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Studies on the Gases Emission of Moulding and Core Sands with an Inorganic Binder Containing a Relaxation Additive

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Abstract

The paper presents the results of an investigation of the gases emission of moulding sands with an inorganic (geopolymer) binder with a relaxation additive, whose main task is to reduce the final (residual) strength and improves knocking-out properties of moulding sand. The moulding sand without a relaxation additive was the reference point. The research was carried out using in accordance with the procedure developed at the Faculty of Foundry Engineering of AGH - University of Science and Technology, on the patented stand for determining gas emissions. Quantification of BTEX compounds was performed involving gas chromatography method (GC).The study showed that the introduction of relaxation additive has no negative impact on gas emissions - both in terms of the total amount of gases generated, as well as emissions of BTEX compounds. Among the BTEX compounds, only benzene is emitted from the tested moulding sands. Its emission is associated with the introduction a small amount of an organic hardener from the group of esters.

Keywords: Moulding sand, Aluminosilicates, Geopolymer, Inorganic binder, Gases emission

1. Introduction

The interest in environmentally friendly moulding and core sands is growing every year, and is mainly due to the stricter regulations related to the emission of harmful chemicals to the environment. At present, most castings are produced in green sands and in moulding sands with organic binders. When pouring molds with a liquid casting alloy, all organic binders decompose (thermal degradation) and is accompanied by the emission of harmful compounds [1-2]. The indicator of gas formation of moulding sand is the emission of compounds from the BTEX and PAH groups [3]. From the point of view of foundry technology, the general amount of gases is also an important issue, which arises as a result of the decomposition of additives found in the moulding sand, because it decides to obtain castings without defects.

Given the above, attention is drawn more and more moulding sands with inorganic binder. The most well-known inorganic binder used in the moulding sand technology is hydrated sodium silicate, commonly known as water glass. In recent years geopolymer and silicate binders have also appeared [4-11].

Moulding sands made with their participation are characterized by good mechanical properties and allow to obtain castings of high surface quality [12–23]. Sands not emit harmful gaseous products when moulds are poured with liquid metal alloy [24]. Their disadvantage is poor knocking out and poor susceptibility to the mechanical reclamation process [25–28]. In order to limit this technological disadvantage a way is being sought to improve the knocking out [5, 29-31].

In the monograph entitled "The phenomenon of dehydroxylation of selected mineral materials from the aluminosilicates group as the determinant factor of the knock-out improvement of moulding and core sands with inorganic binder" it has been shown, that the use of mineral relaxant additives, it eliminates the problem of poor knocking out [32].

The aim of the research presented in the article was to show that introduction of mineral additives has no negative impact on the amount of gas generated during pouring mold with liquid metal alloy, as well as increasing their harmfulness - BTEX and PAH emissions.

2. Materials for research

Material for investigations consisted of moulding sand with the inorganic binder Geopol®, containing mineral relaxants, prepared on the basis of silica sand from the "Szczakowa" mine.

The hardener was a mixture of esters, dedicated to the Geopol® binder, under the trade name SA72.

Two types of additions were used. One of them was introduced into the moulding sand in the form of two different fractions and with different proportions in relation to the grain matrix (quartz sand). For comparison, moulding sand without additives was used. The sands were prepared according to the composition shown in Table 1.

For the tested additives and quartz sand, constituting the matrix of moulding sands, the sieve analysis was performed. Selected parameters of the tested samples obtained on its basis are presented in Table 2.

3. Research methodology

Gas-forming studies in the aspect of the total volume of gases emitted and emissions of compounds from the BTEX group in semi-industrial conditions were carried out on a patented stand for determining the intensity of emissions and harmfulness of gases emitted from technological materials used in foundry and metallurgical processes (Patent PL 398709) [33].

Their purpose was to determine the impact of the type, quantity and grain size of introduced loosening additives on the amount of generated gases. A standard fitting Φ50 × 50 mm prepared from the tested molding sand, with a known mass of the sample, was placed in a steel bell and fixed in a previously prepared mold cavity. The mold was cast with gray iron at temperature 1350°C.The gases formed as a result of contact with the liquid metal alloy were adsorbed on an activated carbon bed, after drying, and then with a pipe system for a peristaltic pump and an electronic recorder. The accurately calibrated peristaltic pump coupled with the recorder allowed the volume of gases formed to be recorded.

