PRODUCTION OF BRONZE PRODUCTS BY CENTRIFUGAL CASTING WITH A VERTICAL AXIS OF ROTATION AND A VERTICAL-TANGENTIAL GATING SYSTEM

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Abstract

This paper considers the production of cast bronze products by centrifugal casting with rotation of the mold around a vertical axis. The design features of a vertical-tangential gating system, the process of molten metal entering the mold, and its movement under the action of centrifugal force were investigated. The effect of two-stage control of the rotational speed on the density, microstructure, and mechanical properties of the castings was studied. During the first stage, a relatively low rotational speed of **300–350 rpm** was used to ensure uniform filling of the mold cavity with molten metal. At the second stage, the rotational speed was increased to **1000 rpm**, which promoted metal densification and increased the density of the casting. The results showed that the use of a vertical-tangential gating system combined with a two-stage rotational regime improves the quality of bronze castings and creates favorable conditions for the formation of a more homogeneous structure.

Keywords:

bronze, centrifugal casting, vertical axis, tangential pouring, molten metal, rotational speed, casting, microstructure, density.

Introduction

In the production of bushings, rings, bearing components, and other cylindrical products from bronze alloys, centrifugal casting is one of the effective technological methods. In this process, molten metal is poured into a rotating mold and, under the action of centrifugal force, moves along the mold wall, forming the required geometry of the casting.

In conventional casting methods, it is relatively difficult to ensure a stable direction and velocity of molten metal flow during mold filling. As a result, casting defects such as porosity, non-metallic inclusions, and non-uniform distribution of alloying components may occur. Therefore, the organization of tangential molten-metal feeding into the mold and optimization of its rotational speed are of great importance.

The use of a vertical-tangential gating system makes it possible to impart an additional tangential velocity component to the molten-metal flow. As a result, the metal begins to move along the wall of the rotating mold, which contributes to a more uniform distribution of the melt over the working surface of the mold.

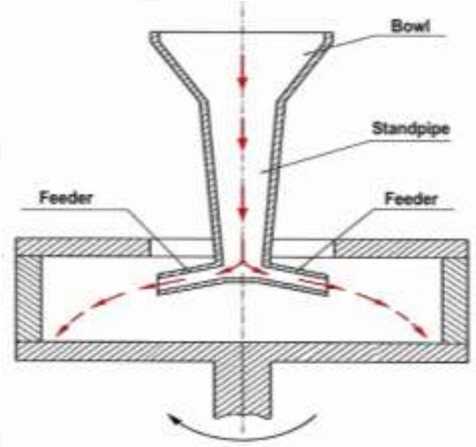

Figure 1. Cross-sectional view of a two-feeder vertical-tangential gating system.

Research Methodology

The study was conducted using a centrifugal casting machine in which the mold rotates around a vertical axis. A vertical-tangential gating system was used to feed the molten metal into the mold.

In this method, the tin-lead bronze alloy enters the mold cavity in the tangential direction and acquires rotational motion. Under the action of centrifugal force, the metal is pressed against the mold wall and moves along it.

One of the main features of the proposed technology is the two-stage control of the mold rotational speed.

At the first stage, a relatively low rotational speed of **300–350 rpm** was applied. The main objective of this stage was to ensure a stable flow of molten metal into the mold and its uniform distribution over the inner surface.

After the mold was filled, the rotational speed was increased to **1000 rpm**. At this stage, the increase in centrifugal force promoted metal densification and reduced the probability of liquation and porosity formation.

To characterize the effect of centrifugal force, the following expression was used:

$$\mathbf{F = m\omega^2 r},$$

where:

F — centrifugal force, N;

m — mass of the molten metal, kg;

ω — angular velocity of rotation, rad/s;

r — distance from the axis of rotation to the considered volume of metal, m.

As the rotational speed increases, the centrifugal force increases, resulting in stronger pressing of the metal against the mold wall.

When selecting the inclination angle of the tangential channel, the condition of stable molten-metal movement along the mold wall was taken into account. Based on the results of the conducted studies, an angle of approximately **15°** was found to be effective.

Results and Discussion

When pouring through the vertical-tangential gating system, a tangential velocity component is generated as the molten metal enters the mold. This intensifies the rotational motion of the melt and promotes its distribution over the mold surface.

Under the action of centrifugal force, both the molten and solidifying metal undergo densification. At the same time, the magnitude of centrifugal pressure increases with increasing radius. Therefore, the outer layers of the casting are formed under a greater centrifugal effect.

An increase in the rotational speed at the second stage of the process contributes to an increase in the pressure exerted by the metal on the mold wall and promotes additional densification of the casting.

In the conducted experiments, changes in the rotational speed were accompanied by changes in the mechanical and physical properties of the bronze castings.

Rotational speed, rpm	**300**	**500**	**700**	**900**	**1000**
Tensile strength, MPa	180	235	281	341	345

Table 1. Tensile strength of a bushing made of BrOCSA5-5-3-0.5 alloy produced by two-stage centrifugal casting as a function of rotational speed.

The data presented in Table 1 show that, as the rotational speed increased from **300 to 1000 rpm**, the tensile strength increased from **180 to 345 MPa**.

The increase in strength can be attributed to a higher degree of metal densification under the action of centrifugal force, reduced porosity, and improved conditions for the formation of the cast structure.

The application of the two-stage rotational regime is of particular interest. At the first stage, the relatively low rotational speed ensures stable filling of the mold, while at the second stage, an increase in the rotational speed promotes further densification of the casting.

This regime makes it possible to separate the processes of mold filling and metal densification, thereby enabling more effective control over the formation of the casting.

Effect of the Technology on Microstructure Formation

In centrifugal casting, the formation of the microstructure is determined by the combined effects of molten-metal flow, heat transfer between the metal and the mold, cooling rate, and crystallization conditions.

The tangential inflow of metal promotes its rotational movement along the mold wall. At the same time, an increase in the rotational speed at the second stage provides additional metal densification during solidification.

As a result, favorable conditions are created for the formation of a denser and relatively homogeneous casting structure.

The two-stage rotational regime also makes it possible to reduce the probability of air entrapment and oxide inclusions during mold filling compared with a regime in which a high rotational speed is established immediately at the beginning of pouring.

Conclusion

Based on the results of the conducted studies, the following conclusions can be drawn:

1. Centrifugal casting with rotation of the mold around a vertical axis is an effective method for producing cylindrical bronze products.
2. The use of a vertical-tangential gating system provides tangential movement of the molten metal along the mold wall and promotes more uniform mold filling.
3. According to the results of the conducted studies, an angle of approximately 15° for the tangential introduction of molten metal was found to be effective.
4. The two-stage rotational regime, with a rotational speed of 300–350 rpm at the first stage and an increase to 1000 rpm at the second stage, makes it possible to separate the processes of mold filling and casting densification.
5. An increase in the rotational speed from 300 to 1000 rpm was accompanied by an increase in the tensile strength of the investigated bronze castings from 180 to 345 MPa.
6. The use of a tangential gating system combined with a two-stage rotational regime creates favorable conditions for increasing the density, reducing porosity, and forming a more homogeneous microstructure of bronze castings.
7. The proposed technology can be recommended for the production of bushings, rings, and other cylindrical products from bronze alloys.

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