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Solidification of the casting in a sand mould with forced cooling

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The casting solidification is one of the most important stages of the manufacturing of casted details. During solidification a microstructure is formed. Final microstructure will affect the mechanical properties of the casting. One of the parameters influencing the casting microstructure, besides the chemical composition, is a cooling rate. By controlling the cooling rate one may affect the type of phases and their size. Therefore so it's important to choose adequate cooling conditions especially in the case of large-size casting that are cast in sand moulds. Due to the thickness of the casting wall the control of the cooling rate becomes difficult. In order to avoid unnecessary scrap computer systems of foundry processes modelling may come with aid [1, 2].

This paper presents an analysis of the solidification process of the ductile iron in sand mould with forced cooling, based on computer simulations done in the Magma Soft. At the stage of numerical examination different simulation parameters were considered. The results of numerical studies showed that under forced cooling the casting can be faster taken out of the mould. Differences in the casting rate at eutectoid reaction allows to control microstructure of the casting [3,4].

Keywords: *solidification, ductile iron, cooling condition, simulation.*

1. Introduction

Quality of casted details depends mostly on the cooling and solidification process run. Especially in the case of ductile cast iron several stages of microstructure forming can be distinguished. The analysis undertaken in this work was to analyse the cooling and solidification process of ingot mould (Fig. 1) for permanent ingot casting.

In presented work the influence of proposed cooling system (Fig. 1) on casting solidification time as well as the time to removal from the mould was analysed. The casting can be shake out from the mould as soon as the temperature in the ingot mould drops below 400 °C.

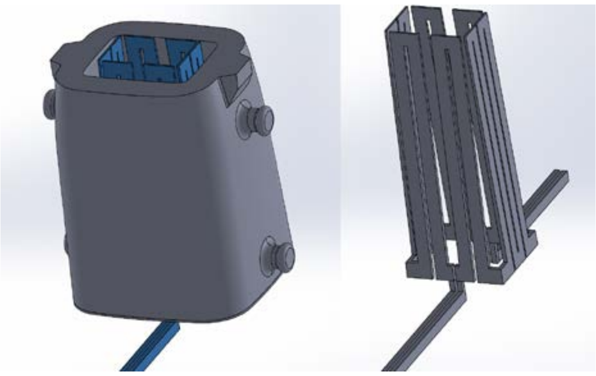

Fig. 1. Ingot mould with cooling system (left hand side) and cooling system (right hand side)

2. Numerical model

2.1 Boundary - initial conditions

The casting geometry as well as design of cooling system was provided by KrakOdlew foundry. Height of ingot mould was 2100 mm its maximal width 2088 mm. It was made of GJS-400 (Table 1) ductile cast iron. Pouring temperature was 1310 °C. Mould, core and pumped cooling liquid (mixture of air and water) temperatures at the beginning of the process were equal to 20 °C. Pumping pressure for the cooling liquid was different for new versions of simulations. Base value was 6 atm. Mould and core was made by furan. Cooling system cover was made by steel plate 50 mm thick.

Table 1. Composition of GJS-400 cast iron (wt.%) – Fe balance [5]

C	Si	Mn	Mg	Cu	P	Cr
3.75	1.8	0.36	0.035	0.013	0.04	0.01

2.2 Simulations

Simulations were performed for case without cooling system and for the cooling systems under different pumping pressures of the cooling liquid : under 4, 6 and 8 atmospheres.

3. Simulation results and discussion

During described work four versions of simulations were performed. Results were analysed under the following conditions: influence of forced cooling on the shake out time, eutectoid reaction rate, core cooling and crystallization process. Results are gathered in the graphs and tables.

In the figure 2 influence on crystallization curve is shown. The influence is not significant, however the system without forced cooling crystallization time is longest.

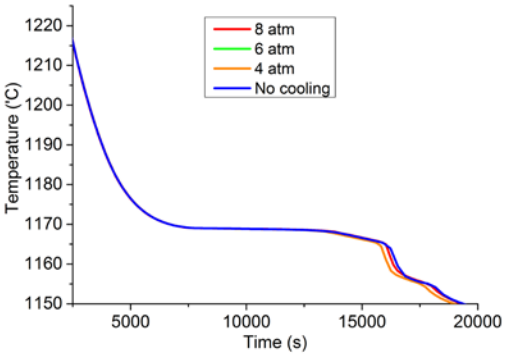

Fig. 2. Forced cooling influence on crystallization process

In the figure 3 influence on core temperature distribution after 4th day of cooling is shown. The cooling system changes behaviour of the core which is much warmer than the casting in the case without forced cooling. Forced cooling lowers significantly temperature near to casting wall.

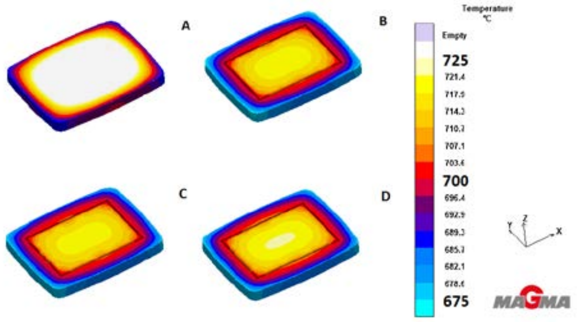

Fig. 3. Core temperature distribution after 4 days of cooling: A – without forced cooling; B – pumping pressure 8 atm.; C – pumping pressure 6 atm.; D – pumping pressure 4 atm.

In table 2 cooling rate at eutectoid reaction temperature is gathered. Differences in the cooling rates can lead to the conclusion that forced cooling may influe on more amount of pearlite

Table 2. Cooling rate at eutectoid reaction, (10^{-4}K/s)

No cooling	4 atm.	6 atm.	8 atm.
-6.87	-7.08	-7.1	-7.18

In table 3 casting shake out times are gathered. The forced cooling makes shake out waiting time about 7% shorter.

Table 3. Casting shake out times (10^4 s)

No cooling	4 atm.	6 atm.	8 atm.
88.28	84.84	84.32	82.15

4. Conclusions

Forced cooling has no significant influence on crystallization process. It has impact on cooling process of the casting. It is important as it reduces the core temperature and makes cooling rate at eutectoid reaction greater. In effect the microstructure of ductile cast iron will be different. Another beneficial impact is reduction of shake out time. This has influence on foundry production capacity and income.

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