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ISSN 0543-5846
METABK 51(4) 437-440 (2012)
UDC – UDK 621.746:621.742=111

HARMFULNESS OF MOULDING SANDS WITH BENTONITE AND LUSTROUS CARBON CARRIERS

Received – Prispjelo: 2012-02-08
Accepted – Prihvaćeno: 2012-04-03
Original Scientific Paper – Izvorni znanstveni rad

Procedures have been developed to determine the volume, rate and composition (particularly BTEX: benzene, toluene, ethylbenzene and xylenes and PAHs (polycyclic aromatic hydrocarbons)) of gas evolution from moulds and cores prepared with various binders as a means of harmfulness of moulding sands. The rate of gas evolution from green sands with four different lustrous carbon carrier and BTEX content were determined. The gas evolution rates are highest in the range of about 20 to 30 s after contact with molten metal. In practice during the first 200-250 s the total emission of gases generated in investigated samples occurred. The main emitted component from the BTEX group was benzene.

Key words: moulding sand, castings, bentonite, foundry.

Neškodljivost kalupnih pjesaka sa bentonitom i svijetlećim nositeljima ugljika. Postupci su razvijeni za određivanje volumena, brzine i sastava (posebice BTEX: benzen, toluen, etilbenzen, xilana) i PAH (policiklički automatski hidrokarbonati) plina koji nastaje iz kalupa i jezgri na različitim nosačima u težnji za neškodljivost kalupnih pijesaka. Brzine nastajanja plina iz pripravljenih pijesaka sa 4 različita svijetleća nositelja ugljika i sadržajem BTEX su određeni. Brzine nastajanja plina su najveće u razini 20 do 30 s poslije dodira sa rastopljenim metalom. Praktično, tijekom prvih 200-250 s ostvaruje se ukupna emisija stvorenih plinova u istraživanim uzorcima. Iz BTEX skupine, benzen je glavna emitirajuća komponenta.

Ključne riječi: kalupni pijesak, odljevci, bentonit, ljevarstvo

INTRODUCTION

The assessment of harmfulness of moulding sands applied for casting moulds and cores concerns two basic problems:

- emission of harmful gases during the sands preparation, moulding, pouring, cooling and shakeout of moulds;
- leaching of dangerous substances into the environment from spent foundry sands e.g. during their storage or waste management.

Therefore, when assessing the influence of the given sand on the environment, these two problems should be taken into account. Only such investigations can provide the total assessment of the moulding sand harmfulness [1-5].

It is expected that the development of binding agents appliedfor moulding and core sands will be more of the evolutional than revolutionary character. Changes will be mainly caused by more and more demanding requirements within the environment protection domain.

Sources of the emission of dangerous substances into the air in the casting production process constitute the typical casting operations (e.g. preparation of moulding and core sands, melting of liquid metal, pouring, cooling and shakeout of moulds), as well as the auxiliary processes (e.g. mechanical treatment, fettling and painting of castings) (Figure 1).

In the case of moulding sands with bentonite and additions of lustrous carbon carriers the main sources of dangerous substances emissions are operations of: pouring, cooling, shakeout of moulds and cores making. The emission from these processes constitutes 90 % of the total emission of dangerous compounds (Figure 2).

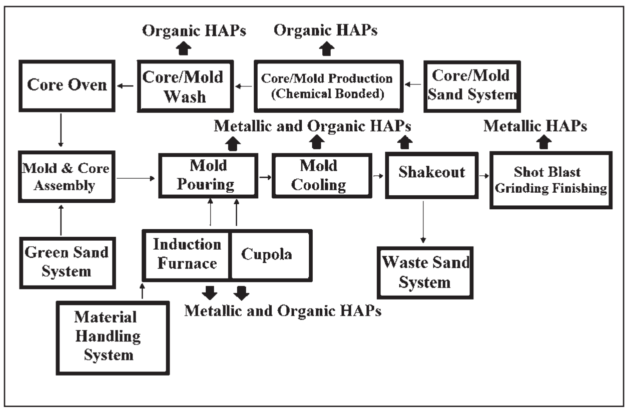

Figure 1 Sources of ferrous foundry HAP (Hazardous Air Pollutants) emission [6]

