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The Formation of Gaseous Atmosphere in a Molten Cast Iron/Moulding Sand Contact System

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Abstract

Drops of molten cast iron were placed on moulding sand substrates. The composition of the forming gaseous atmosphere was examined. It was found that as a result of the cast iron contact with water vapour released from the sand, a significant amount of hydrogen was evolved. In all the examined moulding sands, including sands without carbon, a large amount of CO was formed. The source of carbon monoxide was carbon present in cast iron. In the case of bentonite moulding sand with seacoal and sand bonded with furan resin, in the composition of the gases, the trace amounts of hydrocarbons, i.e. benzene, toluene, styrene and naphthalene (BTX), appeared. As the formed studies indicate much higher content of BTX at lower temperature it was concluded that the hydrocarbons are unstable in contact with molten iron.

Keywords: Moulding sand, Cast iron melt, Gas in metal, Mould atmosphere

1. Introduction

In recent years, much attention has been paid to the phenomenon of gas formation in a foundry mould during pouring, solidification and cooling. This is due to a strong attempt to protect the environment from the presence of hydrocarbons emitted by the sand. Of particular interest here is the group of benzene hydrocarbons (BTX) and polycyclic aromatic hydrocarbons (PAH) [1-9]. The development of new moulding materials and wide-scale use of synthetic resins increase the risk of environmental contamination. It has also been expressly stated that even the use of carbon-containing bentonite sands carries with itself some danger for the environment. In most studies of the toxicity of moulding sands, the sample (usually in the form of a core) is immersed in liquid metal for a time necessary to achieve

the predetermined temperature on the sample axis. The produced gases are discharged from the core into a special container and subjected to analysis. What is important is the weight of selected gas emitted throughout the whole casting process. J. F. Schifo et al. [3] measured and analysed the total amount of gas emitted from the sand during pouring, solidification, cooling and knocking out of casting. A. Chojecki et al. [10] and A. Siewiorek et al. [11] studied the composition of gases emitted from various moulding sands during the process of heating. It has been found that gases are released within certain temperature range. A. Chojecki and J. Mocek [12-14] studied the content of hydrogen and oxygen in the mould atmosphere and at the mould - metal interface. The research shows that at temperatures above 600°C, this sand emits small amount of hydrocarbons, and the main component of the evolved gas is water vapour.

Table 1.
Moulding sands tested

Moulding sand	Humidity	Type of binder	Content of binder	Seacoal
Bentonite sand	3.2%	bentonite	8%	-
Bentonite sand with seacoal	3.2%	Bentonite (seacoal)	8%	5%
Sand with resin	-	resin (KALTHARZ X 850 TN011)	1%	-
		hardener (100T3)	0,5%	
Sand with water glass	*	water glass (R-145)	3.5% + hardener (flodur5) 0,35%	-

When the sand contains carbonaceous components, carbon monoxide is also present. It is important to determine what gases are released from the sand when it comes into direct contact with molten metal, as the composition of these gases may have a significant impact on the casting surface quality. Studies conducted so far have finally resulted in designing and putting into operation an apparatus developed by a team of research workers at the High-Temperature Research Centre of Foundry Research Institute in Cracow. The apparatus, coupled with a spectrograph, is used to produce drops of molten metal placed on a ceramic substrate.

2. Methodology

Studies were carried out on moulding sands whose characteristics are given in Table 1.

From moulding sand, samples of dimensions $\varnothing 12 \times 5$ mm were prepared. They were next placed in a cold zone of the apparatus shown in Figure 1.

The device has a heating chamber in which the metal sample weighing about 5 G is placed.

The sand sample is placed in a quartz pot in a cold zone insulated from the heating area. A vacuum is produced in the apparatus, and then a small amount of argon acting as a carrier gas is introduced into both chambers. Gas from the cold zone is fed to a spectrometer which performs analysis of this gas for the presence of the gaseous components of a molecular weight (amu) from 1 to 200. The hot zone is heated at a constant rate of 30 K / min. Figure 2 shows an example of changes in temperature and pressure in the cold chamber during the test.

