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# The Influence of the Pouring Temperature on the Structure and Mechanical Properties of High-Chromium Cast Iron

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## Abstract

The article presents the results of the influence of pouring temperature on the structure and selected properties of high-chromium cast iron. The study was performed on two different pouring temperatures 1490°C and 1460°C for cast iron of the same chemical composition. Melts were performed in the induction furnace crucible capacity of 15 kg located in the Department of Engineering Alloys and Composites in Foundry Engineering Faculty of AGH. For each temperature cast 2 sets of rollers with dimensions ø30mm, ø20mm, ø15mm x 250mm. During the heats poured cup with installed S type thermocouple to record the cooling curves. Rollers put to the static bending strength test. Samples were cut from the rollers for the test microstructure. The study shown that the pouring temperature has a significant impact on the way of crystallization of high-chromium cast iron and consequently, on the microstructure and mechanical properties. It follows that, by appropriate selection of the pouring temperature can control certain properties of the casting.

**Keywords:** High-chromium cast iron, pouring temperature, bending strength, cooling curves, microstructure.

## 1. Introduction

The pouring temperature has a significant impact on the structure and thus the properties of cast iron, but the views of researchers at the direction of the effects are varied [1-9]. No unanimity is mainly connected with the lack of stabilization of test; namely increasing the temperature of pouring is often correlated with an increase in temperature of overheating or prolonged time withstand iron. The pouring temperature and other thermal phenomena occurring in the metal after casting to mold affect the entire crystallization process, and consequently the formation of structure.

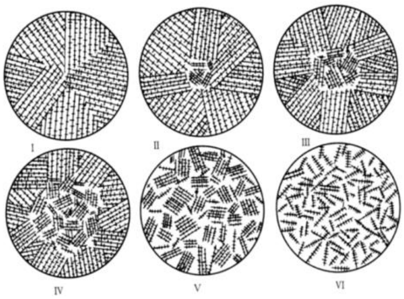

Fig. 1. Range of types of dendritic crystallization of primary austenite in white cast iron. Marking: I - crystallization exogenous (directional), II, III, IV - crystallization exogenous - endogenous, V, VI - crystallization endogenous [1]

In the paper [1] distinguished range of types of primary crystallization of austenite in white cast iron (Fig. 1). White cast iron (including chromium cast iron) has mainly morphology I and II type. The type of crystallization of austenite dendrites can be controlled by changing technological factors. Tendency to crystallize endogenous increases with increasing carbon content and pouring temperature.

For the correct interpretation of the changes that occur in the structure of high-chromium cast iron during self-cooling, it is necessary to analyze the triple phase system Fe-C-Cr alloys (Fig. 2). However it should be noted, that the other elements that occur in the high-chromium cast iron, has also the influence on the structure. Phase equilibrium systems are the basis for the interpretation of the structure of all alloys. They illustrate the phase composition of alloys and phase transitions as a function of the chemical composition of the alloy and temperature.

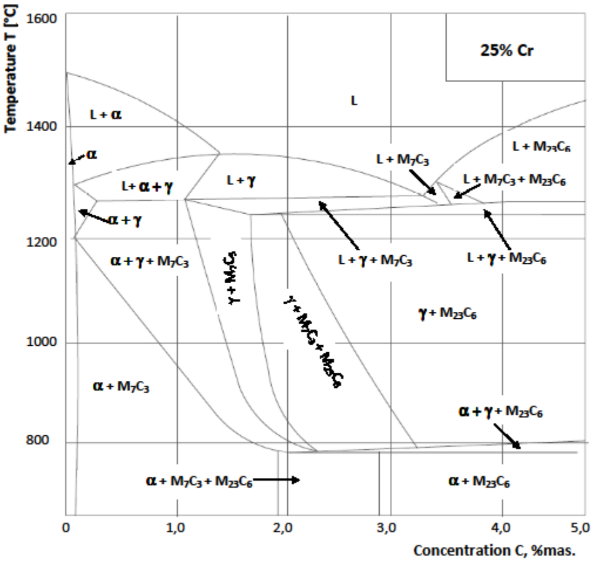

Fig. 2. The isopleth section of the phase system of alloy Fe-C-Cr containing 25 %Cr [1]