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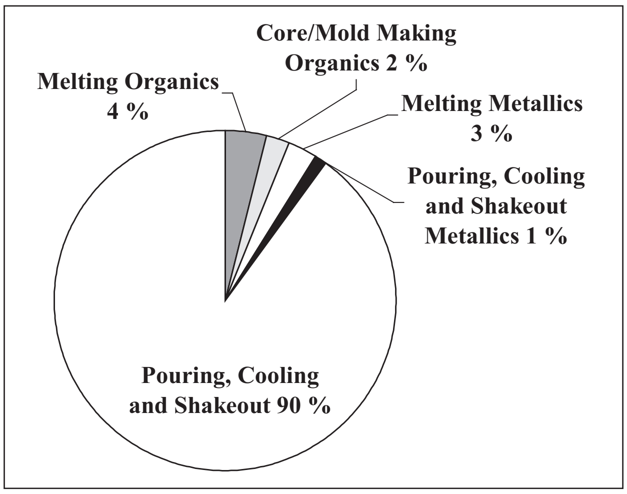

Figure 2 The pouring, cooling and shakeout operations contribute the most emissions in a green sand casting facility [7]

MOULDING SANDS WITH BENTONITE

Moulding sands with bentonite, applied for the production of moulds for steel or aluminium alloys castings are considered to be ecologic* and not emitting organic compounds. However, after introducing coal dusts, synthetic resins or other lustrous carbon carriers into such sands (which is necessary to obtain the adequate surface quality of iron castings, to decrease casting defects and facilitate casting shakeout), they become very harmful for the natural environment as well as they cause harmful working conditions. As the result of a liquid metal high temperature influence on a moulding sand the compounds containing carbon undergo incomplete burning or a cracking process, which causes emission of dangerous substances (PAHs). Wastes of spent moulding sands from this technology also contain some of these substances, which can render difficult their storing or reusing.

Approximately 70-80 % of iron castings are currently produced in moulding sands with bentonite [8] and probably this tendency will be maintained in the world during the next years. Therefore the world companies, producing mixtures for the foundry industry, as well as the research institutions are performing intensive investigations attempting to develop coal-containing additions, which could substitute traditional coal dusts. Such companies as: S&B Industrial Minerale (Germany), Süd-Chemie (Germany), ZGM Zębiec S.A. (Poland), should be mentioned. It is also possible to apply the technology of oxidising harmful substances, the so-called Advanced Oxidation Process [9-10], or to introduce into moulding sands additional substances neutralizing, to a significant degree, the harmful compounds [6].

* Sands with bentonite, without coal dust additions, are not always without organic compounds. Using core sands with organic binders causes that organic compounds evolving due to high temperatures can concentrate in these sands.

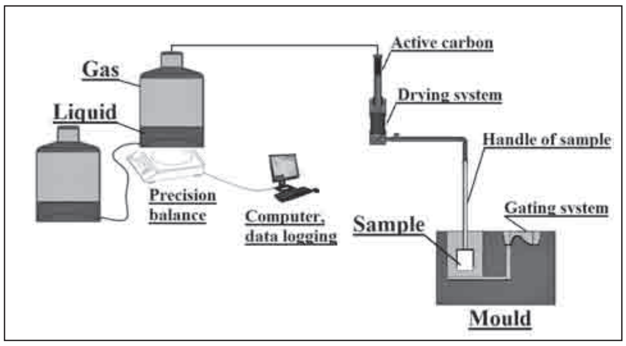

Figure 3 Scheme of stand of measurement of gas volume and BTEX emission

EXPERIMENTAL PROCEDURE

Investigations of the gases emission were performed according to the original method developed in the Faculty of Foundry Engineering, AGH UST [4, 11]. The schematic presentation of the experimental stand is given in Figure 3. A sample of the investigated moulding sand of a roll shape of dimensions Φ 50 x 50 mm, compacted by a moulder's rammer stroke, is poured with liquid cast iron of a temperature of 1 400 ^{o}C. Gases emitting from the sample - after pouring it with liquid metal - are led by means of a steel pipe via the drying system and the capsule with active carbon into a tightly sealed container with liquid, from which they push out the liquid. The weight of displaced liquid was measured as a function of time. Gases from the BTEX group (benzene, toluene, ethylbenzene and xylenes) are adsorbed on active carbon. The tested sample was heated rapidly to a temperature of 1 400 ^{o}C at the surface and then relatively slow inside, to a temperature of 900 ^{o}C. In such a system all tested samples are passing through a temperature range: 400-900 ^{o}C, in which the majority of volatile substances is emitted. The whole mould is made of green sand. The active carbon layer with adsorbed organic substances is extracted in carbon disulphide. The analysis is carried out by the gas chromatography method with the application of the flame-ionising detector (FID).