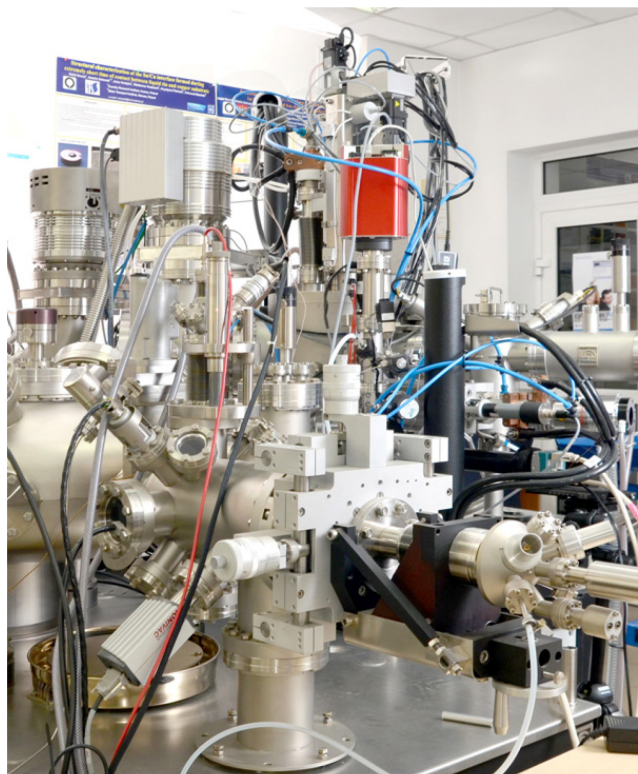


Fig. 1. View of the apparatus for placing drops of metal on the moulding sand substrate

Table 2.

The results of analysis of the gaseous phase formed during molten cast iron/ moulding sand contact

Molecular weight [amu]	2 (hydrogen)	14 (nitrogen)	16 (oxygen, methane)	18 (water vapour)	28 (nitrogen, carbon monoxide)	32 (oxygen)	44 (carbondioxide)	55 (BTX)	69 (BTX)
	E-10	E-10	E-10	E-10	E-10	E-10	E-10	E-10	E-10
Bentonite sand with seacoal	580	70	80	2500	115	40	67	1,82	0,68
Sand with X 850 resin	500	3	28	1150	52	17,5	26,5	0,33	0,122
Bentonite sand	700	5	5,8	2650	80	20,5	61	0,82	0,315
Sand with water glass	400	2	2,15	1000	37	22	22	0,037	0,130

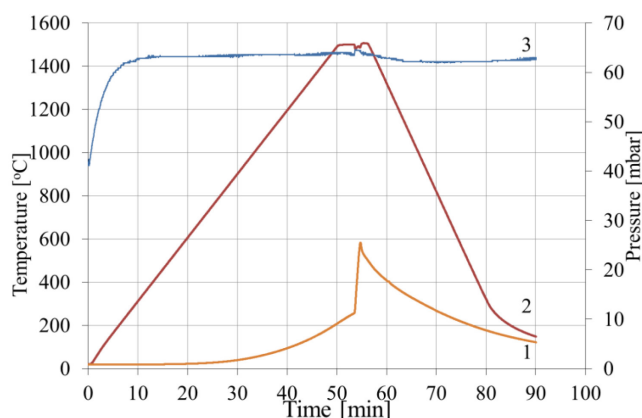


Fig. 2. Distribution of temperature and pressure during the test: 1 - moulding sand temperature, 2 - metal temperature, 3 - pressure in the measuring chamber

3. Results and discussion

After melting the metal and heating it up to 1500°C, the drop of metal was squeezed through a capillary onto the moulding sand surface. Figures 3 to 6 and Table 2 show the results obtained. The largest amount of gas was emitted from the bentonite sand with seacoal. Also in this case, during heating of the sand without contact with metal [7,8] mainly water vapour and carbon oxide were produced. Yet, here, the amount of hydrogen evolved almost equaled the amount of water vapour. The scale of the graph was reduced to 100amu, as no precipitates of an intensity above 1E-11 A were observed to exist.

In analysis of the hydrogen content, a peak for molecular weight 2 was taken into account, since previous studies [1] indicated that the peak at 1amu rather originates from the hydrogen ion formed during water vapourisation. The amount of hydrogen depends on the moisture content in moulding sand. Most of the hydrogen appears in green bentonite sand without the addition of seacoal, since this sand contains the highest amount of water (3,2%). For the sand bonded with resin and for the sand bonded with water glass, the amount of the emitted hydrogen is two times lower. Interesting to note is peak 14amu, corresponding to the presence of nitrogen. While it seems natural that the lowest amount of nitrogen is precipitated from the sand with water glass, a higher amount could be expected in the case of furan resin bonded sand. The authors have not analysed the nitrogen content in resin, but it is believed to be very small. Peak 16amu corresponds to the atomic oxygen and methane and must be interpreted jointly with peak 32amu (the main peak for oxygen). Moulding sands containing carbon have higher peak 16amu (especially the sand with seacoal), while peaks 32amu are comparable. This suggests that in the carbon-containing sand, small amounts of CH₄ are formed. Water vapour (peak 18amu) is the dominant component of the gaseous phase. Its content is the higher, the higher is the moisture content in the sand. This result indicates the need to reduce moisture content in the moulding sand to an absolute minimum. In peak 28amu, the highest content has carbon monoxide, but as mentioned previously it also includes molecular nitrogen, although the height of peak 14amu indicates that the content of this element is rather low. The lowest amount of carbon monoxide was precipitated from the sand with water glass. Presumably the reason for its formation was carbon oxidation in the surface layer of the casting. The peak from oxygen (32) assumes the highest value for the sand with seacoal. It is hard to believe that this is the sand that contributes most to creating an atmosphere enriched with oxygen. According to the authors, this result indicates the precipitation of small amounts of sulphur.

