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Influence of a Liquid Metal Temperature on a Thermal Decomposition of a Phenolic Resin

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Abstract

Due to the presence of harmful substances in resins those mould sands may be hazardous to the natural environment and workers. The general assessment of harmfulness of sands used for molds and cores encompasses 2 basic points: emission of hazardous substances during processes of preparing sands, pouring mold with liquid metals (high temperatures), cooling and shaking-out; possibility of washing out hazardous substances from used sands to the environment, during storage or economic use outside foundries. We present the results of research on the emission of BTEX compounds from mould sands with phenolic resins during pouring liquid metal of different temperature (cast iron and Al alloy). The research was conducted according to the original method prepared by the authors, which has been used for years in cooperation with various foundries (Poland, abroad).

Keywords: Environment Protection, Phenolic Resin, BTEX, Alluminium, Foundry

1. Introduction

Application of synthetic resins as binding agents for moulding and core sands constitutes a threat for the natural and work environment. This is caused by generating, under an influence of high temperatures, highly toxic substances from the BTEX (benzene, toluene, ethylbenzene, xylenes) and PAHs group (polycyclic aromatic hydrocarbons), and others [1-6]. These compounds are partially released into the atmosphere when a mould is poured with liquid metal and during a mould cooling. However, to a significant degree, they permeate to further mould parts condense on matrix grains and when castings are knocked out these compounds can be released into the atmosphere or eluted during storing of spent foundry sands [7-8].

As it was shown by previous investigations a temperature influencing a binder essentially decides on a composition and concentration of emitted substances [10, 11]. Temperatures 900-1100ºC constitute the range within which the most harmful substances are formed. Since several resins are applied both for making moulds and cores for castings of non-ferrous metals and for ferrous alloys, it is essential - from the point of view of the environment protection as well as the casting quality – to determine amounts and compositions of gases generated both at pouring with alloys of low temperatures (e.g. aluminium alloys) and with alloys of high temperatures (e.g. cast iron).

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2. Investigated resins

The subject of investigations constituted the alkaline phenolic resin soluble in bases and hardened by means of CO_2. This resin is intended for the production of moulds and cores. It is characterized by a small odour evolution during cores production and pouring of moulds with liquid metal. Moulding sands with this resin have a good knocking out ability and provide a good surface quality of castings.

All moulding sands intended for investigations were prepared on the matrix of the standard high-silica sand from Szczakowa.

3. Methodology of testing

Investigations of the gases emission in the test foundry plant were performed according to the original method developed in the Faculty of Foundry Engineering, AGH UST [1-3, 11].

The schematic presentation of the experimental stand is given in Figure 1.

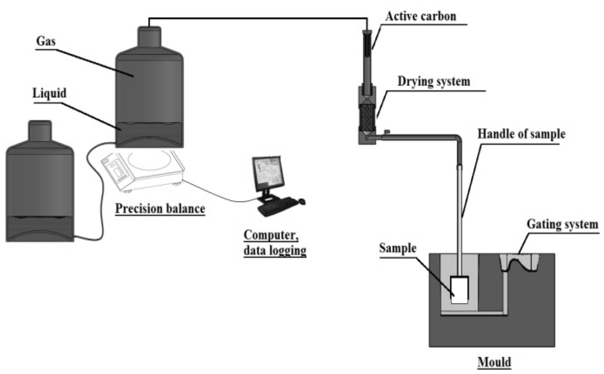

Fig. 1. Experimental stand for the determination of the emitted gases volume and the BTEX emission [1]

A sample of the investigated moulding sand, on the bases of high-silica sand, of a roll shape of dimensions Φ 50 x 50 mm, and a mass of app. 150 g, compacted by a moulder's rammer stroke, was poured either with cast iron of a temperature of 1350ºC or with aluminium alloy of a temperature of 700ºC. The composition of each moulding sand was in agreement with the producer's recommendations (standard composition). 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 (during the BTEX measurement) or polyurethane foam[1] (during the PAHs measurement) 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. The whole mould (a weight equal to 24 kg) was made of green sand. The measuring time was up to 15 minutes (in dependence on the gas evolution intensity). At the determination of BTEX two layers of active carbon separated from each other were placed in the glass tube. One layer (1) containing 700 mg of active carbon was the main adsorption place, while the second layer (2) containing 200 mg of active carbon was of a control character, providing information on an eventual 'breakthrough' of the first adsorption layer[2]. 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).

[1] Raw Polyurethane Foam 0,022 g/cm^2 density (RESTEK) for collection of semivolatiles (pesticides, PCBs, PAHs).

