have a negative effect on the operational stability of molds, but the most significant are cyclically repeated thermal power and influence on the shaping surface of the mold.

Modern theoretical recommendations can improve certain parameters affecting the operational resistance. They are: the proposals on the use of a special grade of steel as the material of the mold [1, 2], the special methods for calculating the operational stability of molds [3], the use of different lubricants and coatings [4]. However, most of them are related to the problem of stability in injection molding in a narrow range of process parameters regimented or using only aluminum alloys, which is not applicable to zinc alloys, owing to significant differences in melting point temperatures: 660 ° C and 380-480 ° C in aluminum and zinc alloys, respectively, and also because of the different chemical and physical activity.

There are some solutions to improve the operational stability of the molds, almost regardless of the initial conditions, such as the use of molybdenum tooling, but from the standpoint of economic efficiency such decisions are hardly applicable in today's workplace.

As a rule, nitriding is used in practice. This type of thermochemical treatment has several advantages: increased surface hardness, wear resistance, corrosion resistance, however, a significant disadvantage of this treatment is the brittleness increase of both the surface layer, and the material of the mold, which leads to the full swing cracks and as a consequence, to a short period of work. That is, this method is aimed primarily for aluminum alloys, which molds for casting can withstand up to 50,000 pressings, while for zinc alloys according to the State standards GOST 19946-74, it's necessary to ensure a minimum rate of 150000 pressings.

2. **The main part**

Thus, the problem of improving the operational stability of molds for injection molding of zinc alloys is relevant and requires further research. The solution to this problem can be multilayer coatings deposited by cathode ion bombardment [5,6,7]. These coatings have a number of advantages, which distinguish them from other possible solutions. Among them, the use of substantially any refractory or heat-resistant metal as a base coating, the possibility of applying several layers having specific, predetermined properties, hardness is also the possibility of layers alternation to inhibit the emergence and growth of cracks. In addition, each new layer does not affect the previous ones.

Thus, a possible solution to the operational durability of molds can be a multilayer coating consisting of a carbonitride molybdenum (MoCN) lower layer 2 microns thick for adhesion of the coating to the mold,metal surface and then on top of the lower layer an intermediate layer of 3 microns thick of nitride titanium (TiN) to provide high hardness of the coating, followed by a top layer with thickness of 2 microns of molybdenum nitride (MoN) for abnormally low coefficient of friction.

Using this coating without determining stresses acting on the molding surface of the mold, and without making the heat balance between the mold and casting is unacceptable. The stresses caused by power factors are completely dependent on the magnitude of the pressure acting on the wall of the shaping mold. An important point is the configuration of the surface contacting with the molten metal. In general, the pressure on the wall can be calculated according to the laws of hydraulics [8]:

$$p_{уд} = \gamma_{ж} \frac{\omega_{в}^{2}}{g}, \qquad (1)$$

wherein $p_{уд}$ - the pressure on the wall, $\omega_{в}$ - the speed of the molten metal inlet, $\gamma_{ж}$ - the volumetric weight of the molten metal, g - acceleration of gravity.

However, if the surface is different from a straight wall, it is necessary to introduce correction factors, so for a concave surface the pressure is doubled:

$$p_{уд} = 2\gamma_{ж} \frac{\omega_{в}^{2}}{g}. \qquad (2)$$

In the case of the concave surface, the pressure will be determined as follows:

$$p_{уд} = \gamma_{ж} \frac{\omega_{в}^{2}}{g}(1-\cos\varphi) \qquad (3)$$

where φ - the angle between the initial direction of flow and its direction after a meeting with the barrier.

Despite the well-known formulas for determining the pressure on concrete surfaces, the definition of specific pressure in a particular mold is a difficult task, since molding surface is a combination of different surfaces smoothly transitioning into each other. Therefore, the confirmation of the positive impact of multilayer coatings applied by CIB method can be a series of experiments in which the pressure and the stress are measured on distinct surfaces with the use of the proposed coating on surfaces with nitriding.

Multilayer coating based on molybdenum tests showed the following results: a slight reduction of pressure on the straight and curved surface does not exceed 1% of the pressure exerted on similar nitrided surfaces. However, the proposed coverage on the concave surface indicated the decline in specific pressure up to 5%, which is especially important when you consider that the most loaded sections of the forming surfaces of molds are precisely concave surfaces, such as hollow chamfer, fillet radius.

These results can be explained by the fact that the coating deposited (inflicted) by CIB significantly reduce the coefficient of friction between the molding surface and the molten metal, due to the physical nature of the molecular building coverage on the molding surface the purity is improved, but also when casting the physical interaction of the mold with the molten metal is decreased.

Thus, a coating deposited (inflicted) by CIB positively affect the decline in pressure and stress on the molding surface of the mold.

At the same time without making the heat balance between the mold and the product of casting it is impossible to make any conclusions about the effectiveness of the proposed coating.

The following papers [8,9,10,11] are devoted to research of shaping processes on hidher temperatures. To determine the thermal balance of the mold, it is generally necessary to determine its two components, one of them Q_n - the input heat and Q_o - the waste heat. The mutual equality of these quantities defines the thermal balance of the mold and the casting; otherwise it demands preliminary heating or cooling the mold. Input heat can be calculated according to the known procedure [12]:

$$Q_n = Q_{пер} + Q_{кр} + Q_{от} + Q_{тр}, \qquad (4)$$

where $Q_{\hat{e}\eth}$ - the heat of crystallization;

$Q_{\hat{e}\eth}$ - the heat of solid casting;

$Q_{кр}$ - frictional heat;

$Q_{пер}$ - overheating of the metal heat.

The amount of the last two components does not exceed 12% of the total value of the amount of input heat.

Equally challenging is the calculation of waste heat, as there are many gaps in the mold. Despite the complexity of the practical point of view, waste heat from the die is defined by two main components. One of them Q_T - this heat is rejected from the closed mold through the side surface, the other Q_P - a waste heat from the forming surface in the open state of the mold. Thus, the waste heat can be calculated as follows:

$$Q_o = Q_T + Q_P \ ; (5)$$

According to the coatings deposited by cathode ion bombardment experimental studies [13], the following results were obtained: the composition of the coating varying did not produce a significant decrease in indicators of heat input and the heat released into the environment and the change in their total value amounted to not more than 1%. This is due to a sufficiently small thickness of the proposed coating not more than 10 microns. However, reducing the coefficient of friction between the molding surface and the flow of molten metal provides the reduction in input heat to 3%, which is 10-12 ° C for zinc alloys.

3. Conclusion

Thus, the coating consisting of the carbonitride molybdenum (MoCN) lower layer of 2 microns thick for adhesion of the coating to the metal surface of the mold, and then of the intermediate layer of 3 microns thick of titanium nitride (TiN) on top of the lower layer to provide high hardness of the coating, and also the molybdenum nitride (MoN) top layer 2 microns thick for abnormally low

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coefficient of friction, provides a decrease in the parameters of pressure and stress on the working surfaces, particularly of a concave shape, as well as the input heat reducing by receiving an abnormally low coefficient of friction between the molding surface and the flow of molten metal, that ultimately will improve the operational stability of molds for zinc alloys casting under pressure.

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