## 2. Methodology

The aim of this work is to determine the effect of pouring temperature on the structure and some mechanical properties of cast iron. The tests were performed on the high-chromium cast iron with the chemical composition shown in Table 1

Table 1. The chemical composition of the high-chromium cast iron

| Element | Fe | C | Si | Mn | P | S | Cr | Mo | Ni | Cu |
|---|---|---|---|---|---|---|---|---|---|---|
| % mas. | 71 | 3,23 | 0,519 | 0,646 | 0,0384 | 0,0259 | 23,8 | 0,119 | 0,34 | 0,108 |

Melts were carried out in an induction furnace with a capacity of 15 kg located in the Department of Engineering of Cast Alloys and Composites in Foundry Engineering of AGH. Performed two melts of the cast iron with the same chemical composition for different pouring temperature 1490 ° C and 1460 ° C. For each temperature was cast 2 sets of rollers with dimensions ø30mm, ø20mm, ø15mm x 250mm. Separately molded the cups with S-type thermocouple to measure the cooling curves using a recorder AGILENT. The rollers were subjected static bending strength test, which was then excised from the microstructure test sample. The samples were mounted in the acrylic resin, followed by the rough grinding discs of diamond grit 120, 220, 600, and 1200 in a forced stream of water, the speed of the wheel - 300 rpm and pressure 30N. Then microsections were polished on the face of the cloth polishing using a slurry with particles of diamond size 9 and 3 microns and lubricant STRUERS. Samples were rinsed in anhydrous ethyl alcohol (ethanol 99.8%) and dried in a stream of hot blow in the oven. Microsections were etched in Vilella reagent. Metallographic analysis was performed using an optical microscope MEF-4M LEICA, aided with automatic image analysis LEICA Qwin.

## 3. Results an discussions

### 3.1. Cooling curves

Each cooling curve has a characteristic points corresponding to the extending phase crystallization processes in the field of solidification and cooling of the casting. Hence, it is important to do the thermal analysis during every melt [3-7].

Figures 3 and 4 show the cooling curves and the first derivative for different temperature of casting. From presented in Figure 5 cooling curves for the two temperatures, it can be seen that the pouring temperature affects the crystallization time. With the increase in pouring temperature the crystallization time increases, and the degree of supercooling decreases. The consequence of this is a lower the density and the speed of grain growth.

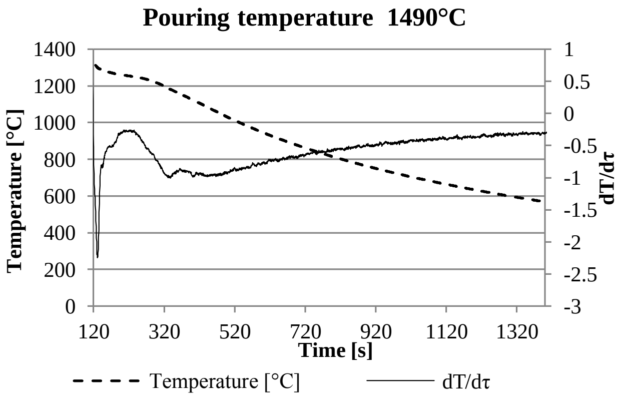

Fig. 3. Crystallization and cooling curve and the first derivative of cooling curve for pouring temperature 1490 °C

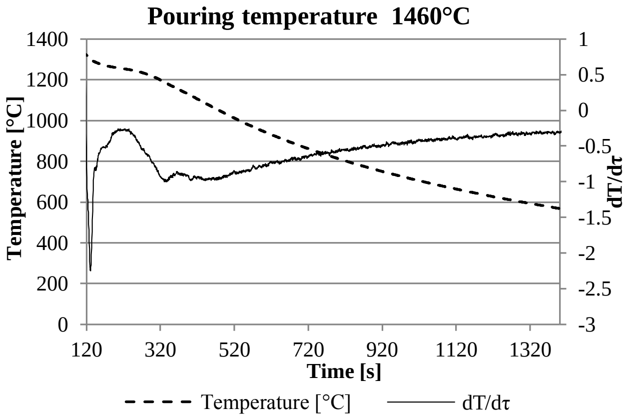

Fig. 4. Crystallization and cooling curve and the first derivative of cooling curve for pouring temperature 1460 °C

