www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.1515/afe-2017-0134

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

DE GRUYTER OPEN

ISSN (2299-2944)
Volume 17
Issue 4/2017

79 – 84

Gases Emission From Surface Layers of Sand Moulds and Cores Stored Under the Humid Air Conditions

N. Kaźnica *, J. Zych, J. Mocek
Faculty of Foundry Engineering, AGH University of Science and Technology
Al. Mickiewicza 30, 30-059 Krakow, Poland
* Corresponding author: Email address: sobula@agh.edu.pl

Received 19.06.2017; accepted for printing 03.08.2017

Abstract

A large number of defects of castings made in sand moulds is caused by gases. There are several sources of gases: gases emitted from moulds, cores or protective coatings during pouring and casting solidification; water in moulding sands; moisture adsorbed from surroundings due to atmospheric conditions changes. In investigations of gas volumetric emissions of moulding sands amounts of gases emitted from moulding sand were determined - up to now - in dependence of the applied binders, sand grains, protective coatings or alloys used for moulds pouring.
The results of investigating gas volumetric emissions of thin-walled sand cores poured with liquid metal are presented in the hereby paper. They correspond to the surface layer in the mould work part, which is decisive for the surface quality of the obtained castings. In addition, cores were stored under conditions of a high air humidity, where due to large differences in humidity, the moisture - from surroundings - was adsorbed into the surface layer of the sand mould. Due to that, it was possible to asses the influence of the adsorbed moisture on the gas volumetric emission from moulds and cores surface layers by means of the new method of investigating the gas emission kinetics from thin moulding sand layers heated by liquid metal.
The results of investigations of kinetics of the gas emission from moulding sands with furan and alkyd resins as well as with hydrated sodium silicate (water glass) are presented. Kinetics of gases emissions from these kinds of moulding sands poured with Al-Si alloy were compared.

Keywords: Surface layer, Sand mould, Emission of gases, High air humidity, Moulding sands with chemical binders

1. Introduction

Casting defects are defined as deviations of material features, structure or properties (mechanical, physicochemical) from the binding requirements [1], so they appear in various forms and kinds [2 – 5]. They are also inherent elements of the technological process of the castings production. One of the main reasons of formations of significant groups of defects are gases emitted from poured moulds and solidifying castings. These gases, when flowing through liquid metal, can become to a certain degree dissolved in it, to get partially into a mould or remain in metal as another phases – bubbles [6]. Gases have several sources; one of them is moisture adsorbed from surroundings by surface layers of moulds and cores. Individual moulding sands with chemical binders indicate various abilities of adsorbing moisture from surroundings [7 – 9]. This moisture can be the source of gases leading to casting defects formation.

An inclination to emission of gases from casting materials (moulding sands, coatings) is usually determined on the bases of two groups of methods:

- related to investigations under laboratory conditions [10 – 14], determining amounts of gases emitted from moulding sands present in the heated flask;
- related to investigations performed under conditions corresponding to the ones occurring directly in a mould [15 – 22] determining amounts of gases emitted from a core (a probe) during contact with liquid metal.

Not for long, the measurements of the gas volumetric emission is also possible in surface layers of sand moulds and cores [23, 24], which are the most important in the gas emission process.

2. Investigation methodology

The determination of the amount of gases emitted from a mould poured with liquid metal concerns mainly layers directly contacting with metal, it means surface layers of a mould cavity or core. It occurs in such a way due to very uneven heating of a casting mould. Layers directly contacting with liquid metal are heated the most intensively.

Striving after the best analysis of the gas volumetric emission from moulding sands, especially taking into account the adsorbed moisture influence, the new, original investigation method [23, 24] - allowing to assess moulding sands under conditions occurring in a surface layer - was applied.

The investigation was based on pouring the thin-walled core, present in the sand mould (Fig. 1), with liquid metal - Al-Si alloy. It should be emphasised, that it corresponds to the surface layer of a moulding sand in the mould work part, contacting directly with the casting.

