# Efficiency of using heat-insulating mixtures to reduce defects of critical parts

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**Abstract.** A study was conducted to reduce defects in especially critical cast large-sized parts of freight car bogies. The side frame was used as the part under study. The main factors influencing the formation of hot cracks in large steel castings are presented. To avoid the rejection of steel castings, the use of heat-insulating mixtures to reduce hot cracks has been investigated. The temperature distribution of the melt along the height of the ladle is modeled. An analysis of the influence of the order of pouring molds and pouring temperature on the number of hot cracks in the side frames is presented.

## 1 Introduction

The category of castings for critical purposes includes products that operate in difficult operating conditions, to which high-quality requirements are imposed, some which are used in units and devices of freight cars of railway (RHD) transport. Railway transport, one of the most important modes of transport in Uzbekistan, plays a significant role in ensuring the work of the domestic economy. In railway freight cars, cast parts determine their operational reliability and durability. According to statistical and practical data, steel castings with casting defects, especially those with hot cracks, lead to many accidents on the railway. Given the increase in the number of accidents in recent years, it should be noted that improving the safety of transportation is the main task of the industry. In this regard, providing the railway industry with high-quality cast products is an important area of scientific research. Fracture of cast side frames is one of the causes of accidents on the railway not only in Uzbekistan but also abroad. Figure 1 shows a recorded case of such an accident. The study of some emergencies showed the presence of hot cracks (HT) on the fracture surface of cast parts of freight car bogies [1, 5-9].

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**Fig. 1.** Emergency on railway (a) as result of destruction of the cast side frame (b)

One of the problems with side frames is the kink. During an operation, a break in the side frame leads to economic losses and human casualties.

During operation, there are mainly two fracture types - fatigue and brittle. The reasons for the fracture of the side frames can be different. For example: due to the formation and development of a fatigue crack, internal casting defects (shrinkage holes, gas holes, hot cracks), thermal stresses, underfilling, and waviness. In the course of studying the causes of the occurrence of a "hot crack" defect in production, a sufficient amount of data was revealed (Fig. 2) [2-4].

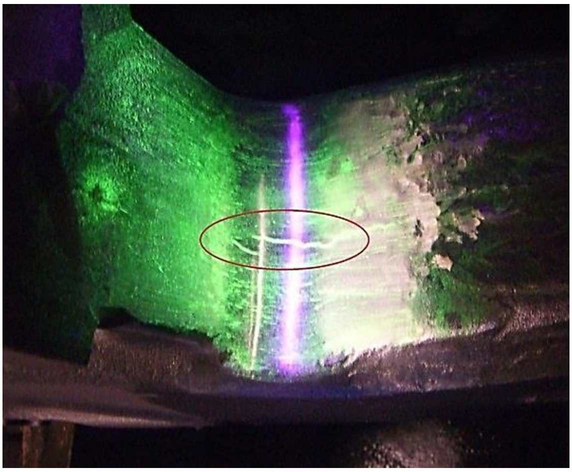

**Fig. 2.** Hot crack

## 2 Methods

In the DP "Casting and Mechanical Plant", 8 molds of the side frames of the steel-pouring ladle with a capacity of 6 tons are poured from each heat with 20GL steel, smelted in an induction crucible furnace into raw sandy-clay molds. The temperature of the metal in the induction furnace before pouring it into the steel ladle is 1680°C. The metal from the furnace is poured into the ladle for 2 minutes, while the temperature in the ladle is 1610±10°C.

The side frame is the bearing part of the freight car bogie, the overall dimensions of which are 2450×550×651 mm. There is one casting in the flask. The frame experiences dynamic, static, and vertical loads during operation. These loads are cyclical. Therefore, the fatigue strength of a part is an important characteristic of operational reliability [3-5].

## 3 Results and Discussion

Under industrial conditions, a series of experiments were carried out in a steel-pouring stop ladle with a capacity of 6 tons with a main lining. As the level of liquid metal in the ladle decreases, its temperature decreases. To find the liquidus temperature and pouring temperature, the following expressions are used:

$$T_l = 1539 - 80 \cdot [C] \qquad (1)$$

$$T_{pour} = T_l + 30 \ldots 50°C. \qquad (2)$$

From this formula, you can find the liquidus temperature and the filling temperature for steel 20GL. The carbon content in steel 20GL ranges from 0.17 to 0.25%. Then, according to formula (1), the filling temperature is in the range of 1519 to 1525°C. According to formula (2), the temperature of pouring metal from the ladle into molds is 1550 to 1575°C.

