

Changes of gas pressure in sand mould during cast iron pouring

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Abstract

The paper presents a test method developed to measure changes of gas pressure in sand moulds during manufacture of iron castings. The pressure and temperature measurements were taken in the sand mould layers directly adjacent to the metal – mould interface. A test stand was described along with the measurement methodology. The sensors used allowed studying the fast-changing nature of the processes which give rise to the gas-originated casting defects. The study examined the influence of binders, clays and refining additives on the nature of the gas evolution process. The effect of the base sand type - quartz or olivine - on the nature of pressure changes was compared. The test stand design ensured the stability of technological parameters in the examined mould elements, and a repeatable process of making pilot castings. The main outcome was classification of sand mixtures in terms of pressure occurring during pouring of iron castings. The obtained results confirm the usefulness of the described method for testing gas pressure occurrence in a sand mould.

Keywords: Gases, Sand mixtures, Casting defects, Pressure, Cast iron

1. Introduction

On pouring of sand moulds, from layers adjacent to the liquid metal – mould interface, large quantities of gases evolve. These gases are the source of numerous casting defects. Quite often, statistically, even one half of all casting defects result from the presence of gas [1]. The temperature and pressure of gases in green sand moulds poured with aluminium alloys were measured by Tadeusz Szmigielski. The studies concerned the thermodynamic processes of heat and moisture transport [2,3,4,5]. The composition of the evolved gases was observed to vary and depend on both moulding sand components and time of contact between the liquid alloy and moulding sand [6,7,8]. On pouring of mould, the gases can quite easily penetrate into the alloy overcoming its surface tension. This applies particularly to hydrogen because of a very small atomic radius it has and hence a very high value of the diffusion coefficient. In

previous studies [6, 7,8, 9] it was noted that the mixture of gases evolved from the green moulding sand is composed mainly of water vapour, carbon monoxide and small amounts of methane. These gases react with iron producing hydrogen, oxygen, and amorphous carbon [10]. Oxygen causes surface oxidation of iron, but its diffusion to the casting interior is hardly probable. On the other hand, hydrogen penetrates into the metal, the more willingly that its partial pressure in the atmosphere of the sand mould cavity is growing rapidly [11].

J. Orlenius et al. [12] found that during casting of grey iron, the hydrogen content increases by 2 - 3 cm³ per 100g. The subject of the present research is to examine the gas pressure in the dry sand mould layer, which determines the amount of gases in mould cavity on pouring of mould and casting solidification.

2. Purpose and methodology of research

The aim of this study is to compare and analyse changes in gas pressure in the sand mould made of various moulding materials. This study has focussed on measurements of the pressure of gases evolved from the sand mould in layers directly adjacent to the liquid metal - mould interface on pouring of mould and during solidification of iron casting. Measurements were taken on the designed test stand shown in Figure 1. The tested mould parts were cylindrical $\text{\O} 50 \times 50 \text{ mm}$ specimens made with standard rammer to keep the assumed dimensions. For comparative studies of pressure in various moulding materials specimens of middle wall thickness (28 mm) was chosen. For the bentonite green sand with coal dust addition, the evolution of pressure and temperature were examined also for 14 mm wall thickness.

The silica sand-based moulding mixture was investigated at a constant apparent density of $1.5 [\text{g} \cdot \text{cm}^{-3}]$.

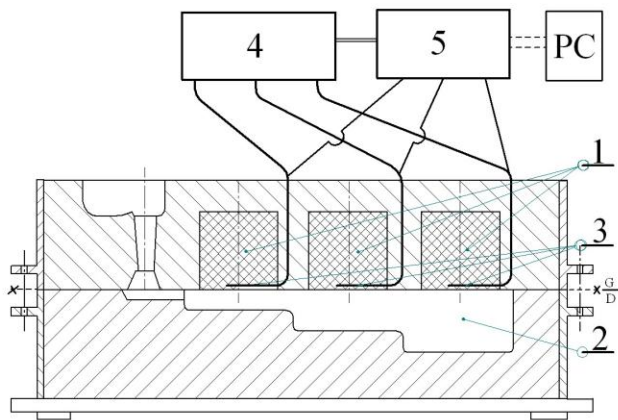


Fig. 1. Test stand: 1) cylindrically shaped specimens of predetermined technological parameters, 2) pilot casting, 3) probe to measure pressure and temperature, 4) pressure transducers, 5) pressure and temperature recorder

For mixtures based on olivine sand with selected grain size distribution, the specimen weight was chosen in such a way as to obtain the porosity comparable with the porosity of the sand mixtures based on silica sand.