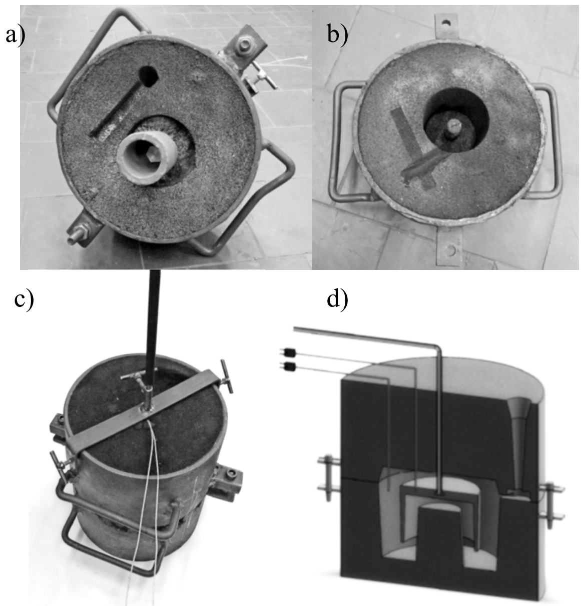

Fig. 1. Sand mould: a – cope with core, b – drag, c – prepared to pouring with liquid metal, d – section

The cores, presented in Fig. 2, of a wall thickness of 8 mm were made of moulding sands with organic and inorganic binders, of compositions shown in Table 1.

Fig. 2. Core for testing the gas emission from the mould surface layer

Table 1.
Composition of moulding sands

Moulding sand	Component	Amount
with water glass binder	sand grains – silica sand	100 parts of mass
	binder – sodium water glass	3,50 parts of mass
	hardener – type of Flodur	10 % to binder
with furan binder	sand grains – silica sand	100 parts of mass
	binder – resin FR75	1,2 parts of mass
	hardener – PU6	60% to binder
with alkyd binder	sand grains – silica sand	100 parts of mass
	binder - resin	1,3 parts of mass
	hardener - SL	25% to binder

After 24 hours of hardening in the air, the cores were dried at a temperature of 50°C up to obtaining the constant mass, in order to ensure the same initial conditions for each core (by removing water adsorbed from surroundings during hardening). Then, the cores were stored under conditions of a high relative humidity of the atmospheric air (above 90%) and at a temperature of approximately 30°C, to exchange moisture between surroundings and moulding sand (moisture penetration into the core surface layer). On account of various sorption ability of individual moulding sands, the cores were stored under the mentioned above conditions, for various time periods. Nevertheless, the total amount of moisture adsorbed from surroundings was similar for each core and equaled approximately 0.4 g (for 100 g of the core mass).

For comparison (and for the determination of the reference point) the gas volumetric emission from surface layers not subjected to the moisture sorption process from surroundings, was also investigated. The cores after 24 hours of hardening in the air were dried at a temperature of 50°C to obtain their constant mass.

3. Analysis of the results

The determination of the influence of the adsorbed moisture on the amount of emitted gases was the purpose of the performed investigations of the gas volumetric emission from surface layers. The test casting is shown in Fig. 3.

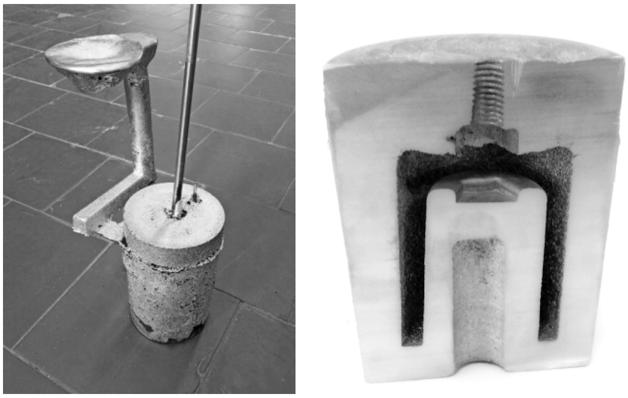

Fig. 3. Appearance of: a – test casting, b – test casting section

From the point of view of the casting defects occurrence the total amount of emitted gases is essential. The applied investigation method allows to determine the specific gas volumetric emission, it means related to 1% of a binder in the moulding sand, as a function of time and temperature. The obtained results for three moulding sands with binders are presented in Figures 4 – 9. It is clearly seen, that moist cores - due to water vapour particles adsorbed from surroundings - are characterised by an increased emission of gases. The moisture excess in moulding sands increases the gas volumetric emission by approximately 0.2 cm^3 for each g of the moulding sand, in relation to the binder amount. In the case of high-dimensional moulds of expanded work surfaces these are essential values. What's more, the largest amount of gases emits during the first app. 100 seconds from the start of the mould pouring with liquid metal. This corresponds to the period during which metal was not fully solidified. Thus, the gases emission occurs at temperatures being above the solidus temperature.