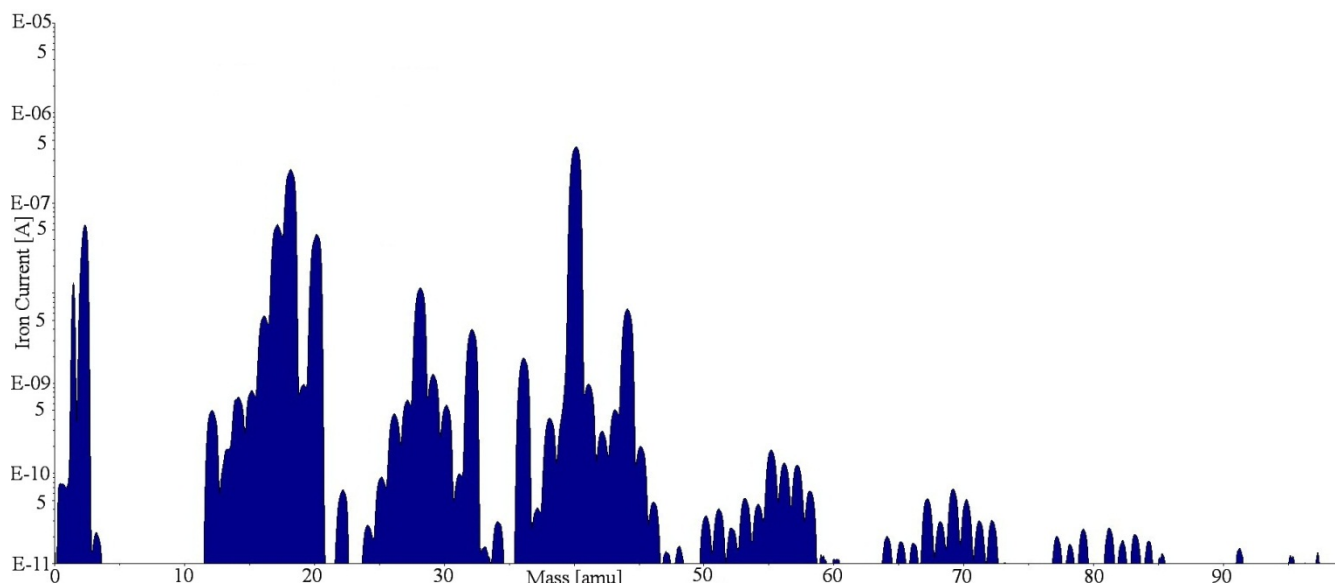


Fig. 3. The composition of gases emitted from the bentonite moulding sand with seacoal in contact with the drops of cast iron