Analysis of the volatile products, with particular emphasis on the BTEX compounds was conducted by gas chromatography method with the use of the flame-ionizing detector (GC-FID), equipped with the capillary chromatographic column RXI 5Sil-MS (Restek) of a length 30 m and internal diameter 0.25 m.

The complete stand is presented in Figure 1. Figure 2 shows scheme of the capsule intended for adsorption of compounds from the BTEX group.

Table 1.
Quantitative composition of moulding sands

Sample	Type of the relaxation additive	Content of the additive in sand, parts by mass	Quartz sand, parts by mass	Content of the binder Geopol®, parts by mass	Content of the hardener SA72, % in relation to the binder
M0	–	–	100	2.5	8
M1	S1	2	100	2.5	8
M2	S1	5	100	2.5	8
M3	S2	2	100	2.5	8
M4	S3	1	100	2.5	8

Table 2.
Sieve analysis of relaxation additives and quartz sand [33]

Parameter	Unit	Sample			
		Additive S1	Additive S2	Additive S3	Quartz sand
Main fraction		0.16/0.10/0.071	0.80/0.63/0.40	0.071/0.056/ bottom	0.32/0.20/0.16
Average grain size, d_L	mm	0.08	0.77	0.06	0.23
Average grain size, *D50*	mm	0.10	0.73	0.07	0.26
Share of the main fraction, F_g	%	92.61	99.34	82.96	81.94
Distribution coefficient, S_0	–	1.27	1.15	1.93	1.27
Inclination indicator, S_k	–	1.04	1.22	0.98	1.00
Degree of homogeneity, *GG*	%	61.00	76.00	21.00	68.00
Specific surface, S_t	m^2/kg	27.36	2.93	38.35	9.42

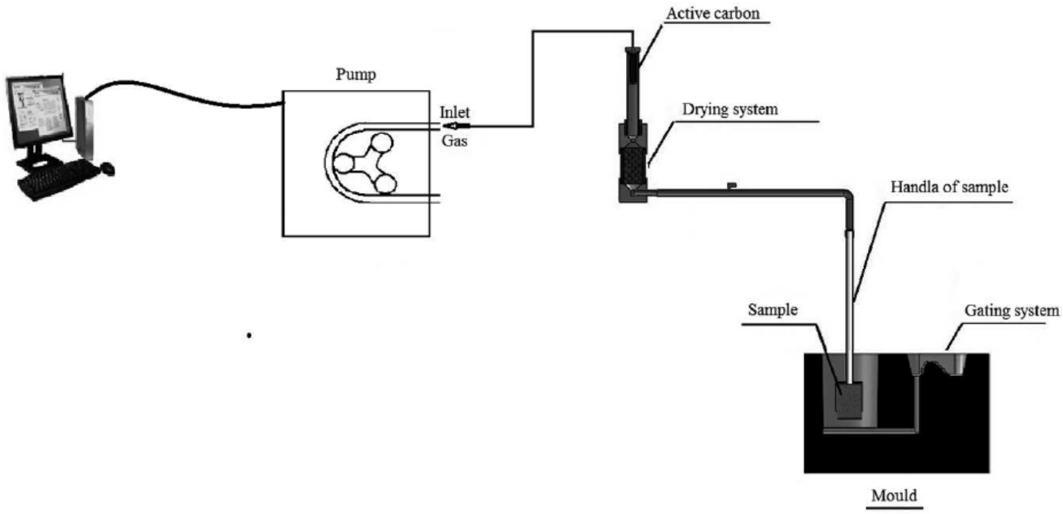

Fig. 1. Scheme of experimental stand for the determination of the emitted gases [24]