Regardless the conditions of the cores storage (dried or moistened cores) the moulding sand with alkyd resin is characterised by the highest gas volumetric emission, while the moulding sand with hydrated sodium silicate (water glass) is characterised by the lowest emission. The cores storage under humid air conditions, causing the moisture sorption into their surface layers, strengthens only this effect.

Simultaneously, it should be taken into account that moisture contained in surface layers causes the pressure increase of emitted gases and their partial escape is seen during the mould pouring through the sprue.

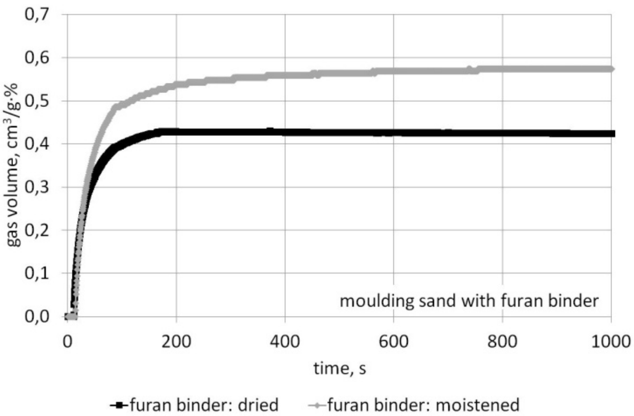

Fig. 4. Volume of gases emitted from the dried and moistened core when the furan mould was poured with Al-Si alloy

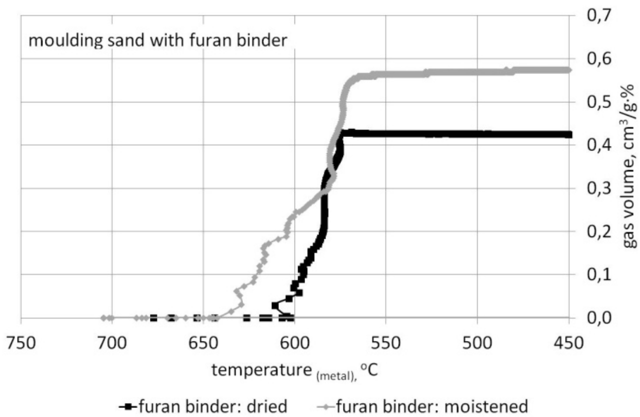

Fig. 5. Volume of gases emitted from the dried and moistened core related to the instantaneous metal temperature

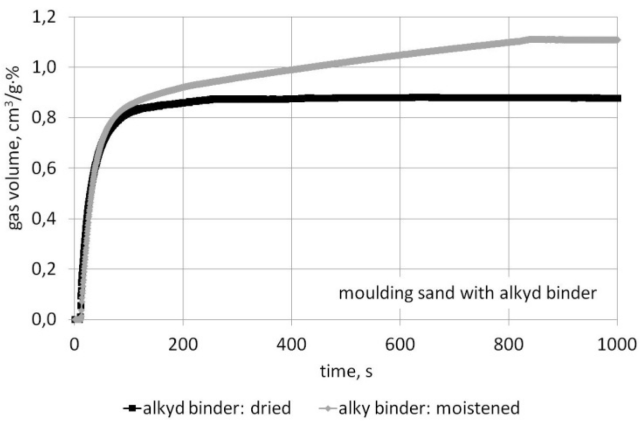

Fig. 6. Volume of gases emitted from the dried and moistened core when the alkyd mould was poured with Al-Si alloy

