UDC 621.771.11

Modeling of Crystallization Processes of Cast Iron Grinding Balls in Casting Molds of Improved Design

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A new design of casting mold for the production of balls on the conveyor molding machine was developed and modeling the crystallization of cast iron in it was performed. Replacement of the mold design has a positive effect on improving the quality of the balls and their operating factors by reducing the shrinkage defects.

Keywords: GRINDING BALLS, CASTING MOLD, MODELING, SHRINKAGE DEFECTS, GATING SYSTEM.

Introduction

During the production of cast iron grinding balls in Ukraine the conveyor molding machine ККУ–1 was the most widely adopted [1]. The quality of cast iron balls produced on this machine is controlled in accordance with GOST 7524-89 and TU U 322-228-144-2004.

The efficiency of grinding mills depends on the quality and the production characteristics of grinding balls (productivity, grinding quality and quantity of milling, etc.). The most important production characteristics of balls are hardness, shock and wear resistance, since during the mill performance balls are subjected to shock and abrasion. Performance indicators in their turn depend on the quality of balls: the conformity of chemical composition, regular geometric shape of balls (without distortions, sink marks, etc.), the presence of shrinkage defects, macro-and microstructure.

When using the conveyor molding machine the casting technology allows achieving the product yield up to 75%. Such a low product yield is determined by the appearance of casting defects (sink marks under the feeder, piping, joint flashes, etc.). The formation of ball defects can be explained by following factors:

- casting factors: casting temperature, chemical composition of cast iron, casting speed and cooling mode of molds, which lead to the formation of sink marks, shrinkage defects, runouts;
- construction factors associated with discrepancy to the given casting mold dimensions, formed due to its wear and tear (mold crazing, center adjustment failure, etc.). These factors lead to the appearance of joint flashes, distortions and other defects. The largest mold crazing is formed in the gating system, due to uneven distribution of the temperature field.

In this regard, the search for alternative methods of improving the production technology of cast-iron grinding balls by the conveyor molding machine that will increase the product yield of casting with minimum economic cost is continued.

Methodology

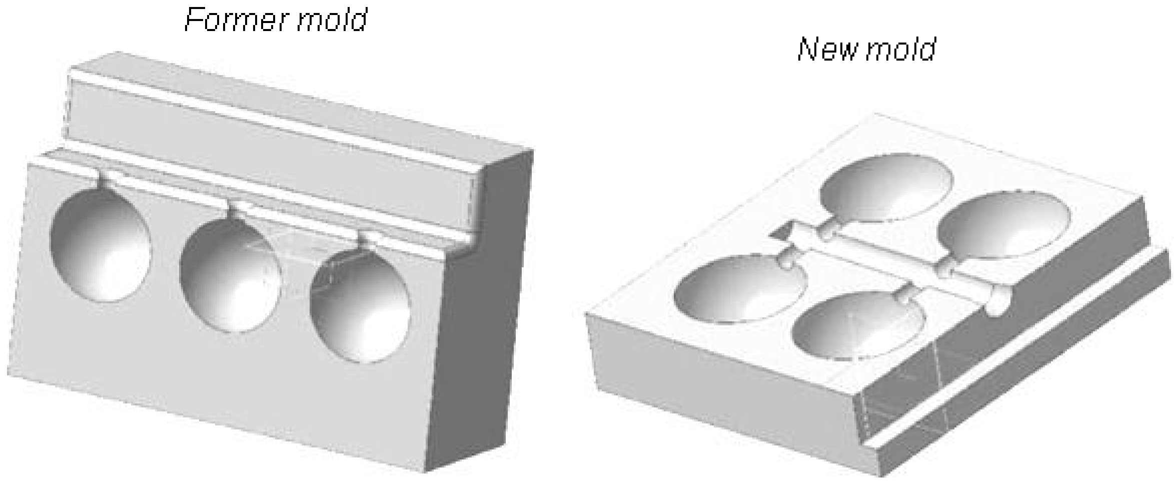
The objective of this paper is to reduce defects of cast iron grinding balls, improving the production characteristics of the balls (shock resistance and lasting quality) while maintaining or increasing productivity of the conveyor molding machine. For this purpose the following suggestions were developed:

- redesign the mold from a 3-matrix into a 4-matrix one, what will increase the productivity of the machine in ~ 1.27 times;
- replace the power supply of gating system from open to closed, what will help to reduce shrinkage defects and, consequently, improve the production characteristics of the balls.