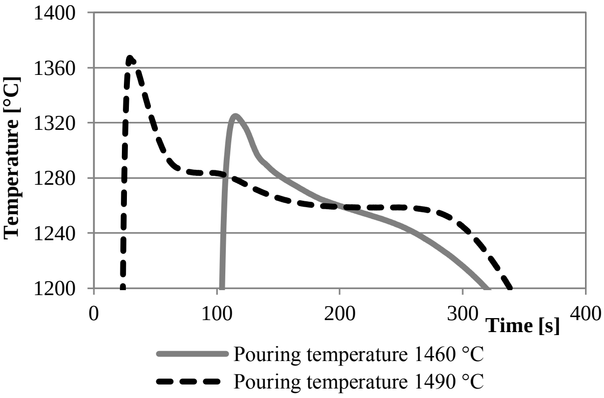

Fig. 5. Crystallization and cooling curves for pouring temperatures 1460 °C i 1490 °C

## 3.2. Bending strength

The cast rollers sample were subjected to the static bending strength. Figure 6 shows the results.

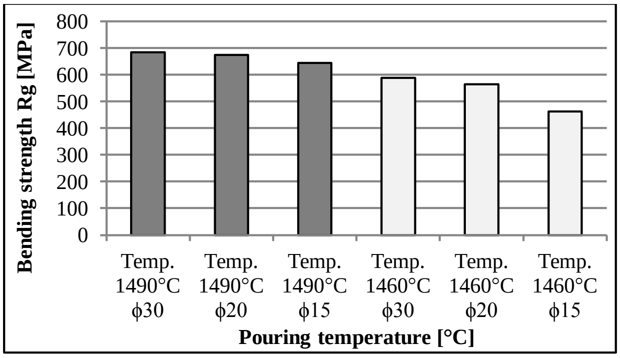

Fig. 6. The bending strength of the rollers with a diameter ø30 mm, ø20 mm and ø15 mm, pouring temperature – 1490 °C and 1460 °C

From Figure 5 it follows that the larger the value of pouring temperature the crystallization time is longer, it is connected directly to the properties of strength (Fig. 6). For the higher pouring temperature the crystallization time is longer, thus the number of grains is larger, and consequently the bending strength Rg is higher.

Figures 7 and 8 show the pictures of breakthroughs and macrostructure of rollers with ø20mm diameter for different pouring temperature.

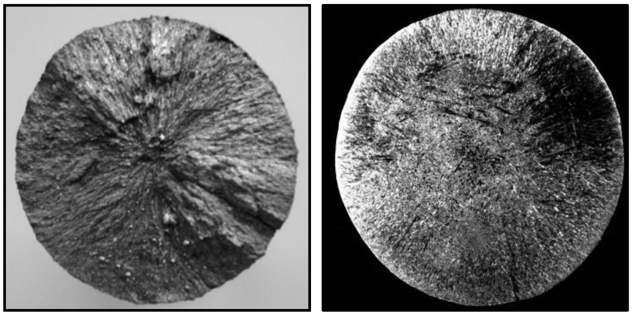

Fig. 7. Breakthrough and macrostructure of sample with ø20 mm diameter for pouring temperature 1490 °C after the test for bending strength

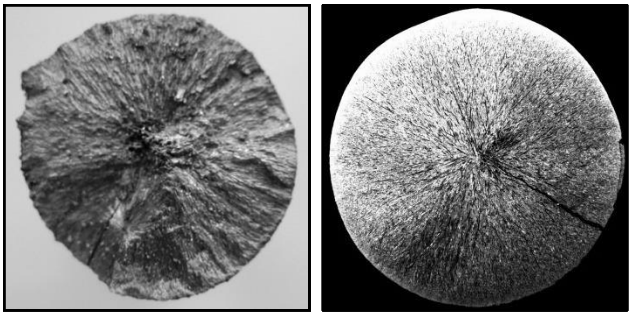

Fig. 8. Breakthrough and macrostructure of sample with ø20 mm diameter for pouring temperature 1460 °C after the test for bending strength

From the Figure above it can be seen that pouring temperature had an impact on type of the crystallization. On the macrostructure for pouring temperature 1460 °C (Fig. 8) only columnar grains can be notice, so the cast crystallized exogenously. For macrostructure of higher pouring temperature (Fig. 7) can distinguished two types of crystallization – in the center of the sample cast crystallized endogenously, and on the border exogenously.