The composition of the tested sand mixtures is given in Table 1. In holes made during moulding of specimens, the probes measuring pressure and temperature were mounted. The distance of the probe from the mould cavity surface was set at 2 mm. The temperature was measured with a Ni-NiCr thermocouple with a 0.2 mm thick wire. The pressure measuring probe was a 1 mm inner diameter copper tube shown in Figure 2. In the pressure measuring zone, the probe had several drilled holes with a diameter of less than 1 mm. In a part of the research, tubes with a vent as shown in Figure 2 were used. It was found that very similar results were obtained using drilled tubes (Fig.2a) and tubes with vents (Fig. 2b).

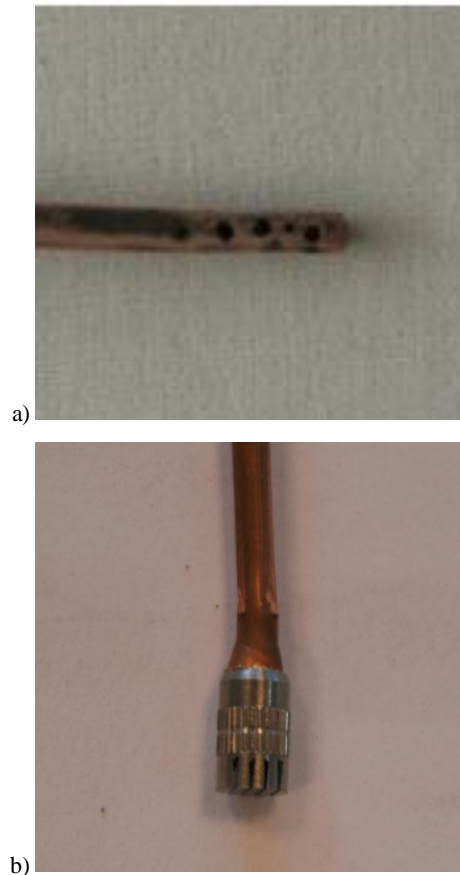


Fig. 2. Probes to measure pressure in the layers of sand mould: a) with drilled holes, b) with mounted vent

Probes were connected with cables to electronic pressure transducers that were placed next to the mould. Moulds were poured with grey cast iron in class ZL200 at a temperature of 1350 to 1380°C. Pressure [9] and temperature measurements were taken and recorded at a frequency of every 0.25s.

Table 1.

Compositions of the examined moulding sands

Moulding sand designation	Base sand	Binder/clay	Hardener	Other additives	Moisture content
Classic moulding sand with bentonite	Silica sand from Jaworzno-Szczakowa 0,2/0,16/0,1	Bentonite 8%	-	-	3,8%
Classic moulding sand with coal dust	Silica sand from Jaworzno-Szczakowa 0,2/0,16/0,1	Bentonite 8%		Coal dust 5%	3,7%
Moulding sand bonded with kalthartz resin	Silica sand from Jaworzno-Szczakowa 0,2/0,16/0,1	Kaltharz X850 TN011 resin 1%	100T3 0,5 %	-	-
Moulding sand bonded with sodium silicate I	Silica sand from Jaworzno-Szczakowa 0,2/0,16/0,1	R - 1,45 sodium silicate 3,5 %	Flodur 5 0,15 %	-	-
Moulding sand bonded with sodium silicate II	Olivine sand 0,2/0,16/0,1	R - 1,45 sodium silicate 3,5 %	Flodur 5 0,15 %	-	-

2.2. Results

The characteristic course of pressure changes on pouring is shown in Fig. 3. Initially, an increase in this pressure up to about 70 Pa is observed. This increase is independent of the type of the moulding sand used and probably results from pressure increase in the mould cavity. After a short lapse of time, the pressure is growing again, this time as a result of processes occurring in the moulding sand. Figure 4 shows changes of pressure in a sand mould bonded with bentonite.