Results and Discussion

After analyzing the current technology of cast iron grinding balls production by the conveyor molding machine, a number of disadvantages associated with the mold design were identified.

The current 3-matrix mold (**Figure 1a**) does not satisfy the feeding requirements of balls during crystallization, because cast iron in the gating system is quickly crystallized, what leads to appearance of shrinkage defects. The gating system of a new 4-matrix mold (**Figure 1b**) is closed, what allows retaining its temperature for maximum feeding the ball with liquid metal. Thus, reducing of the balls flaw, determined by shrinkage defects, is assumed. Replacing the 3-matrix molds by 4-matrix ones would not lead to the change of the fixing points.

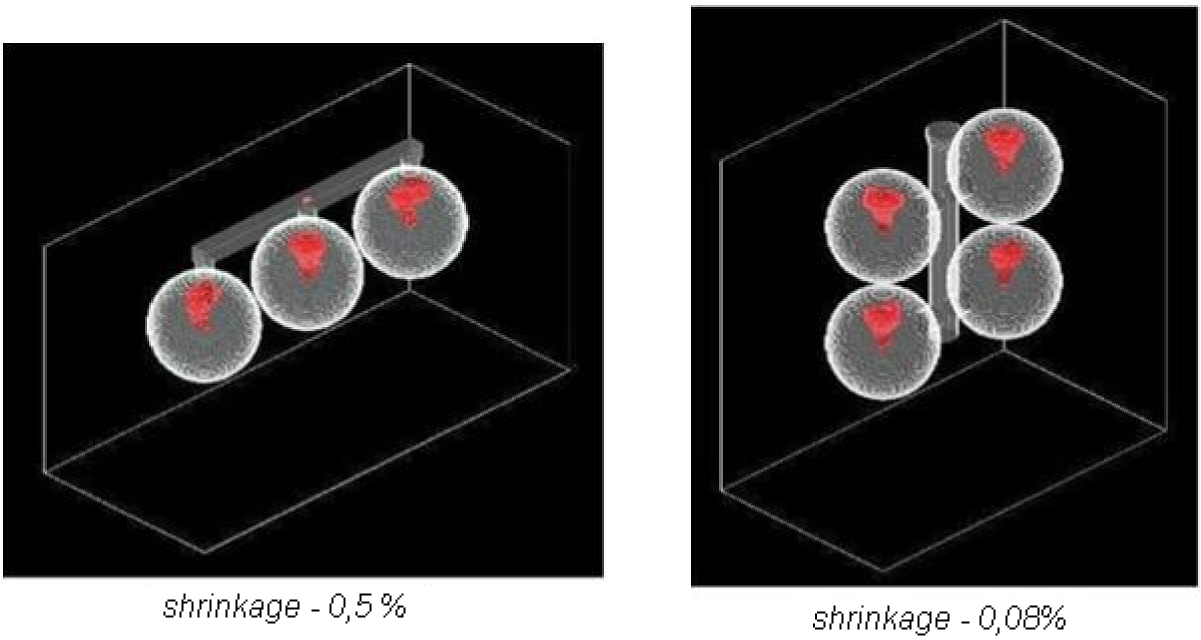


a **b**

Figure 1. General view of the molds: a – 3-matrix mold, b – 4-matrix mold

In order to predict the formation of shrinkage defects in the balls a computerized modeling of cast iron crystallization in the mold was performed with the use of computer program LVMFlow.

The modeling results showed that the design replacement allowed reducing mold shrinkage defects significantly (**Figure 2**).



a **b**

Figure 2. Modeled shrinkage defects in a 3-matrix mold (a) and 4-matrix mold (b)

The reasons for the mold crazing, with which such defects as joint flashes, penetration, etc. are associated, were also analyzed. The main reason for the mold crazing is connected to the uneven distribution of temperature fields in the mold. Besides, the uniformity of the mold temperature fields contributes to the direct crystallization of the balls.

