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The identification of pouring conditions of cast iron to sand moulds

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Abstract

The structure and properties of the castings in cast iron put on spheroidization depend especially on the pouring conditions. Decisive factor of local castings properties can be the flow ability of liquid metal in sand mould, which depends not only on chemical constitutions but also on temperature and velocity of pouring. The parameter, which take into consideration various factors is a substitute rheological parameter θ proposed in early author's papers [1, 2]. The parameter determined in fluidity test can be used to calculation of thickness of rheological boundary layer metal in gating system channel and in casting. The identification a thermal properties of sand mould material has been require of investigation proposed in literature [3, 4]. In the article presented also the experimental of measurement results of metal levels in piezometers located on the horizontal cross gate.

Keywords: Metallography, Boundary layer of metal, Spheroidal graphite iron, Sand mould, Piezometer

1. Introduction

Application of up-to-date engineering process in metal foundry, does not guarantee the automatic elimination of casting defect, if the gating system is not adequately designed. It has been estimated, that percent defective caused by inapproprate of gating system construction can achieve a few dozen percent of total number faulty castings. In process of pouring the sand moulds with liquid metal, the most often defects are: misruns castings, porosity, slag inclusions, sand holes [2]. In channels of gating system there forms a boundary layer where we can distinguish layers: rheological and solidifying, fig. 1. There is a rheological layer there in a surface of the wall channel where occur velocity gradient along normal to surface [1, 2]. The thickness of solidified layer depends on the flow time *t* and the solidification factor *k*.

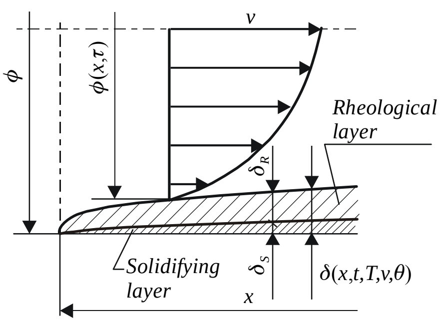

Fig. 1. Boundary layer of metal in channel of gating system

The castability of metal is a parameter which determines a distance for metal flow in channel of sand mould, before the stop of flow by the progressive process of solidification. In preceding author's papers [1, 2] there has been described the derivation of formula (1):

$$\theta = \frac{\delta_R \cdot \sqrt[4]{h}}{0{,}672 \cdot \sqrt{l}} \quad (1)$$

where:

h – metalostatic pressure, m,
l – the length of rod, m,
δ_R – the thickness of rheological boundary layer, m.

This parameter determined in fluidity test can be used to calculation the thickness of rheological boundary layer and to calculation of reduction coefficient ε of channel section from formula [1, 2]:

$$\varepsilon = \left(\frac{2r_h - \delta_R - \delta_S}{2r_h} \right)^2 \quad (2)$$

where:

r_h – hydraulic radius of theoretical channel section, m,
δ_S – the thickness of solidification boundary layer, m.

The thickness of solidifying boundary layer of metal describe formula (3):

$$\delta_S = k \cdot \sqrt{t} \quad (3)$$

After the determination of the coefficient b_f of heat accumulation of mould material by means of methods describe by Z. Ignaszak [3], solidification factor *k* can be calculate with formula [2]:

$$k = \frac{2b_f \cdot (T_z - T_f)}{\sqrt{\pi} \cdot \rho_m \cdot L_m}$$

where:

T_z— temperature of pouring metal, K,
T_f — temperature sand mould in the contact zone with boundary layer of metal ($T_f = T_k$), K,
ρ_m — density of metal, kg/m^3,
L_m — heat of solidification metal, J/kg.

The solidification factor *k* depends on the thermo-physical material mould and temperature of pouring metal [2, 3].

2. Methods of investigations

Temperature measurement of liquid cast iron put on graphitization by means of sink thermal in foundry ladle has been realized.

The identification of thermal-physical parameters of moulding sand has been made with experimental method which Z. Ignaszak [3, 4] has been offered. In order to determine thermal-physical properties of mould material in casting mould, it was installed the thermals which permit to register the temperature changes in time function.

The determine of substitute rheological parameter of liquid metal has been made on the basis method of analysis of results investigations of fluidity test [2].

Estimate of the flow pattern of metal stream in channel of cross- gate has been made on the basis of distribution of heights of piezometers rods. In this casting mould there was a cross gate with 18 piezometers (spaced 0,1 m) and the sprue, which differentiated the cross gate in two equal parts, fig. 4.