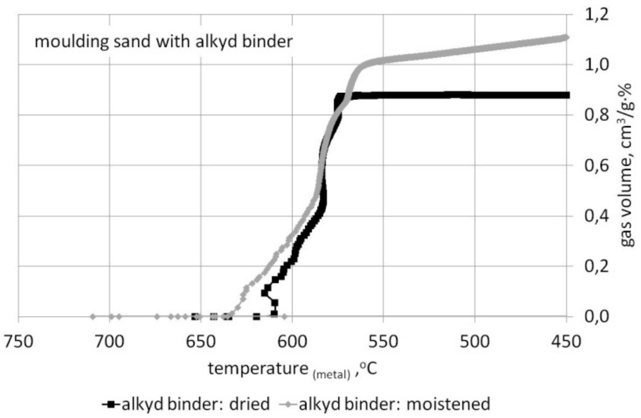

Fig. 7. Volume of gases emitted from the dried and moistened core related to the instantaneous metal temperature

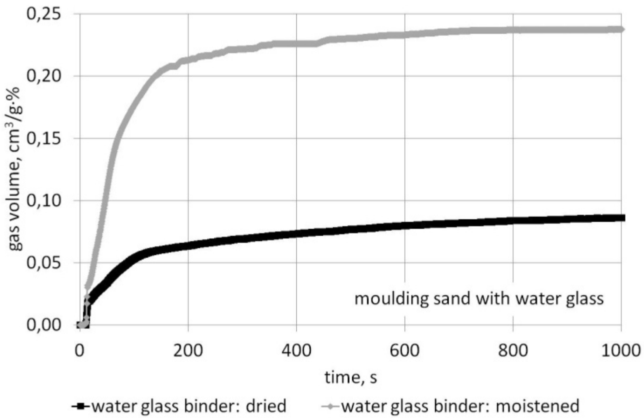

Fig. 8. Volume of gases emitted from the dried and moistened core when the water glass mould was poured with Al-Si alloy

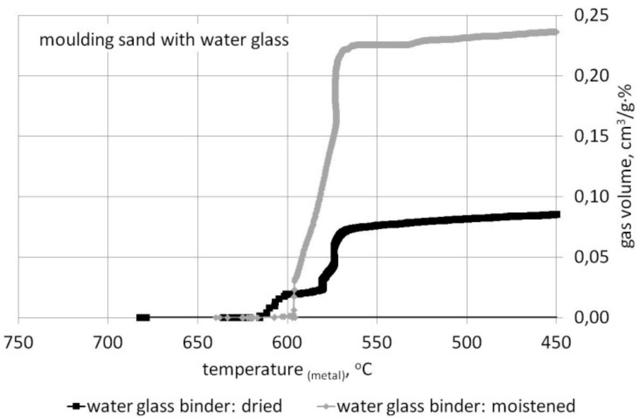

Fig. 9. Volume of gases emitted from the dried and moistened core related to the instantaneous metal temperature

Apart from the total amount of emitted gases their emission kinetics is essential. An increased emission rate of gases can be increasing the amount of not dissolved gases remaining in metal as a free phase and - in consequence - casting defects such as blisters will be formed.

The applied method of investigating the gas volumetric emission allows to present the gas emission pathway in relation to the instantaneous metal temperature as well as to the core temperature. The results are presented in Figures 10 – 12 and 13 – 15, respectively. Such graphical presentation clearly indicates that gases are emitting when metal is either in a liquid or semi-solid state. The most intensive emission occurs at the highest temperatures. Along with a temperature decrease, i.e. a slow metal solidification, the gases emission rate also decreases. The process decays when the solidus temperature (app. 575°C) is reached.

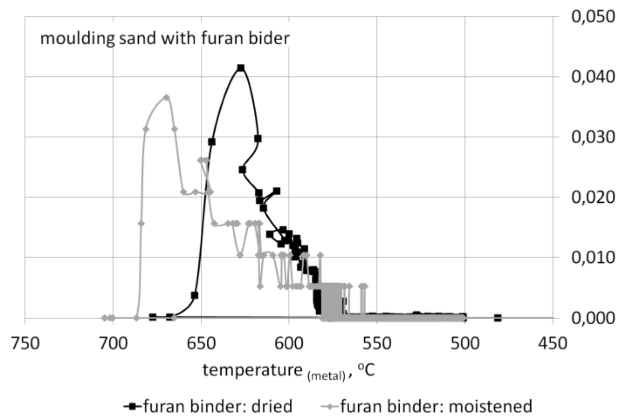

Fig. 10. Kinetics of gases evolutions from cores of furan moulding sands related to the instantaneous metal temperature

Additional moisture content in the core influences the moulding sands gas emission. It changes the position of the first maximum – shifts it in the direction of higher temperatures. Thus, the emission of gases from moulding sands occurs earlier as compared to dried cores.