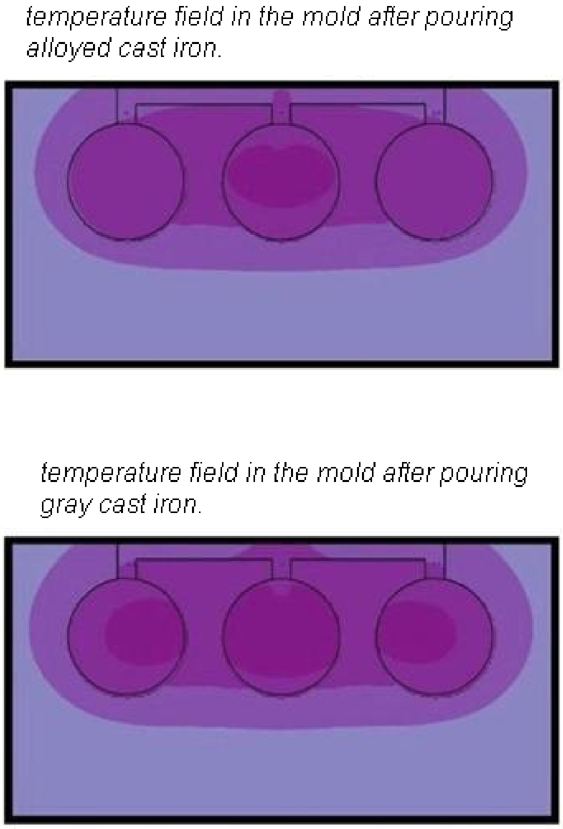


Figure 3. Distribution of temperature fields in the 3-matrix mold after pouring alloyed and gray cast iron.

One of the main characteristics of the mold technological effectiveness is its thickness. According to recommendations [4], the mold thickness should be 0.5-0.8 D_{cast}. On this basis, the mold for the ball Ø 60 mm thick must be at least 30 mm, maximum 48 mm as opposed to the one used at the conveyor molding machine MCC - 50 mm.

The process of distribution of temperature fields in the 3-matrix mold, depending on the chemical composition of cast iron, was modeled. Two chemical compositions were selected for the modeling: alloyed and gray cast iron, which are used in current production. After pouring alloyed and gray cast iron into the mold (**Figure 3**) it can be observed that when pouring alloyed cast iron under the same conditions the temperature field is not distributed uniform. When pouring gray cast iron the temperature field is more uniform compared to alloyed cast iron. In 4-matrix mold compared to the 3-matrix one (**Figure 4**) it can be seen that the gating system remains hot longer and can be a feeder for the ball. When analyzing the effect of increasing the thickness of the mold it can be observed that its increase over 30 mm leads to a violation of the uniformity of the temperature field and results in an increase of shrinkage defects and the mold crazing (**Figure 5**).