3. Results of investigations

Experimental investigations were made in a big iron foundry. To the investigations it has been used the spheroidal graphite iron EN-GJS-400-15. Every casting mould poured with liquid metal about 500 kg. Cast iron was smelting in electric furnace. Spheroidizing process was made in the ladle of spheroidizing process disposable was put on about 540 kg cast iron.After spheroidizing process the temperature of metal was about 1750 K (1477^0 C) and during pouring to sand moulds about 1600K (1330^0 C). The analysis results of chemical component of cast iron after spheroidizing process has been presented in table 1.

Table 1.
The analysis of chemical components after spheroidizing process

Element determine	C	Si	Mn	P	S	Cu	Mg	Sc
Contents [%]	3,59	2,49	0,12	0,033	0,008	0,17	0,049	1,033

The boundary layer section of spheroidal graphite iron in the sprue, where during 4 second the mass flow of metal achived 1,25 kg/s, has been shown fig. 2.

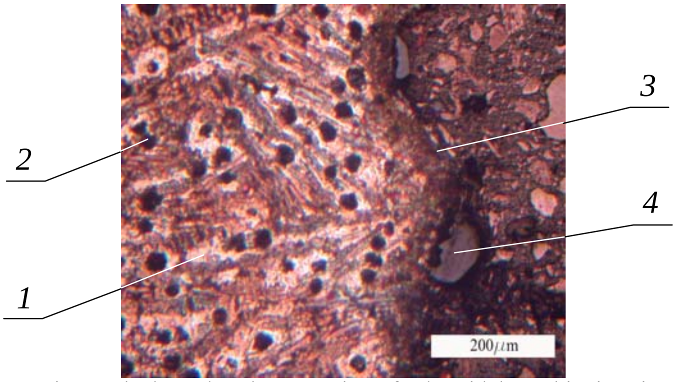

Fig. 2. The boundary layer section of spheroidal graphite iron in the sprue: 1 – perlitic-ferritic structure, 2 – spheroidal graphite inclusion, 3 – oxides phase, 4 – low- melting phase

The results of metallography tests confirmed that the required structure of spheroidal graphite iron has been required. On the fig. 2 there are visible two zone: the boundary layer metal and material of sand mould wall. The boundary layer metal and material of sand mould wall have been separated by oxides layer.

The boundary layer metal have a ferritic – perlitic structure and spheric graphite inclusions. At the section wall of sand mould there are visible low -melting phases. The process on the boundary liquid metal and green sand mould cause create a large amount of gas during a few seconds. The products of chemical reactions of liquid metal with SiO_2 and binders can be the oxides and low-meltings, which penetrate to the stream of metal in channel and can flow to casting niche [2, 6].

In order to investigate the parameters of spheroidal graphite iron has been determined rheological parameter on the basis rod fluidity test and thermo-physical properties of sand mould.

Table 2.
Results of rod fluidity test for spheroidal graphite iron with pouring temperature 1470 K

ϕ [mm]	3,2	3,8	4	5	6	7	8	9,2
l [mm]	98	135	157	190	280	338	370	410

On the basis of fluidity test results for spheroidal graphite iron (table 2) there has been calculated the substitute rheological parameter, fig. 3. This graph (fig, 3) shows that values substitute rheological parameters vary between 0,0061 and 0,0067 $m/s^{0,5}$ (average value 0,0064 $m/s^{0,5}$). This parameter depends on chemical constitution of alloy metal and its pouring temperature. Moreover its depends on: metallurgical quality (the existence of non-metallic inclusions with various size and modification method), the pressure distribution and other factors influenced on the local velocity during pouring and the construction of gating system.

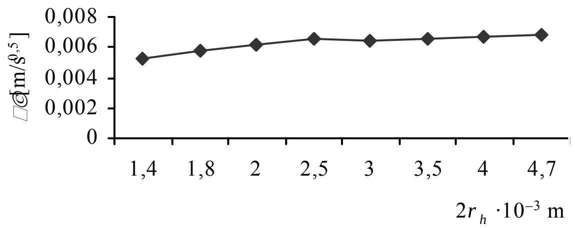

Fig. 3. The dependence of substitute rheological parameter on the hydraulic radius (2 r_h) of channels of rods fluidity test for spheroidal graphite iron with pouring temperature 1470 K

With the growth of value of substitute rheological parameter Θ has been enlarged the thickness of rheological boundary layer.

The boundary layer in channels of gating system , where flow velocity is almost zero and occur solidification process, causes decrease of real section channel and reduce of flow metal.

In order to verification the flow conditions liquid metal in horizontal cross gate, autors made the experimental casting mould, fig. 4.