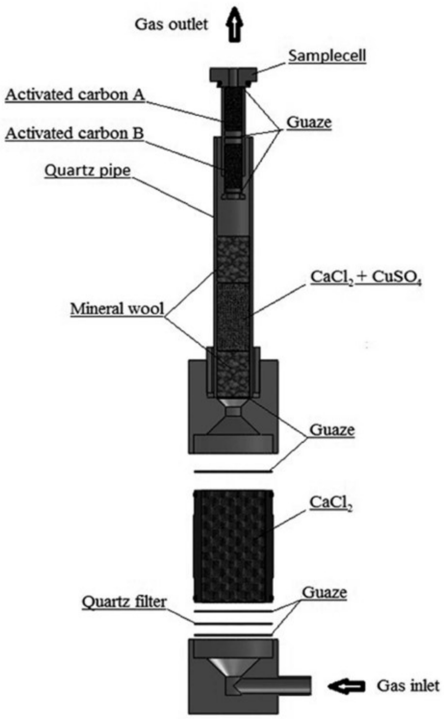

Fig. 2. Scheme of capsule for adsorption of BTEX compounds [24]

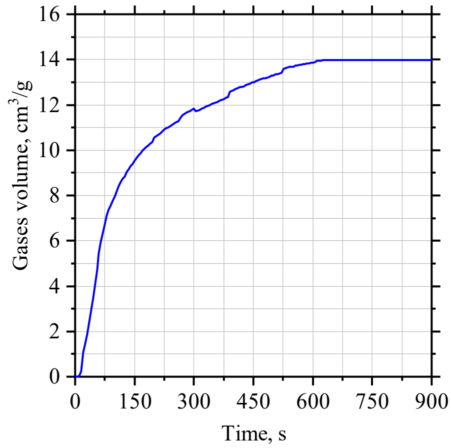

Fig. 3. Total gases volume over time from the moulding sand with geopolymer binder (Geopol®) without mineral additives

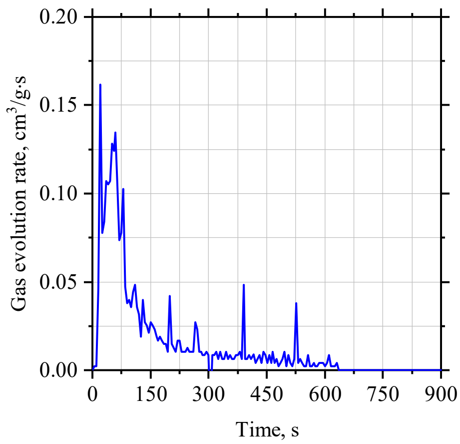

Fig. 4. Gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) without mineral additives

4. Results and their discussion

Figures 3–4 show the total gases volume and gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) without mineral additives.

Figures 5–6 show the total gases volume and gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) with mineral additives (5.0 parts by mass)

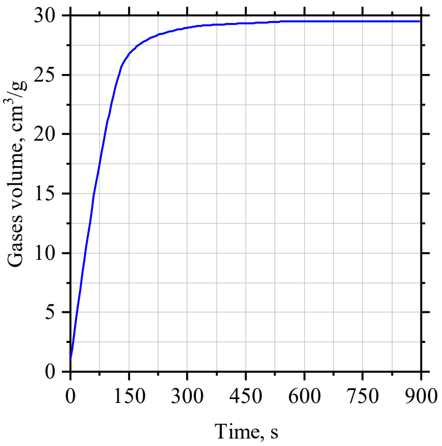

Fig. 5. Total gases volume over time from the moulding sand with geopolymer binder (Geopol®) with mineral additive S1 (5.0 parts by mass)

The rate of gas evolution from the moulding sans with a geopolymer binder without relaxant additives reaches the highest value (0.17 cm^3/g·s) after about 25 seconds from the moment the mold is pouring with liquid metal alloy (Fig. 4).

The rate of gas evolution from moulding sands, which each time contained 2.0 parts by mass of relaxant additive, reaches a value similar to the speed obtained for the moulding sand without additives - only after about 40-60 seconds after pouring with liquid metal alloy (Fig. 8).

Whereas the moulding sand with the participation of 5.0 parts by mass of the S1 additive (Fig. 6), it is characterized by a higher gas evolution rate (0.27 cm^3/g·s). The largest amount of gas is formed within 2–3 minutes of contact with high temperature of liquid metal alloy.