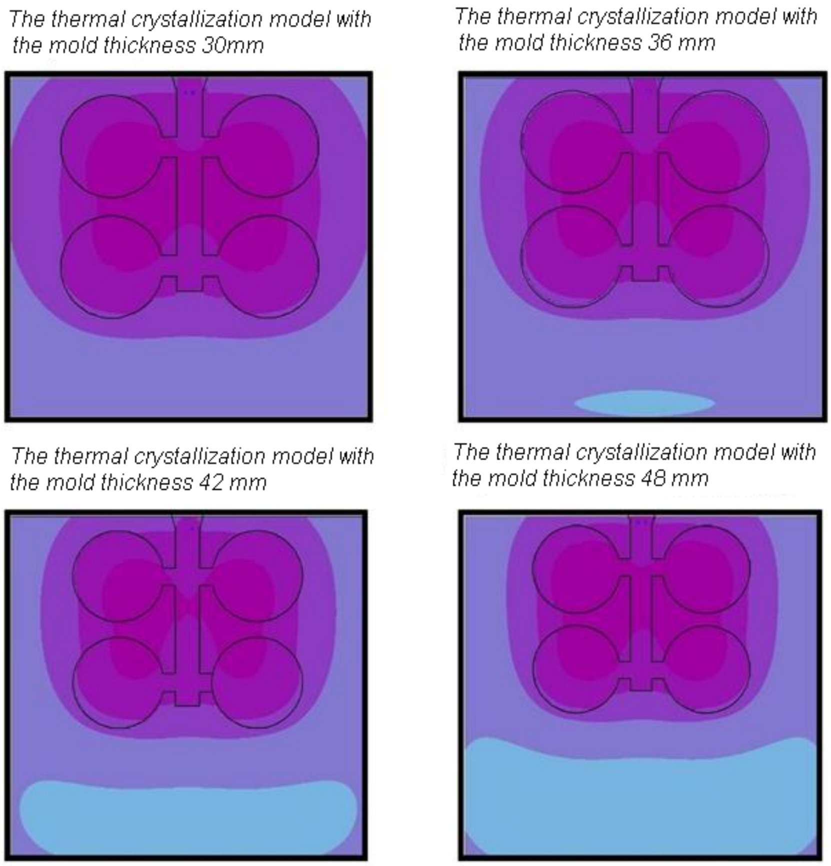


Figure 4. The thermal model of the cast iron crystallization with different thickness of 4-matrix mold

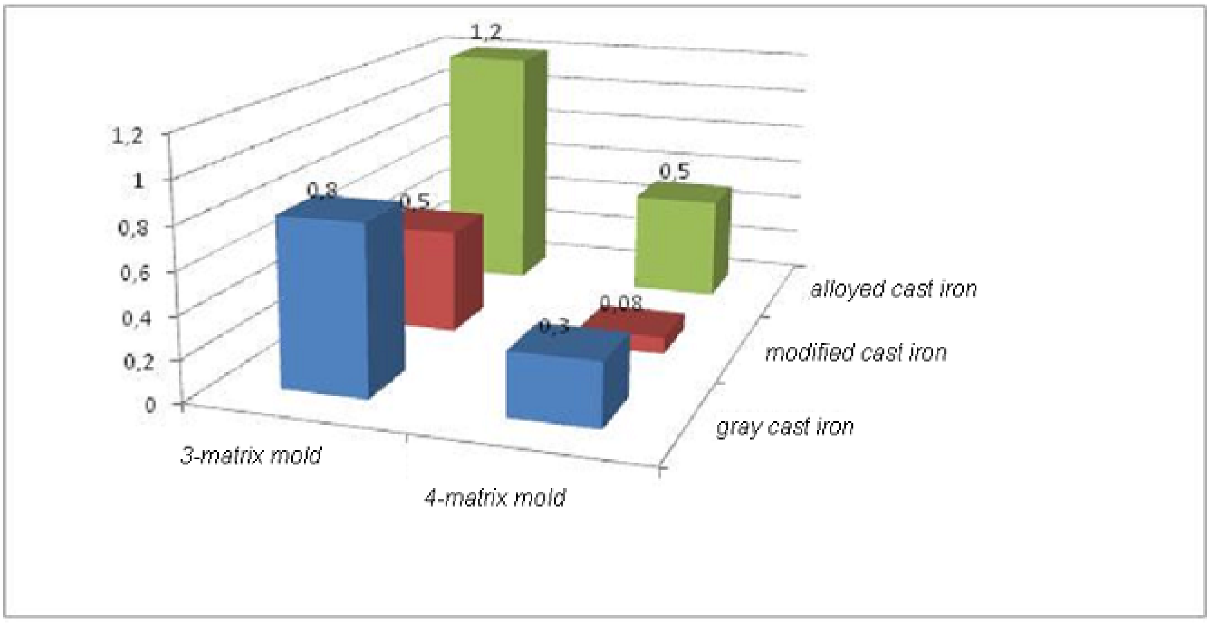


Figure 5. The level of balls shrinkage depending on the mold construction and chemical composition of cast iron.

Conclusions

As a result of modeling the recommended replacement of a 3-matrix with a 4-matrix one, it can be concluded that the mold improvement will allow:

- reducing the shrinkage of the balls from 0.5 to 0.08% at the expense of feeding the closed gating system;
- reducing the mold crazing and, accordingly, the ball rejects according to the discrepancy of the ball configuration of the ball by means of equalizing the temperature fields in the mold.

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* Published in Russian

Received June 30, 2011

Моделирование процессов кристаллизации чугунных мелющих шаров в кокиле усовершенствованной конструкции

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Разработана новая конструкция кокиля для производства шаров на конвейерно–кокильной установке и проведено моделирование кристаллизации в нем чугуна. Замена конструкции кокиля положительно влияет на повышение качества шаров и их эксплуатационные характеристики за счет уменьшения усадочных дефектов.