When pouring the first and last mold, the temperature of the poured metal is lower than the temperature in the middle of the ladle. This is because the poured metal on the first mold is located in the bottom of the ladle and contacts with the large volumetric surface of the ladle; that is, part of the drained metal is cooled, giving off heat to warm up the lining [11-13]. The metal intended for pouring the last form is in contact with atmospheric air. A Heraus Electronite thermocouple (Germany) determined the metal temperature in the steel-pouring stop ladle. A high-temperature pyrometer was used to determine the temperature of the metal jet during pouring into molds. A certain regularity in the occurrence of hot cracks has been established, depending on the sequence at three different temperatures for pouring hot crack molds, which form in the middle part of the steel-pouring ladle at the beginning, middle, and end [14-22]. The results of experiments on the number of reject depending on the pouring sequence at different temperatures are shown in Figure 3.

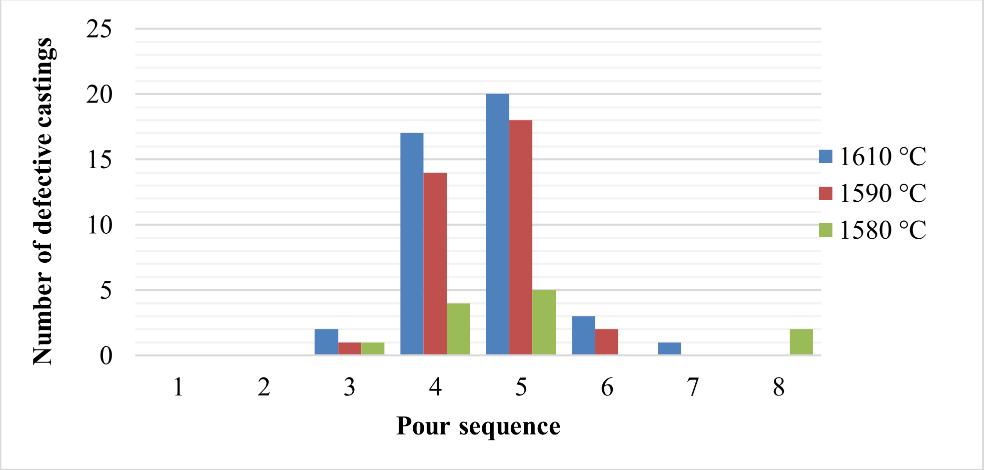

**Fig. 3.** Dependence of number of defective parts on pouring sequence at different temperatures

As can be seen from Figure 3, defective parts are found from the third to the fifth form. The pouring temperature, in this case, ranges from 1580 to 1610°C. To explain this fact, computer simulations of the process of temperature distribution over the volume of a steel-pouring ladle with a capacity of 6 tons were carried out during metal holding in transporting liquid metal and pouring metal (Fig. 3).

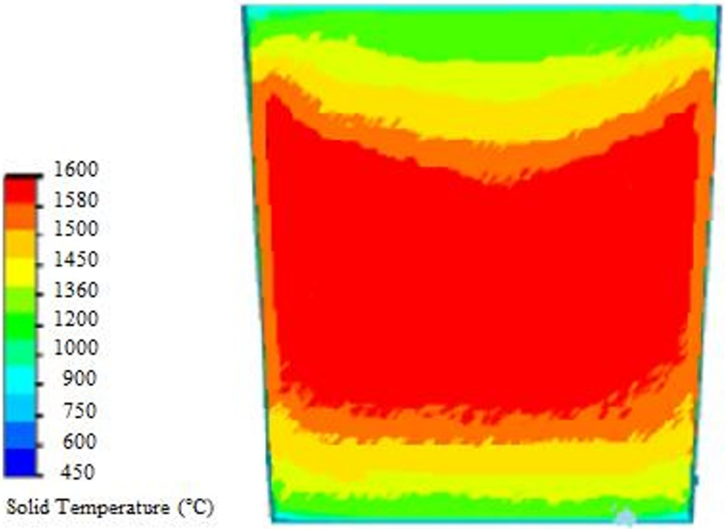

**Fig. 4.** Temperature distribution in melt during its transportation

As can be seen from Figure 4, built based on the rejection of castings, the largest number of castings rejected by hot cracks is observed during the period of pouring medium molds (filling order 4 ... 6). Computer simulations are shown in fig. 5. shows that at the middle stage of pouring, the temperature of the liquid metal is higher. This is because at the moment of pouring, the metal is hotter (heat does not escape sufficiently due to contact with the lining on two side walls), and its temperature in the ladle with a capacity of 6 tons during this period is 1550 ... 1560°C against 1590 ± 10°C before pouring.