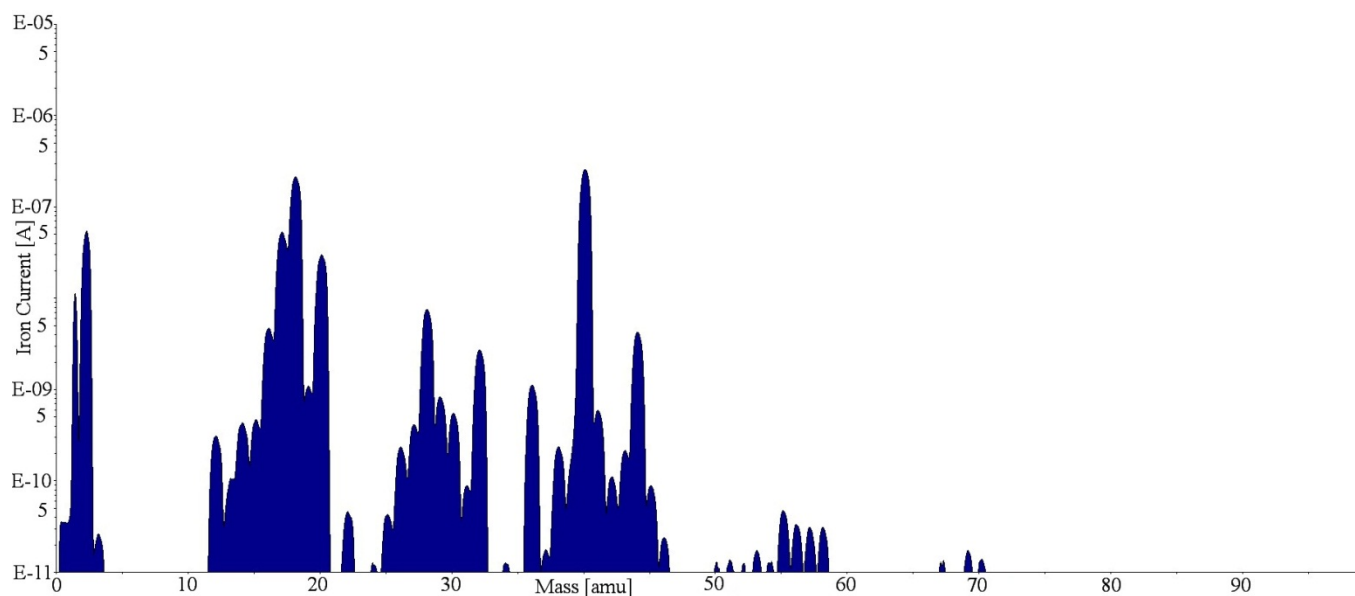


Fig. 4. The composition of gases emitted from the sand bonded with Kaltharz X850 resin in contact with the drops of cast iron

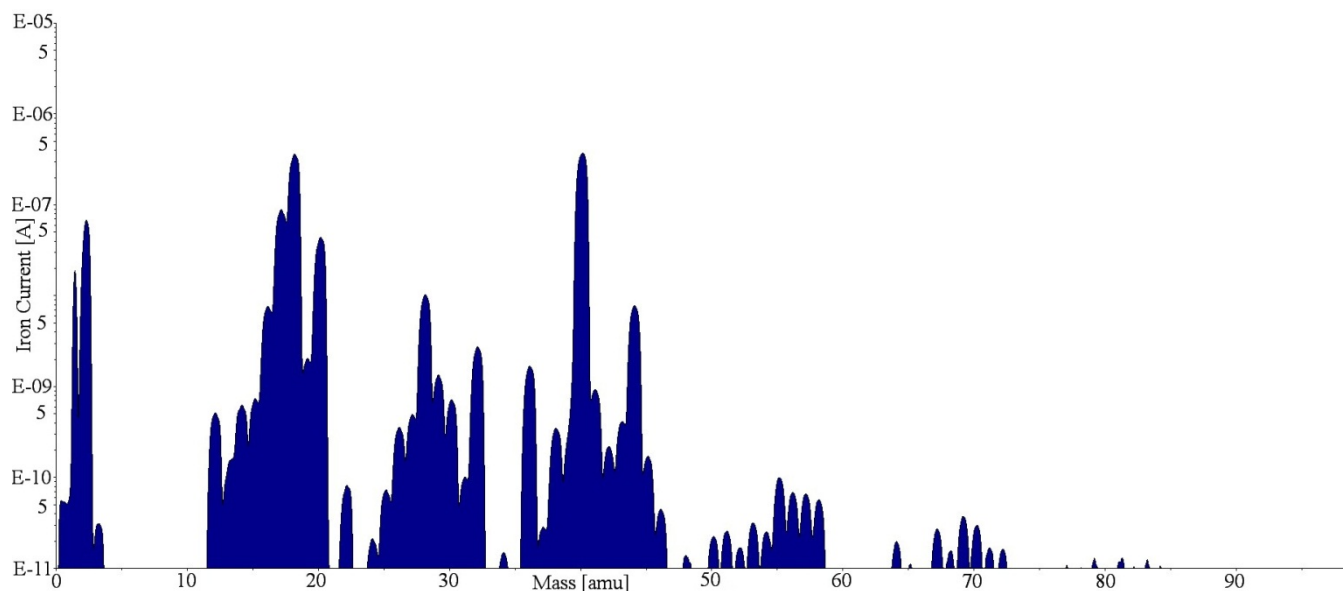


Fig. 5. The composition of gases emitted from the bentonite moulding sand in contact with the drops of cast iron