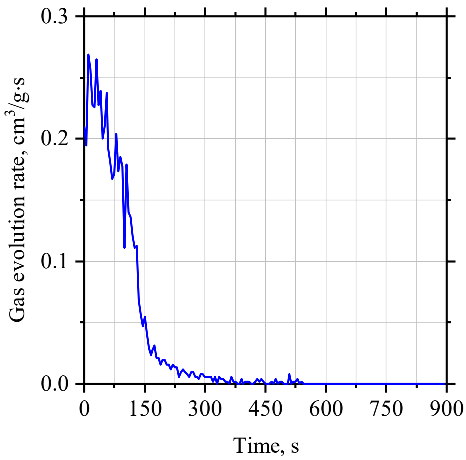

Fig. 6. Gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) with mineral additives S1 (5.0 part by mass)

Figures 7–10 show the total gases volume and gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) with mineral additives S1, S2 (2.0 parts by mass), while figures 11-12 show the results for the moulding sand with the additive of S3 (1.0 part by mass).

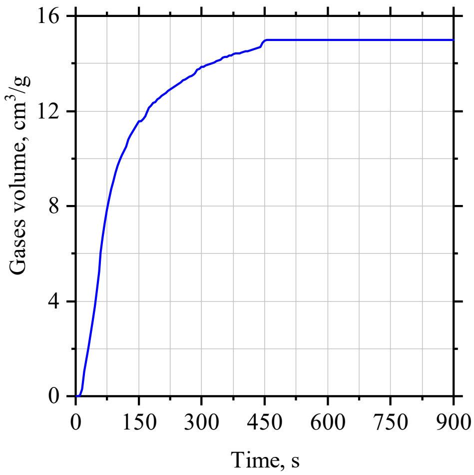

Fig. 7. Total gases volume over time from the moulding sand with geopolymer binder (Geopol®) with mineral additive S1 (2.0 parts by mass)

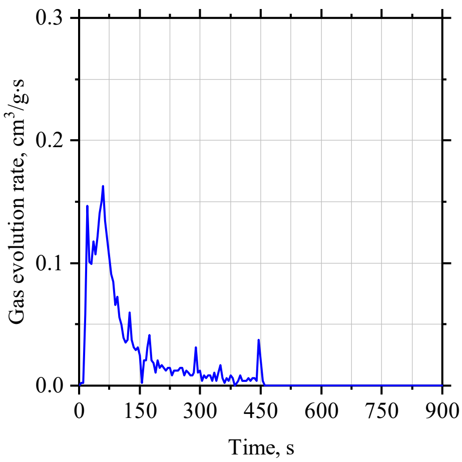

Fig. 8. Gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) with mineral additive S1 (2.0 part by mass)

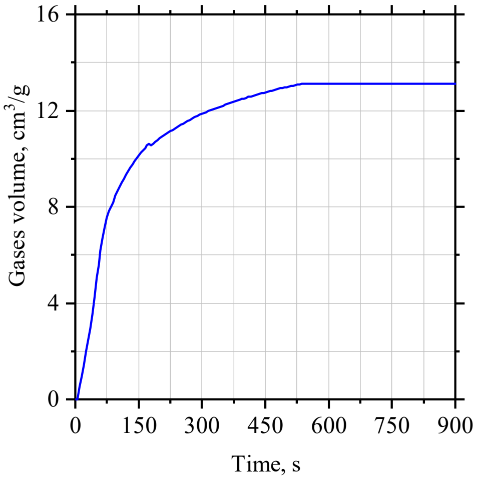

Fig. 9. Total gases volume over time from the moulding sand with geopolymer binder (Geopol®) with mineral additive S2 (2.0 parts by mass)

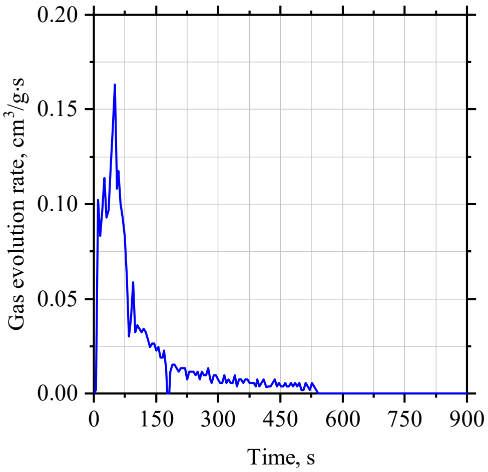

Fig. 10. Gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) with mineral additive S2 (2.0 part by mass)