These results show that the pouring temperature has influence on the type of crystallization and consequently on the strength properties.

## 3.3. Microstructure

Figures 9 and 10 show the microstructures of samples cut from the rollers with the ø20 mm diameters, for different temperatures, appropriately 1490 °C i 1460 °C.

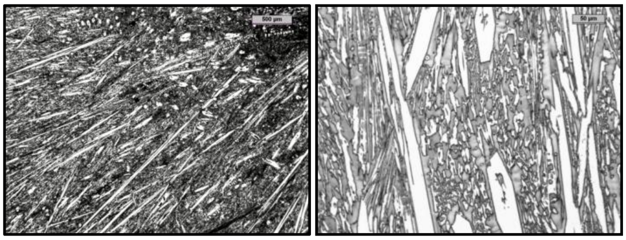

Fig. 9. Microstructure of sample with the ø20 mm diameter for pouring temperature 1490 °C, magnification 25x and 200x

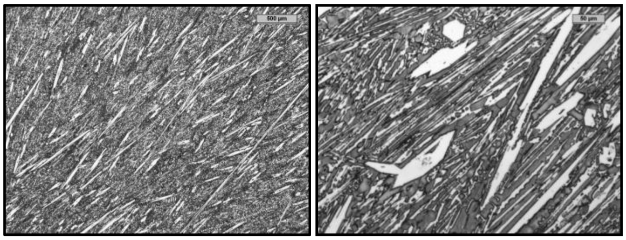

Fig. 10. Microstructure of sample with the ø20 mm diameter for pouring temperature 1460 °C, magnification 25x and 200x

On the microstructure with magnification 25x for pouring temperature 1490 °C (Fig. 9) it can be seen that cast crystallized endogenously – exogenously. In the middle of sample there are equiaxial grains and on the border - columnar grains. For the lower pouring temperature 1460 °C (Fig. 10) cast crystallized only exogenously.

Analyzing the microstructure of samples with different pouring temperature it can be noticed that they have the similar morphology – longitudinal carbide dispose on the metal matrix. This means that the impact on strength properties has a pouring temperature, and what is connected with this – type of crystallization.

## 4. Summary

The experimental results indicate that pouring temperature has an impact on the type of crystallization the high-chromium cast iron. Controlling only the pouring temperature does not get a satisfactory amount of equiaxial grains, so recommend is to use modification.

Pouring temperature has directly influence on a crystallization time and the degree of supercooling, so consequently on the strength properties. It is important to registration the cooling curves because, through appropriately large database of its, the way of crystallization of high-chromium cast iron can be predicted. It follows that, by appropriate selection of the pouring temperature can control certain properties of the casting.

## Acknowledgements

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# Wpływ temperatury odlewania na strukturę i właściwości mechaniczne żeliwa wysokochromowego

W pracy przedstawiono wyniki badań wpływu temperatury odlewania na strukturę i wybrane właściwości wytrzymałościowe żeliwa wysokochromowego. W ramach badań wykonano dwa wytopy z różną wartością temperatury odlewania 1490 °C i 1460 °C, dla żeliwa o tym samym składzie chemicznym. Wytopy wykonano w piecu indukcyjnym o pojemności tygla 15 kg znajdującym się w Katedrze Inżynierii Stopów i Kompozytów Odlewanych na Wydziale Odlewnictwa AGH. Dla każdej temperatury odlano 2 zestawy wałków o wymiarach ø30 mm, ø20 mm, ø15 mm x 250 mm. Podczas wytopów zalano kubki pomiarowe z termoelementem typu S do rejestracji krzywej krystalizacji i stygnięcia. Wałki poddano statycznej próbie wytrzymałości na zginanie. Następnie z wałków wycięto próbki do badania mikrostruktury. Z przeprowadzonych badań wynika, że temperatura odlewania ma istotny wpływ na sposób krystalizacji odlewu z żeliwa wysokochromowego, a w konsekwencji na mikrostrukturę i właściwości wytrzymałościowe. Wynika z tego, że przez odpowiedni dobór temperatury odlewania można sterować niektórymi właściwościami mechanicznymi odlewu.