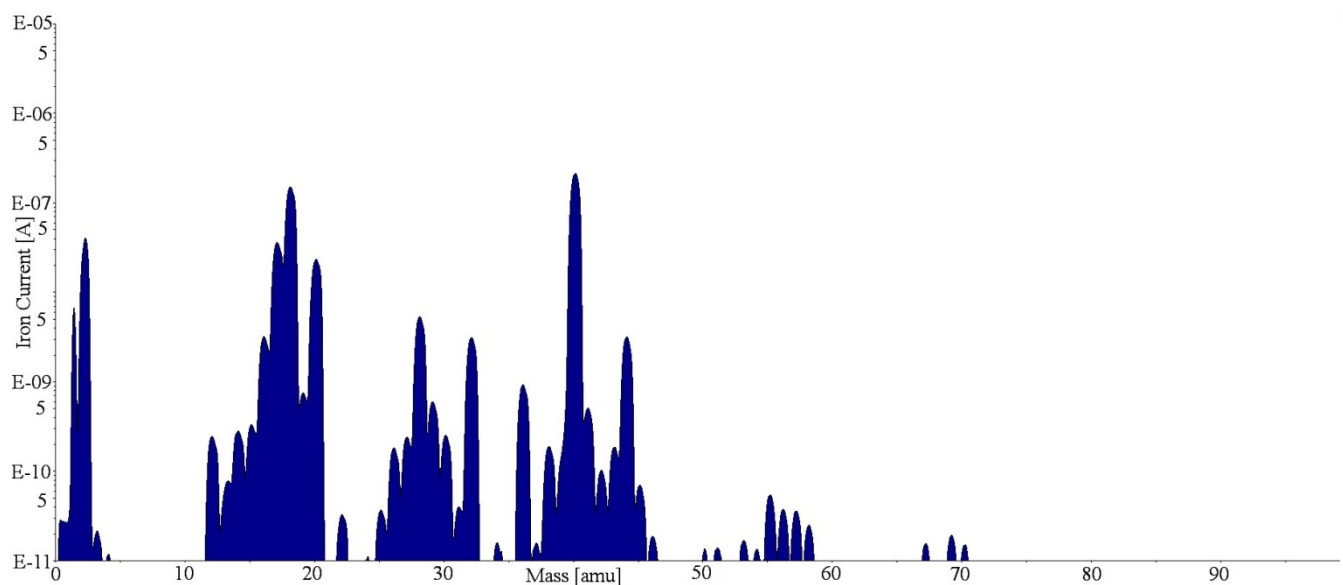


Fig. 6. The composition of gases emitted from the sand bonded with water glass in contact with the drops of cast iron

The content of carbon dioxide in the gaseous atmosphere is much lower than the content of carbon monoxide, which is quite obvious considering the high temperature of metal droplets. As in the case of monoxide, the amount of dioxide is the lowest in the sand bonded with water glass. Between 44 and 100 amu, small peaks from benzene, styrene, and toluene (BTX) appear as well as several secondary peaks

difficult to identify. They are most numerous in the sand with seacoal, in other sands, including the resin-bonded sand, their amount is at a background level. Particles with the weight above 100, observed in the process of heating the sand without contact with metal [7], do not appear. This confirms earlier observations that at temperatures above 600°C, they are unstable.

4. Conclusions

As a result of contact between the molten cast iron and moulding sand, a significant quantity of gaseous matter is formed affecting the surface layers of casting.

The main component of the generated gaseous atmosphere is water vapour. Its amount depends on the sand moisture content and assumes the highest value in the sand with bentonite.

The lowest amount of the vapour was formed in sands bonded with water glass.

The water vapour reacts with metal and the result is the formation of a significant quantity of hydrogen, which is the second main component of the gaseous phase.

Low oxygen content indicates that it is bound in the surface layer of metal causing, among others, the oxidation of carbon. Therefore, even in contact with the sands containing no carbon, small amounts of CO and CO₂ appear.

The gaseous atmosphere contains no nitrogen. Because nitrogen is considered to be a major factor promoting the formation of pinholes, it would be advisable to carry out studies on sands bonded with resins other than Kaltharz X-850.

The atmosphere of mould shows only trace amounts of aromatic hydrocarbons, while the presence of aromatic hydrocarbons has not been detected. Hydrocarbon peaks are most pronounced for the bentonite sand with seacoal, and the weakest for water glass-bonded sands. Studies have confirmed that water glass-bonded sand moulds are the safest in use for both the environment and casting surface quality.

Acknowledgements

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