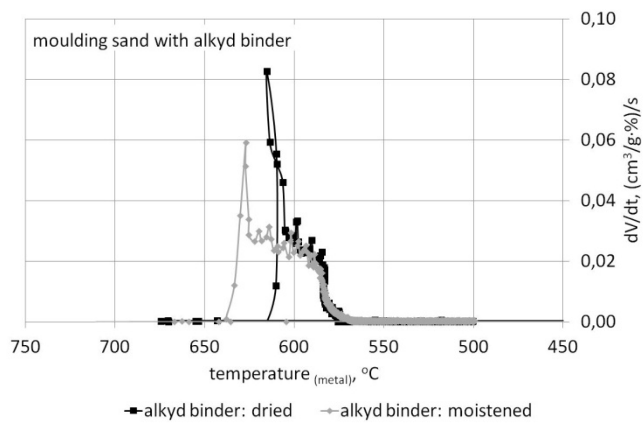

Fig. 11. Kinetics of gases evolutions from cores of alkyd moulding sands related to the instantaneous metal temperature

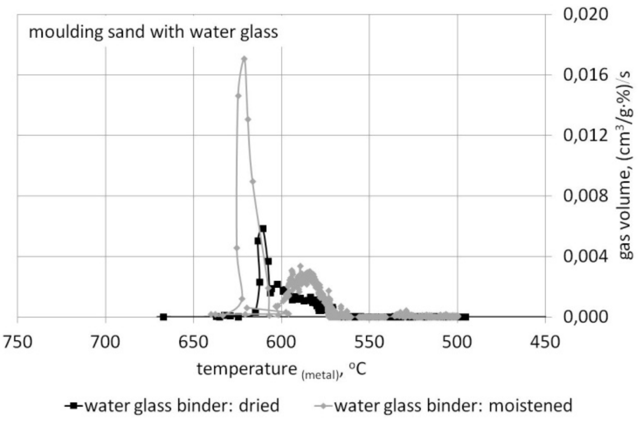

Fig. 12. Kinetics of gases evolutions from cores of water glass moulding sands related to the instantaneous metal temperature

When performing the comparison between individual moulding sands, it should be noticed that the moulding sand with furan resin undergoes destruction in the fastest way. It means at higher metal temperatures - in comparison with the remaining moulding sands - the binder components undergo gasification. In case of moistened cores - in each tested case - the fast evaporation of water present in surface layers occurs at the beginning.

The pathways of gases emission in dependence of the instantaneous core temperature are presented in Figures: 13 – 15. It is characteristic that gases are emitting within a very wide range of temperatures, which increases the possibility of the casting defects formation. Additions of water in surface layers of cores increases this effect. Simultaneously, it should be noticed that regardless of the fact that gases are emitted from moulding sands within similar temperature ranges, this process occurs with various rates. The most intensive is the emission from the moulding sand with alkyd resin, nearly less than a half from the moulding sand with furan resin and decisively the slowest from the moulding sand with water glass.

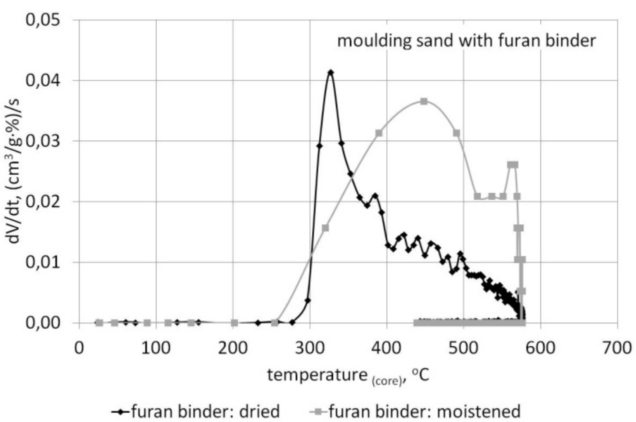

Fig. 13. Kinetics of gases evolutions from cores of furan moulding sands related to the instantaneous core temperature