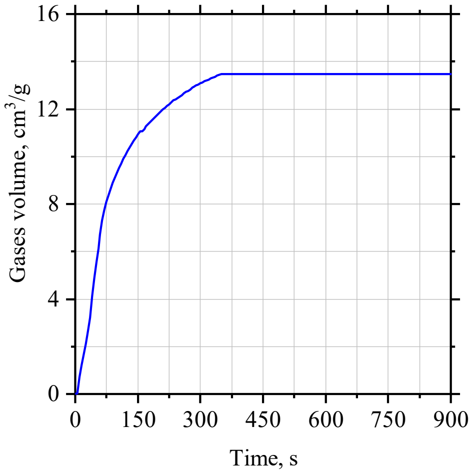

Fig. 11. Total volume over time from the moulding sand with geopolymer binder (Geopol®) with mineral additive S3 (1.0 parts by mass)

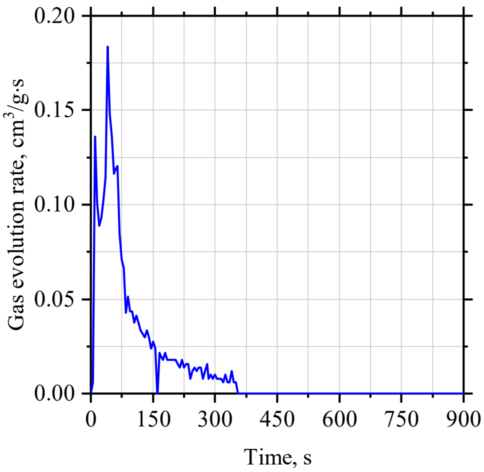

Fig. 12. Gas evolution rate over time from the moulding sand with geopolymer binder (Geopol®) with mineral additive S3 (1.0 part by mass)

As follows from Table 3, the introduction of mineral relaxant additives does not have a significant effect on the total volume of gases formed during the pouring of moulding sands with liquid metal alloy. A small amount of compounds from the BTEX group is also formed from the tested sands, regardless of the amount of additive introduced (Tab. 3).

Studies have also shown a beneficial effect of the S3 additive introduced into the moulding sand in relation to the amount of benzene emitted from the sands. This is probably due to its sorption properties. This type of additive can therefore contribute to minimizing the amount of benzene resulting from the thermal decomposition of the hardener [32].

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Table 3.
Emission of gases from the moulding sand with a geopolymer binder Geopol® containing mineral relaxant additives

Sample	Gas volume, dm^3/ kg moulding sand	Gas evolution rate, $cm^3/g\cdot s$	BTEX content in emitted gases, mg/kg moulding sand			
			Benzene	Toluene	Ethylbenzene	Xylenes
M0	13.99	0.16	25.08	0.00	0.00	0.00
M1	14.99	0.16	20.63	0.00	0.00	0.00
M2	29.48	0.27	23.71	0.00	0.00	0.00
M3	13.10	0.17	21.63	0.00	0.00	0.00
M4	13.46	0.19	15.57	0.00	0.00	0.00

5. Conclusions

Based on the results of the research, the written below conclusions were formulated:

- The proposed relaxant additives belong to the group of inorganic materials. Thanks to this, during pouring molds with liquid casting alloy, no emission of harmful gaseous compounds occurs, and moulding sands with inorganic binders retain their main advantage - they are still environmentally friendly.
- The introduction of relaxant additives in the amount of 2.0 parts by mass has no effect on the amount of generated gases and the rate of their release.
- Among the BTEX compounds, only benzene is emitted from the tested moulding sands. Its emission is associated with the introduction a small amount of an organic hardener from the group of esters.
- The size of the fraction of relaxant additives introduced does not affect the amount of gases formed.
- A positive effect of the addition of S3 on the amount of emitted benzene was shown. This is due to its sorption properties. It can therefore be assumed that this addition may reduce the amount of benzene formed from the thermal decomposition of the hardener.

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