4. Results and their discussion

4.1. Measurement of emitting gases amounts

At each resin test the amount of emitting gases was recorded every 5 seconds. The diagram showing the amount of generated gases with respect to time is presented in Fig. 2, while the rate of their evolution in Fig. 3.

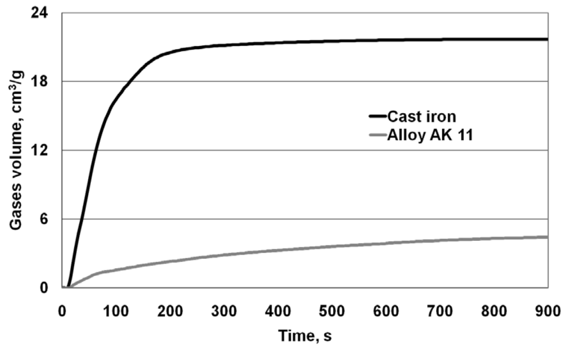

Fig. 2. Emissivity of gases in time, from the investigated sands: after pouring the mould with alloy AK 11 of a temperature of 700^{o}C (grey line); after pouring the mould with cast iron of a temperature of 1350^{o}C (black line)

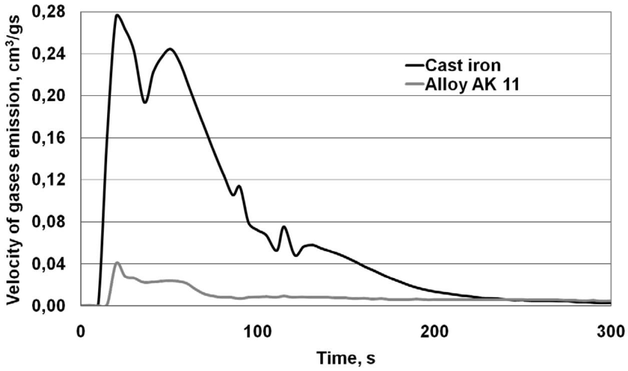

Fig. 3. Velocity of gases emission, from the investigated sands: after pouring the mould with alloy AK 11 of a temperature of 700^{o}C (grey line); after pouring the mould with cast iron of a temperature of 1350^{o}C (black line)

[2] Both layers of active carbon (1 and 2) were analyzed. It was assumed that, if the BTEX amount in the control layer (2) was less than 10% of these compounds concentration in the adsorption layer (1), none 'breakthrough' took place and the measurement was the correct one.

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4.2. Measuring the content of components from the BTEX group

Quantitative data of the emissivity of components from the BTEX group counted over for 1 kg of a moulding sand, are listed in Table 1.

Chromatograms obtained for the BTEX compounds contained in gases emitted from the mould when it is poured with aluminium alloy and with cast iron (under semi-technical conditions) are shown in Fig. 4 and in Fig. 5, respectively.

Table 1.
Results of gas analysis from the BTEX group, generated in tests performed in a semi-technical scale

Sample	Gases volume dm^3/kg moulding sand	Gases emission mg/kg moulding sand				Maximum velocity of gases emission, dV/dt $cm^3/g\cdot s$	Time of max. velo-city, s
		B	T	E	X		
1	21,673	317,89	23,17	0,204	4,143	0,275	20
2	4,424	11,55	2,86	0,047	0,211	0,040	20

B – benzene, T – toluen, E – ethylobenzene, X – xylenes,
1 – sample poured with cast iron, 2 – sample poured with aluminium alloy

1 2

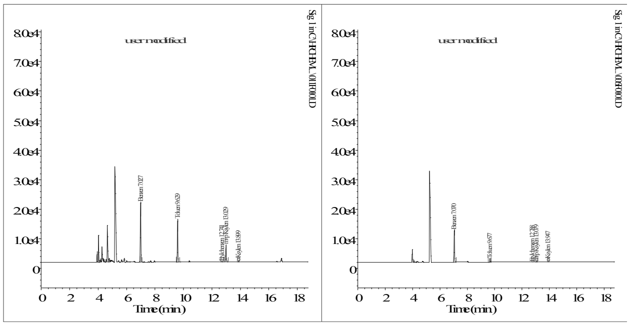

Fig. 4. Report from the chromatographic analysis of BTEX gases for the moulding sand with resin being poured with aluminium alloy (1 – test sample, 2 – control sample)