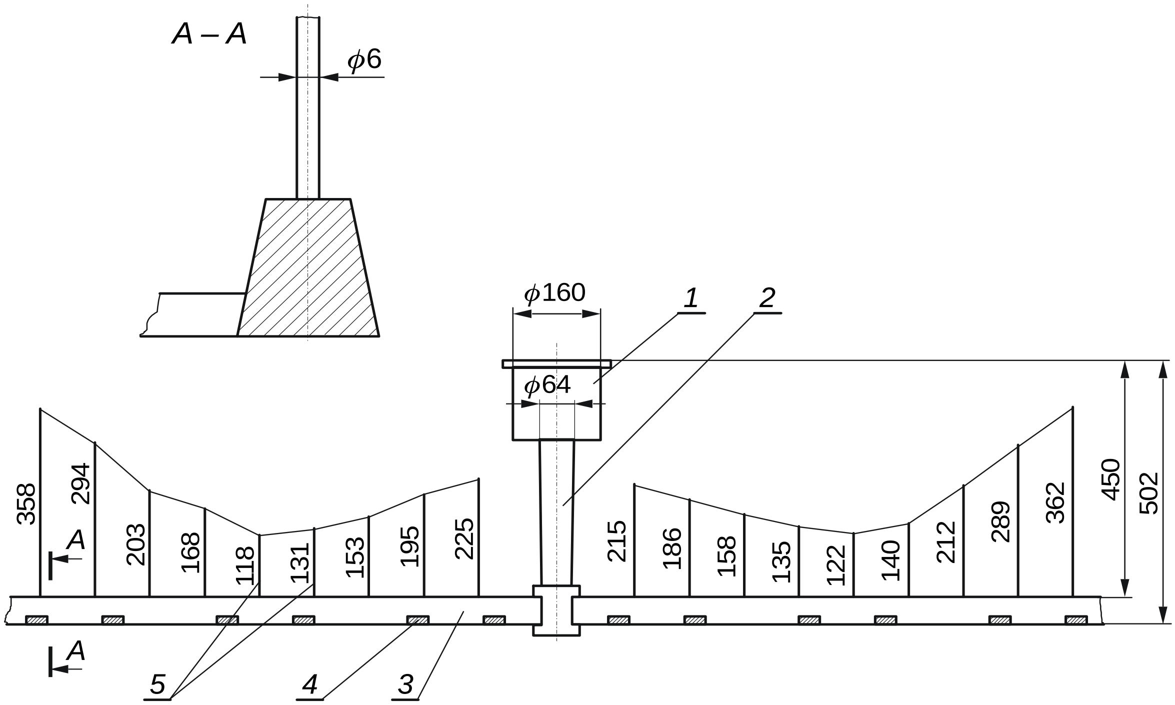

Fig. 4. The distribution of filling levels of piezometers channels located on the horizontal cross gate (spaced 0,1 m): 1 – pouring cup, 2 – sprue, 3 – cross gate, 4 – runner, 5 – piezometers rods

The piezometers filling level was diversified. The heights of the piezometers rods determine a curve which minimum is almost the middle. The heighests piezometers rods were farthest from the sprue and the smallest in the middle every parts of cross gate.

The filling level of piezometers characterizes of distribution metallostatic pressure and flow rate of liquid metal in horizontal cross gate and permit to conclude about the change of channel geometry. When metal doesn't flow by full cross section channel, there can occur gas suction and non-metallic inclusions to stream liquid metal and their transfer to cast niche.

The importance geometry of gating system elements during pouring the sand mould and espacially horizontal cross gate has been already presented by other were other researchers [5, 7, 8].
J. Campbell [5] and Karsay [7] has been take note of horizontal cross-gate shape. Tomasevic [8] proposes the calculation of flow ratio of liquid metal through gating system with respect to reference point set on the level cross gate and almost its middle length. Theoretically at the point flow rate can have similar average value appointed for the gating system.

The factors which have big influence on the filling niches and on the cast quality are: rheological properties of liquid metal and thermo-physical properties of material mould [2, 3]. Chemico-physical process on the boundary of liquid metal and sand mould in horizontal cross gate with constant section can have considerable influence on quantity of gas and non –metallic inclusions transfer to the casting [2,6].

The casting properties can be controlled by introduction of construction changes in gating system. The changes should respect the factors such as: temperature of pouring metal, rheological properties of liquid metal, thermo- physical properties of sand mould and geometry of elements of gating system.

4. Conclusions

1. After the calculation of the value of parameter θ from fluidity test it can be determined a thickness of rheological boundary layer of metal in channels of gating system.

2. The values of heat accumulation coefficient of mould material described in literature [3, 4] can be used to calculate of solidify coefficient *k* and thickness of solidifying boundary layer.

3. The coefficient ε, of reduction of active channel section can be determined for any channel section independence on its location in sand mould during pouring process.

4. Pressure distribution of liquid metal in piezometers placed on the horizontal cross gate permit to define the pattern flow in this channel and to conclude about direction change of geometry of this element.

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