Gas pressure in sand mould poured with cast iron

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Abstract

The results of measurements of gas pressure in foundry moulds made from sands bonded with bentonite, sodium silicate and furan resin were disclosed. It was found that the maximum pressure during pouring of mould with metal occurs in the case of bentonite sands, especially with the addition of coal dust. The effect of this pressure on the formation of surface defects in castings was examined.

Keywords: Moulding sand; Gas pressure; Defects of casting surface

1. Introduction

Castings made from iron alloys, steel in particular, are often observed to suffer from severe defects on the raw surface, which is coated with a light-coloured layer of the strongly adhering sintered moulding material. After removal of this layer, small and smooth inside depressions appear on the casting surface. These defects occur mainly in the upper part of casting. An example of the defect noted on the surface of a railway buffer is shown in Figure 1. Defects of this type are often accompanied by pinholes. Figure 2 [1] shows the scanning image made on a section perpendicular to the surface. Figures 3 to 6 show the results of linear analysis of a sintered layer sticking to the casting surface. The oxide layer is rich in iron, which indicates that intense oxidation took place in the surface layer of casting. Additionally, the occurrence of manganese and silica, originating probably from the moulding sand, was observed. It can therefore be assumed that the surface defect was due to the pressure of gas evolving from the sand when metal was still in liquid state or during solidification.

Fig. 1. Defect on the cast surface of a railway buffer
It has been noted that surface of the oxide layer is of an obviously convex shape, which suggests that it has been pushed into the solidifying metal by an impact of the gas phase. Earlier studies done by the authors [2] have indicated that the gas phase, especially at the first stage of mould pouring, is composed mainly of water vapour. In reaction with metal, the vapour undergoes decomposition. Oxygen causes oxidation of alloying elements in the surface layer, while hydrogen is dissolved in the liquid metal. The decreasing solubility due to cooling and metal solidification, in particular, leads to the formation of surface blowholes and pinholes. Figure 2 shows the presence in metallic phase of small tubular channels, perpendicular to the casting surface, which are a remnant of the removed gas.

Fig. 2. Scanning made in direction normal to the defect surface

![Scan Image](image_url)

Fig. 3. Distribution of silicon lengthways the line pointed in Figure 2

![Silicon Distribution](image_url)

Fig. 4. Distribution of oxygen lengthways the line pointed in Figure 2

![Oxygen Distribution](image_url)

Fig. 5. Distribution of manganese lengthways the line pointed in Figure 2

![Manganese Distribution](image_url)

Fig. 6. Distribution of iron lengthways the line pointed in Figure 2

![Iron Distribution](image_url)

So, it is the composition and pressure of gases evolving from the sand that seem to decide about the quality of the casting surface. This problem has been the subject of numerous studies [3 – 7]. The studies were mainly devoted to the analysis of the composition of the emitted gas, but rather in terms of its harmful impact on the environment. The total amount of gases emitted from moulding sand during pouring of the casting was measured. Their chemical composition was determined, but after cooling to room temperature. Only Scraber et al. [9] measured pressure of the evolved gases and changes in their pressure during the casting process, reporting that the highest level of gas evolution was from the bentonite-bonded sands. Similar studies were conducted by T. Szmigielski [8].

The aim of this study was to develop a method for the measurement of the pressure of gases emitted from various moulding and core sands and determination of factors influencing both the magnitude and kinetics of changes in the value of this pressure during the process of mould pouring with grey iron.
2. Research methods

2.1. Test mould design

For studies, foundry mould of the design shown in Figure 7 was proposed.

Fig. 7. Test mould - 1. Cylindrical specimen of the tested sand, 2. Place and method of mounting the measuring elements

The mould was made from bentonite-bonded green sand. In the mould, specimens of the examined sand mixture of Ø 50 x 50 mm dimensions were placed. In the specimen, at a distance from the metal-mould interface predetermined in the preliminary studies, a copper tube (a capillary of 1 mm inner diameter) with bored holes was placed together with an Ni-NiCr thermocouple. The tube was connected with a flexible duct to a pressure gauge. Measurements were recorded continuously.

2.2. Sample preparation

Samples were made from silica sand of 0.20/0.16/0.10 granulation. Table 1 shows the composition of the sand mixtures used for samples.

Moulds were poured at a temperature comprised in the range of 1350 – 1380°C, using grey iron melted in induction furnace.