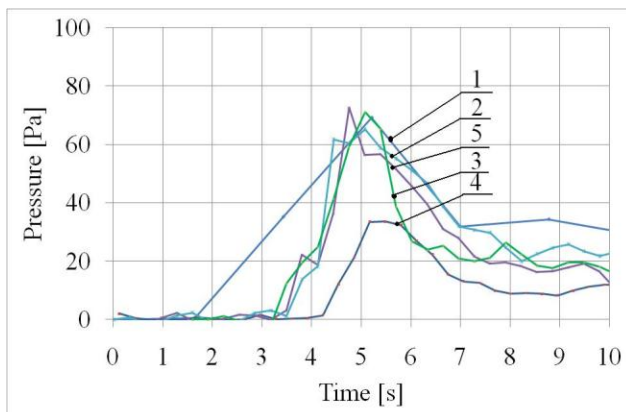


Fig. 3. Gas pressure during mould pouring: 1) Green moulding sand with bentonite and coal dust, 2) Green moulding sand with bentonite, 3) Moulding sand with furan resin, 4) Silica sand-based moulding mixture with sodium silicate, 5) Olivine sand-based moulding mixture with sodium silicate

The amount of the evolved gases is increasing as a result of moisture evaporation reaching its maximum at about 100°C. On further heating, the pressure decreases at first and then increases once again to another maximum after about 200s counted from the beginning of mould filling. The individual tested moulding sands differed in the achieved maximum, this regarding both value and the time and temperature of occurrence.

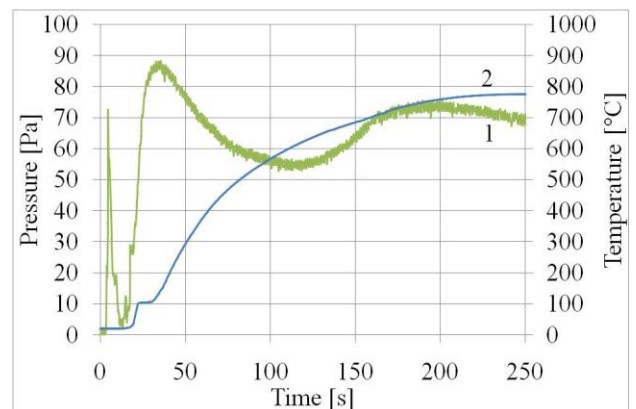


Fig. 4. Pressure and temperature of gases during mould pouring and solidification of pilot casting in green sand mould with bentonite: 1) pressure, 2) temperature

The highest gas pressure is generated by classic green moulding sands with an addition of coal dust. The course of changes in pressure and temperature for sand with an addition of coal dust is presented in Figures 5 and 6. The pressure is two times higher than in the green sand without the addition of coal dust. For both moulding sands bonded with bentonite, distinct pressure peaks at about 100°C are observed. In the presence of coal dust, the recorded pressures are several times higher.

A value of pressure depends on the casting mould thickness. For the green sand with a coal dust it is presented in the Figures 5

and 6. Explanation of this phenomenon needs the supplementary studies.

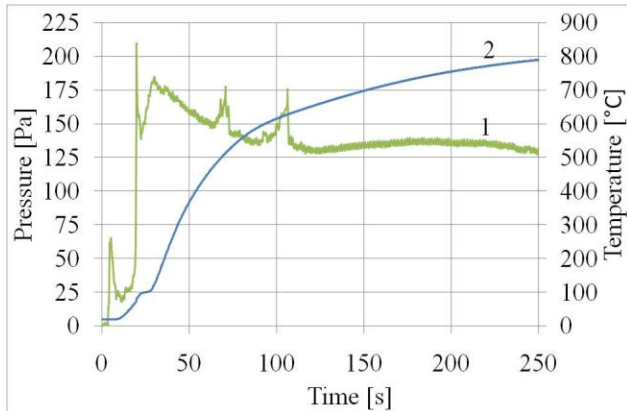


Fig. 5. Gas pressure and temperature during mould pouring and solidification of pilot casting (casting thickness 28 mm) in green sand mould with bentonite and coal dust: 1) pressure, 2) temperature.

Moreover, the randomly distributed rapid transient increases in pressure are observed at temperatures from 450 to 700°C. These increases do not exceed with their values the maximum pressure reached during the evaporation of water. Their random nature and the instantaneous local temperature “jumps” may suggest that they are the result of physico-chemical reactions occurring in the immediate vicinity of the probe.