The gases emission measurements were performed for four green sands with different lustrous carbon carrier originated from 4 various producers from the EU countries. The total gas emission, kinetics of this emission and the content of the BTEX compounds in the emitted gases were estimated.

RESULTS AND DISCUSSIONS

The obtained results are presented in Table 1. The emissivity of gases from green sands and the BTEX content, is presented in Figure 4 a, b, c; 5. The results obtained for the moulding sand with the ENVIBOND binder, developed by the S&B Industrial Minerals Germany, where additions of microcrystalline graphite and natural zeolite were applied, are added for comparison [12]. The kinetics of the emission of gases from the tested moulding sands, expressed for 1 g of the sand, is presented in Figure 6.

Table 1 **Gases emission from moulding sand**

No.	Gases volume / dm^3/kg moulding sand	Gases emission / mg/kg moulding sand				Maximum velocity of emission, dV/dt / cm^3/g·s
		B	T	E	X	
1	19,53 21,37 average 20,45	254,69 231,69 243,19	9,57 7,09 8,33	0,06 0,07 0,065	0,39 0,32 0,35	0,164
2	19,11	386,73	9,76	0,13	1,19	0,156
3	24,73	166,64	3,02	0,05	0,29	0,236
4	22,19	370,85	15,52	0,06	0,47	0,175
5	20,92	128,65	15,43	0,52	3,40	0,5*
B – Benzene, T – Toluene, E – Ethylbenzene, X – Xylene						

* In this case a little different way of leading gases from the sample was applied, which could influence the process kinetics (higher resistances during flow), but should not influence the total amount of gases emitted neither their composition.