Table 1. Composition of the examined moulding sands

<table>
<thead>
<tr>
<th>Binder type</th>
<th>Binder content [wt.%]</th>
<th>Hardening technique</th>
<th>Apparent density [g*cm$^{-3}$]</th>
<th>Moisture content in sand [%]</th>
<th>Sand permeability [$<em>10^{-8}$ m$^2$/Pa</em>s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>bentonite</td>
<td>8%</td>
<td>mechanical</td>
<td>1.5</td>
<td>3.5</td>
<td>220</td>
</tr>
<tr>
<td>bentonite + 5% coal dust</td>
<td>8%</td>
<td>mechanical</td>
<td>1.5</td>
<td>3.5</td>
<td>220</td>
</tr>
<tr>
<td>Kaltharz resin (90% furfuryl alcohol)</td>
<td>1%</td>
<td>hardener 0,5%</td>
<td>1.5</td>
<td>0</td>
<td>235</td>
</tr>
<tr>
<td>R-145 sodium silicate</td>
<td>3.5%</td>
<td>Flodur 57/0.35%</td>
<td>1.5</td>
<td>0</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mechanical</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7/ acetic acid ester

3. Results

The preliminary studies were carried out on bentonite sand with an addition of coal dust, placing the probe at a distance of 1, 2 and 6 mm from the mould cavity surface. The results disclosed in Figure 8 show clearly that the gas pressure obviously decreases with increasing distance from the metal-mould interface. At a distance of 1 mm, after the initial rapid increase in pressure, the sand layer separating the metal from the probe was probably destroyed, while at a 6 mm distance the pressure rise was slow and lasted for a long time due to the relatively slow heating. For further studies, a constant distance of 2 mm was adopted.

Figures 9 and 10 show the results obtained for bentonite-bonded moulding sand with an addition of coal dust.

Fig. 8. Effect of probe distance from the casting surface on gas pressure in the sand with bentonite and coal dust of 3.8 % moisture content
The results are repeatable. During mould pouring, gas pressure in the moulding sand is growing rapidly, reaching the level of almost 150-180 Pa at an instant when the temperature approaches 100°C. Further heating leads to stabilisation of pressure at a slightly lower level. Local re-growth occurs in the range of 500 - 600°C, which corresponds to the precipitation of bound water. In the case of bentonite sand, without the addition of coal dust, the measured values of pressure are lower. This shows a graph in Figure 11.

4. Discussion

In the surface layer of moulding sand, intense evolution of gas takes place as a result of heating. This causes sudden increase in pressure, which is growing the more, the smaller is the distance from the mould cavity surface. The authors performed measurements at a specific and constant depth, which did not allow accurate determination of pressure acting on the metal-mould interface from the side of the moulding sand, but provided a background for the comparison of different sand types. The highest values were observed in the bentonite-bonded sand, especially when coal dust additive was used. The increase of pressure in the surface layer is due to intense evaporation of moisture – the maximum pressure is observed at about 100°C. Higher values obtained for the sand with coal dust are probably due not only to the presence of coal dust particles, but also to the formation of pyrolytic carbon. Figure 14 shows a macroprecipitate in the form of scale on the surface of a test mould cavity.

Carbon precipitates formed not only on the surface of mould cavity where the evolving gas enters into contact with cast iron. They were found in the entire volume of samples heated during examinations of the newly formed gas atmosphere [10]. Figure 15 shows carbon platelet. Figures 16 and 17 show the results of spectral analysis carried out at points 1 and 3.
The sand with sodium silicate was also observed to evolve water vapour, but kinetics of this effect was different than in the case of sands bonded with bentonite. In the range of up to 100°C, a fast increase took place but only to about 20Pa, and this value remained constant for a long time. This indicates that due to a specific binding mode developed in this sand, the water vapour is removed on heating very evenly. From the resin-bonded sand, only a very small amount of gas is removed. The maximum pressure is reached at about 60°C and proves the occurrence of binder evaporation. As soon as the maximum is reached, the pressure drops very rapidly.

Fig. 14. Precipitates of lustrous carbon on mould cavity surface after pouring of cast iron

Fig. 15. Scanning of bentonite sand with 5% coal dust after heating to a temperature of 1300°C

4. Conclusions

The results obtained show that during pouring of foundry mould, in the layers close to mould cavity, an overpressure caused by the emission of gases is formed. Its value increases when the mould cavity surface is approached. In bentonite-bonded sands, this pressure is much higher than in sands with other types of binders, especially with furan resins. Previous observations confirm this statement [10, 11] and explain why the majority of surface defects are present in castings poured in bentonite sands. An addition of coal dust to these sands strongly raises the maximum pressure value, due to the formation of pyrolytic carbon reducing the sand permeability. On the other hand, the presence of the precipitates of amorphous and lustrous carbon considerably deteriorates wetting of mould surface by the liquid iron alloys.

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References