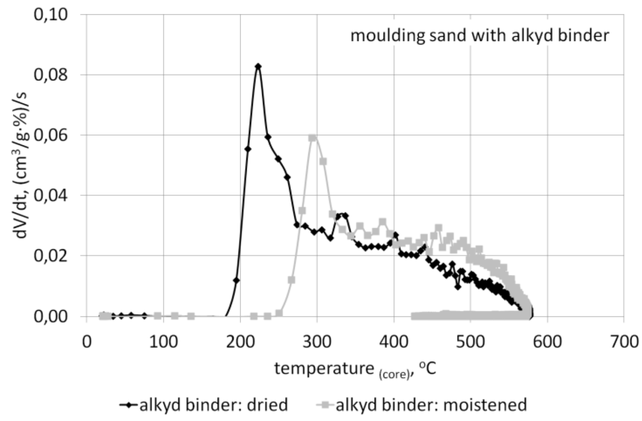

Fig. 14. Kinetics of gases evolutions from cores of alkyd moulding sands related to the instantaneous core temperature

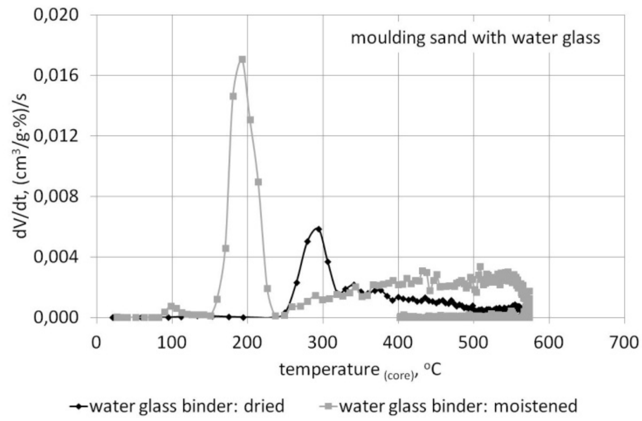

Fig. 15. Kinetics of gases evolutions from cores of water glass moulding sands related to the instantaneous core temperature

4. Conclusions

The conclusions written below can be formulated on the basis of the performed investigations of gases emissions from surface layers of moulds and cores stored under the humid air conditions.

- Surface layers of sand moulds and cores poured with liquid metal are emitting various amounts of gases depending on the applied binder – the moulding sand with alkyd resin emits the most while the moulding sand with water glass emits the least.
- Additional moisture contained in surface layers increases the effect of gases emission - e.g. in the moulding sand with water glass causes a threefold increase of the amount of emitted gases.
- Gases are emitted up to the moment of the metal solidification, it means at temperatures above the solidus temperature.
- The heated moulding sand emits gases in a wide range of temperatures, and moisture adsorbed from surroundings increases this range.

- The effect of the increased emission of gases from the moist - due to variable atmospheric conditions - surface layer should be taken into account in designing the mould and cores technologies.

Acknowledgements

The study was performed as the Dean Project No. 15.11.170.570.