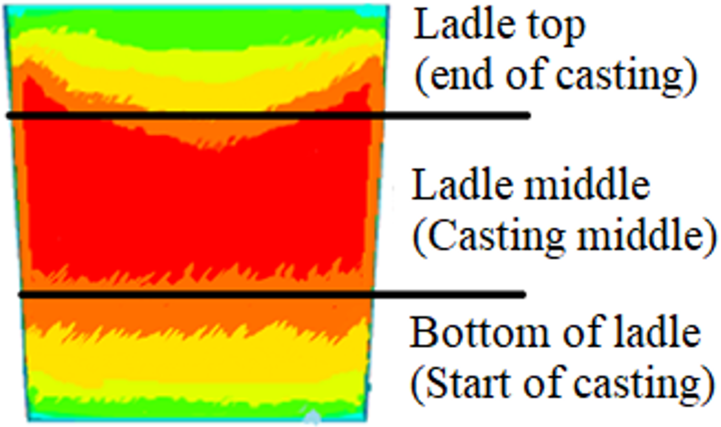

**Fig. 5.** Temperature distribution in melt by sections

At the beginning of the pouring period and at the end of the pouring, there is no rejection since in these periods, the temperature of the liquid alloy is 1550 ... 1570°C, that is, less than in the average casting period, therefore it crystallizes faster, and the resulting crust of the crystallized metal has sufficient thickness and strength to resist shrinkage.

During the experiments, it was revealed that if the pouring temperature is lowered, then underfilling is formed in the last forms, and part of the metal cools down in the ladle. The main reason for this is that as the liquid metal decreases in the cavity, more heat is lost compared to the initial period (top of the ladle)

The modern technology of steel casting puts forward the task of reducing the heat loss of the metal during its stay in the steel-pouring ladle during holding and casting. It is known that the slag on the metal surface has insufficient thermal insulation properties, causing increased lining erosion in the operation of the slag belt. Therefore, it is necessary to replace the slag with an inert heat-insulating mixture (Fig. 6).

**Fig. 6.** Insulating compound

Experiments were carried out using heat-insulating mixtures. After pouring the metal from the furnace onto the ladle, a carbon-based heat-insulating mixture was added to the metal surface in an amount of 20 kg. The temperature of metal tapping from the furnace was 1640°C. The temperature in the ladle was 1585 ± 5°C. According to this technology, 32 side frames were poured.

When using the proposed technology, that is, heat-insulating mixtures did not show hot cracks, while the fit parts increased from 60 to 97%. The temperature at the beginning of pouring ranged from 1560 to 1565°C, in the middle, 1570 to 1580°C, and at the end of pouring, 1565 to 1575°C.

## 4 Conclusions

An effective technology for pouring metal using heat-insulating mixtures has been developed to reduce defects in large critical parts of freight car bogies. Quantitative dependences of the technological parameters of pouring metal into molds are obtained, which form the basis of a new technological instruction for pouring steel 20GL. The proposed technology for pouring 20GL steel into molds using heat-insulating mixtures made it possible to increase the yield of good parts for railway bogies by 40%. The results of theoretical analysis, experimental studies, and conclusions made in this work allowed us to formulate the following recommendations for improving the technology of pouring 20GL steel using heat-insulating mixtures. In the future, to homogenize the temperature of the metal in the volume of the ladle, the technology of purging argon through blocks installed directly in the bottom of the steel-pouring ladle, without exposing the metal, will be used. This leads, first of all, to a decrease in the number of non-metallic inclusions in steel and their uniform distribution in the volume of the metal. As a result of the implementation of the results of an effective pouring technology using heat-insulating mixtures, an annual economic effect of 2.5 billion soums was obtained.

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