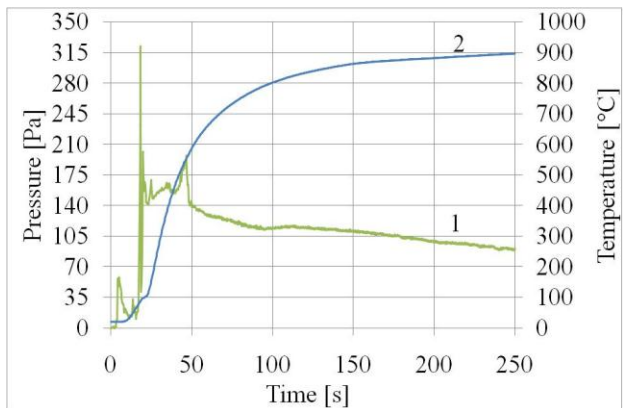


Fig. 6. Gas pressure and temperature during mould pouring and solidification of pilot casting (casting thickness 14 mm) in green sand mould with bentonite and coal dust: 1) pressure, 2) temperature

Loose self-setting sands bonded with inorganic sodium silicate generate the lowest maximum gas pressure reaching on an average a half of the pressure generated by the green moulding sand with bentonite. This is illustrated in Figure 7. The nature of the pressure occurrence is similar to that observed in green sands with bentonite.

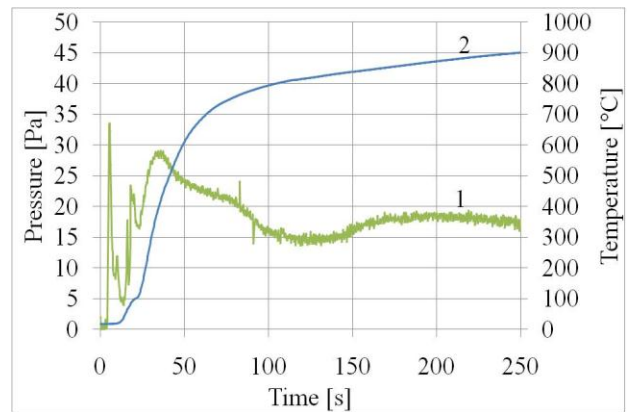


Fig. 7. Gas pressure and temperature during mould pouring and solidification of pilot casting in sand mould bonded with sodium silicate: 1) pressure, 2) temperature

To analyse the effect of the base sand type on the nature of changes in pressure, the measurements of pressure were carried out on moulds bonded with sodium silicate but based on olivine sand. The results of the tests were compared with the results obtained for silica sand and plotted in Figure 8. The occurrence of maximum pressure is similar. The time shift occurs because of higher conductivity and heat capacity of the sand.

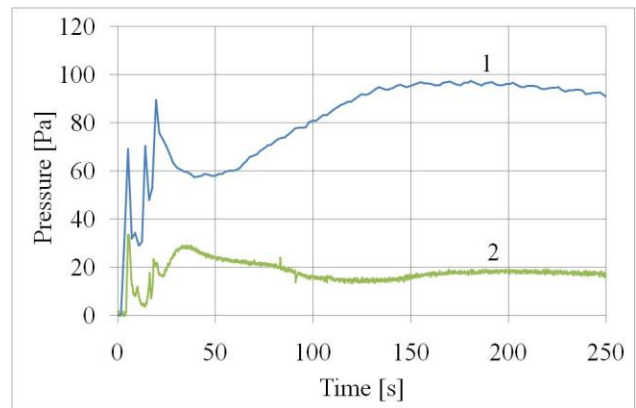


Fig. 8. Pressure during mould pouring and solidification of pilot casting in a mould bonded with sodium silicate based on 1) olivine sand, 2) silica sand

The second pressure maximum in the above described sands is related with the presence of water in a moulding mixture. The value of the maximum depends not only on the moisture content but also on the evaporation rate. Higher evaporation rate is reached by the moulding sand with water in unbound state. Previous studies done by the authors [9] showed that from bentonite sands containing coal dust, large amounts of carbon oxide started evolving as early as at about 150°C. This explains the very high pressure recorded during the conducted studies. Moulding sands with sodium silicate contain most of water in bound form, and therefore the evaporation of this water is much slower. Definitely different course of changes in gas pressure is observed in moulding sands with organic binders. Examples of pressure and temperature changes are shown in Figure 9. The

second maximum pressure starts much earlier, i.e. at a temperature of about 50°C. This is due to the release of significant amounts of carbon oxides and hydrocarbons. Another maximum is observed after about 200 s, like in the case of other moulding sands.