1 2

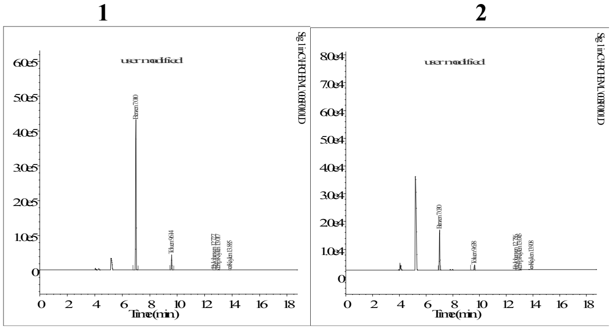

Fig. 5. Report from the chromatographic analysis of BTEX gases for the moulding sand with resin being poured with cast iron (1 – test sample, 2 – control sample)

Conclusions

1. At pouring the moulding sand with the investigated resin by aluminium alloy of a temperature of 700°C approximately 5 times less gases are emitted than when pouring with cast iron of a temperature of 1350°C. This is of an essential importance for the quality of the produced castings.
2. When aluminium alloy is used for pouring, amounts of the BTEX group are of one order of magnitude smaller than when cast iron is used. It is especially visible in case of benzene and toluene, the emission of which is 30-times less.
3. When the investigated resin is applied for moulds and cores for castings of light non-ferrous metals alloys it constitutes only a very small threat for the environment.
4. The results of the previous studies stating, that in case of resins applied as binders for the moulding sands the temperature of 900°C is the one in which the highest amounts of compounds from the BTEX group are formed (especially benzene), were confirmed. Below this temperature the danger of these compounds formation is much smaller [10].
5. It can be assumed that in case of cast iron castings, the source of emitting compounds from the BTEX group will constitute only this part of the moulding sand which reaches temperatures of 900°C and above. Applying simulation programs, it is possible to determine the temperature field around the casting, and thus to estimate the amount of the moulding sand, which will reach these temperatures. In combination with the results obtained during experiments, it is possible to calculate the approximate amounts of compounds from the BTEX group evolving at making the individual casting.

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References

[1] Kubecki, M., Holtzer, M., Bobrowski, A., Dańko, R., Grabowska B. & Żymankowska-Kumon, S. (2012). Analysis of the compounds from the BTEX group emitted during thermal decomposition of alkyd resin. *Archives of Foundry Engineering.* 12(3), 67-72. DOI: 10.2478/v10266-012-0084-z.

[2] Holtzer, M., Kubecki, M., Dańko, R., Żymankowska-Kumon, S. & Bobrowski, A. (2013). Research on the influence of moulding sand with furan resin on the environment. *4th International Symposium on High-Temperature Metallurgical Processing*. 643-650. DOI: 10.1002/978111-8663448.ch77.

Unauthenticated | 89.73.89.243
Download Date | 9/26/13 1:30 PM

[3] Holtzer, M., Grabowska, B., Żymankowska-Kumon, S., Kwaśniewska-Królikowska, D., Dańko, R., Solarski, W. & Bobrowski A. (2012). Harmfulness of moulding sands with bentonite and lustrous carbon carriers. *Metalurgija.* 51(4), 437-440.

[4] Humfrey, C.D.N, Levy, L.S. & Faux, S.P. (1996). Potential carcinogenicity of foundry fumes: a comparative in vivo-in vitro study. *Food and Chemical Toxicology.* 34, 1103-1111. DOI: 10.1016/S0278-6915(97)00081-1.

[5] Ribeiro, M.G. & Filho, W.R.P. (2006). Risk assessment of chemicals in foundries: the international chemical toolkit pilot-project. *Journal of Hazardous Materials.* 136(A), 432-437. DOI: 10.1016/j.jhazmat.2006.01.019.

[6] Scarbel, P., Bats, C.E. & Griffin, J. (2006). Effect of Mold and Binder Formulation on Gas Evolution When Pouring Aluminum Casting. *AFS Transactions.* 114, 435-445.

[7] Ji, S., Wan, L. & Fan, Z. (2001). The toxic compounds and leaching characteristics of spent foundry sands. *Water, Air and Soil Pollution.* 132, 347-364. DOI: 10.1023/A:1013207000046.

[8] Holtzer, M., Lewandowski, J.L., Bilska, M. & Grabowska, B. (2004). Leaching of harmful substances from some moulding and core sands used in iron foundry. *Przegląd Odlewnictwa.* 54(10-11), 870-874.

[9] LaFay, V.S., Neltner, S., Carroll, D. & Couture, D.J. (2010). Know the Environmental Impact of Your Additives. *Modern Casting.* 10, 27-29.

[10] Report from research No. BO-1316 (2011). Institute for Ferrous Metallurgy, Gliwice, Poland.

[11] Experimental stand for investigating the emissivity and harmfulness of gases emitting from technological materials applied in casting and foundry processes (2012). Patent application: P-398 709 with legal effect.

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