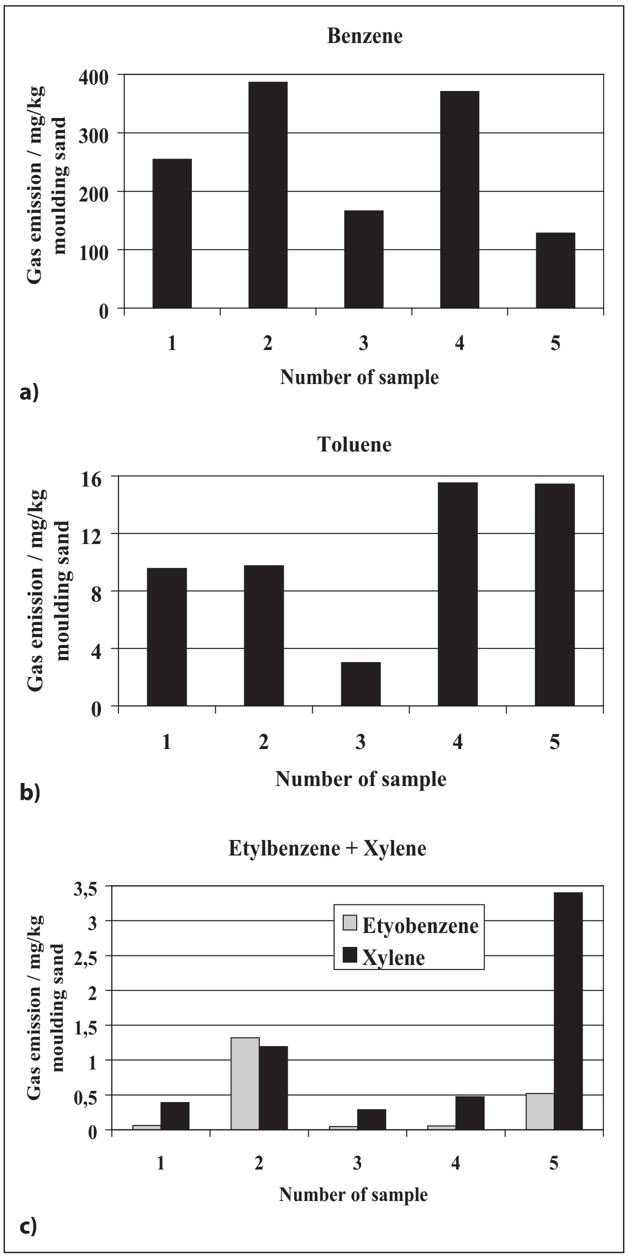

Figure 4 The content of BTEX in gases emitted from moulding sands

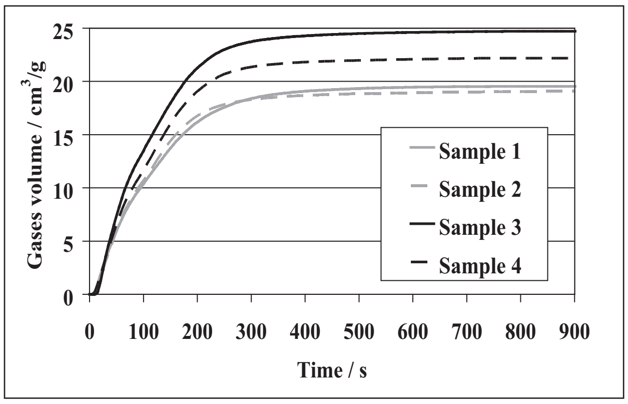

Figure 5 Gases volume emitted from moulding sands

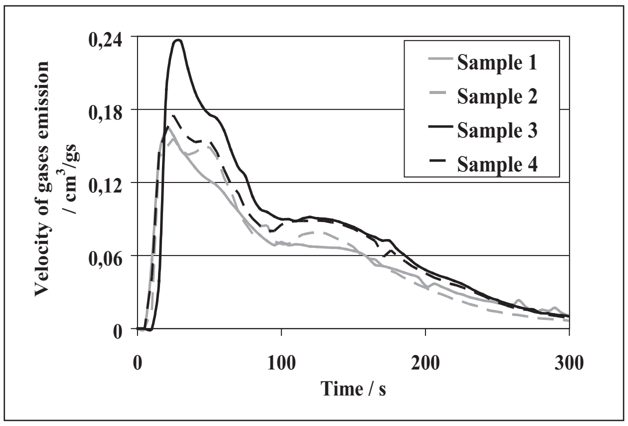

Figure 6 Kinetics of gases emission from moulding sands

The losses on ignition (LOI) and volatile parts (VP) contents are certain indicators of the organic additions content in moulding sands with bentonite. The smaller LOI and VP in sands, the smaller is also the emission of gases during the processes of pouring, cooling and shakeout of moulds [7].

CONCLUSIONS

The performed investigations of gases emissivity from moulding sands with bentonite, containing various additions of lustrous carbon carriers and different kinds of bentonite, indicated that the volumes of emitted gases are within the range: from 19,1 dm^3 to 24,7 dm^3 expressed for 1 kg of the moulding sand. As expected, the main emitted component from the BTEX group was benzene. However, within the investigated moulding sands there are significant differences in the benzene content in emitted gases; e.g. sand No. 2 emits two times more benzene than sand No. 3, in spite of the fact that the volume of the gases emitted from sand No. 2 is 25 % smaller than from sand No. 3. Thus, from the point of view of the casting quality, sand No. 2 is better since it emits less gases and the velocity of their emission is much lower; for sand No. 2 v = 0,156 cm^3/g·s, while for sand No. 3 the maximum velocity v = 0,236 cm^3/g·s. However on account of the environment hazard, due to the carcinogenic benzene emission, moulding sand No. 2 is more dangerous. Therefore LOI and VP content can be only indicators of the volume of the gases emitted from the given sand, but these indicators are not providing any information concerning the chemical composition of gases.

In practice, during the first 200-250 s the total emission of gases generated in investigated samples occurred, and later on the emission level was quite minimal. The gas evolution rates are highest in the range of about 20 to 30 s after contact with molten metal.

The developed method of measuring the gases emission from moulding sands is characterized by a high repeatability of results, and the applied system of sampling (gas drying system, filters for catching dusts, etc.) warrants the correctness of the performed measurements. However, one should be aware, that the moulding sand is a mixture of a high degree of heterogeneity and therefore local differences in the composition can occur, which can influence the obtained results.

Conditions created during experiments can be considered extreme, in respect to the investigated moulding sand, very close to the ones to which the core in the mould is subjected, however much more drastic than in the case of the mould. Thus, it can be assumed that the measured emission values are maximum values, which can occur under the real conditions in the foundry.

The study was performed within the Project No. 07-0016-10/2010 from NCBiR.

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Note: The responsible translator for English language: "ANGOS" Translation Office, Kraków, Poland