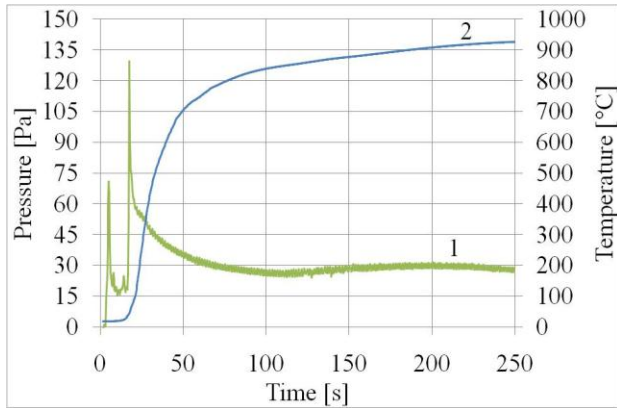


Fig. 9. Gas pressure and temperature during pouring of mould and solidification of pilot casting in a sand mould bonded with resin:
1) pressure, 2) temperature

Figure 10 compares the occurrence of the second maximum pressure in moulding sand bonded with furan resin with the gas pressure in green moulding sand bonded with bentonite and containing an addition of coal dust. The graph shows the pressure changes in function of temperature. To better identify the phenomena that are characterised by gas evolution, Figure 11 shows pressure in function of temperature.

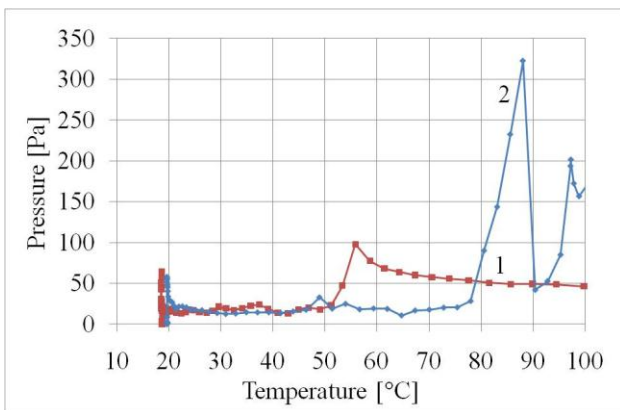


Fig. 10. Gas pressure in function of temperature:
1) resin-bonded sand, 2) green moulding sand with bentonite and coal dust

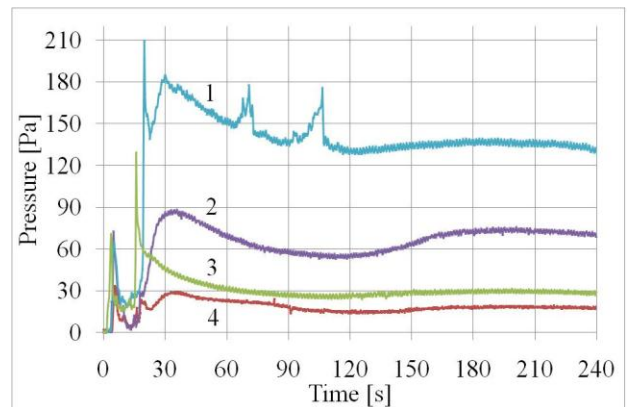


Fig. 11. Gas pressure in function of temperature for the examined moulding sands: 1) green moulding sand with bentonite and coal dust, 2) green moulding sand with bentonite, 3) moulding sand bonded with resin, 4) moulding sand bonded with sodium silicate

3. Conclusions

The conducted research has proved that the greatest impact on the value of the maximum pressure in the layers of sand mould directly adjacent to the metal – mould interface has moisture content in the sand mixture, and the amount of clay or binder.

The highest pressure values are generated by the classic green moulding sands with an addition of coal dust. This is the result of simultaneous evaporation of water and the evolution of carbon oxides.

The sands with binders produce less pressure than the classic bentonite-bonded mixtures. Higher pressures are achieved for sands with organic binders, while lower pressures occur in sands with inorganic binders.

The presence of unbound water in the sand mixture determines the temperature and therefore also the time at which the maximum pressure occurs. Bound water is gradually released and evaporated. In the absence of water, the maximum pressure occurs in the moulding sand during rapid evaporation of binder at temperatures much lower and therefore in time shorter than in moulds made from the sand mixture with water content.

Acknowledgments

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