References

[1] Falęcki, Z. (1997). *Analysis of casting defects*. Kraków: Wydawnictwo AGH. (in Polish).
[2] PN-85/H-83105, *Castings - division and terminology of defects.*
[3] Hiremath, S.S. & Dulange, S.R. (2015). Advanced techniques in casting defects and rejection analysis: a study in a industry. *International Journal of Innovations in Engineering Research and Technology.* 2(9), 364-371.
[4] Davis, J.R. (Eds.) (1996). Casting Defects, Nondestructive Inspection, and Quality Control Measures. In: *ASM Specialty Handbook Cast Iron* (287-321). Ohio: ASM International.
[5] Rowley, M.T. (Eds.). (1974). *International atlas of foundry defects.* International Committee of Foundry Technical Associations. Committee of Metallurgy and Foundry Properties. English Edition.
[6] Fruehan, R.J. (1988). The thermodynamics and kinetics of gas dissolution and evolution from iron alloys. In: Foundry Processes: Their Chemistry and Physics (pp. 411-426). New York: Plenum Press.
[7] Kaźnica, N. & Zych, J. (2015). Investigations of the sorption process' kinetics of sand moulds' surface layers under conditions of a high air humidity. *Archives of Foundry Engineering.* 15 (spec.3), 29-32.
[8] Kaźnica, N. & Zych, J. (2015). Moisture sorption and desorption processes on the example of moulding sands' surface layers. *Archives of Foundry Engineering.* 15(4), 63-66. (in Polish).
[9] Kaźnica, N. & Zych, J. (2017). Role of sand grains in sorption processes by surface layers of components of sand moulds. *Archives of Foundry Engineering.* 17(1), 87-92.
[10] Sarkar, A.D. (1967). Sand Testing (pp. 5-19). In*: Mould & Core Material for the Steel Foundry*. Oxford: Pergamon.
[11] Lewandowski, J.L., Solarski, W. & Pawłowski, Z. (1993). Classification of moulding and core sands in terms of gas emission. *Przegląd Odlewnictwa.* 5, 143-149. (in Polish).
[12] Zych, J., Mocek, J. & Snopkiewicz, T. (2014). Gas generation properties of materials used in the sand mould technology - modified research method. *Archives of Foundry Engineering.* 14(3), 105-109.
[13] Zhang, B., Garro, M., Chautard, D. & Tagliano, C. (2002) Gas evolution from resin – bonded sand cores prepared by various processes. *Metallurgical Science and Technology.* 20(2), 27-33.
[14] Godding, R.G. (1962). Measurement of gas evolution from core sand. *British Cast Iron Research Association Journal.* 9, 687-692.
[15] Holtzer, M., Kwaśniewska-Królkowska, D., Bobrowski, A., Dańko, R., Grabowska, B., Żymankowska-Kumon, S. & Solarski, W. (2012). Investigations of a harmful components emission from moulding sands with bentonite and lustrous carbon carriers when in contact with liquid metals. *Przegląd Odlewnictwa.* 62 (3-4), 124-132. (in Polish).
[16] Bobrowski, A., Holtzer, M., Dańko, R. & Żymankowska-Kumon, S. (2013). Analisys of gases emitted during a thermal decomposition of the selected phenolic binders. *Metalurgia International.* 18 (spec.7), 259-261.
[17] Holtzer, M., Dańko, J., Lewandowski, J.L. et al. (2012). *Station for research of the volume and harmfulness of gases compounds from the materials used in foundry and metallurgical processes.* AGH Polska Patent PL 398709 A1.
[18] Holtzer, M., Dańko, R., Dańko, J., Kubecki, M., Żymankwska-Kumon, S., Bobrowski, A., Śpiewok, W. (2013). *The assesment of harmfulness of binding materials used for a new generation of core and molding sands.* Kraków: Wydawnictwo Naukowe Akapit (in Polish).
[19] Winardi, L., Littleton, H., Bates, C.E. (2007). Variables Affecting Gas-Evolution Rates from Cores in Contact with Aluminum. *Foundry Management & Technology.*
[20] Winardi, L., Weiss, D., Scarber, P. Jr ., Griffin, R.D. (2008). Comparison of Gas Evolution Results from Chemically Bonded Cores in Contact with Magnesium and Aluminum Melts. *AFS Transactions.* 116, 769-783.
[21] Winardi, L., Griffin, R.D., Littleton, H.E., Griffin, J.A. (2008). Variables Affecting Gas Evolution Rates and Volumes from Cores in Contact with Molten Metal. *AFS Transactions.* 116, 505-521.
[22] Scarber, Jr. P., Bates, C.E. & Griffin, J.A. (2006). Effects of Mold and Binder Formulations on Gas Evolution When Pouring Aluminum Castings. *AFS Transactions.* 114.
[23] Zych, J., Mocek, J. (2016). Gas generation the top layer of sand mould. In: *Nauka i technika w inżynierii procesów odlewniczych* (pp. 65-78), Kraków: Wydawnictwo Naukowe AKAPIT. (in Polish).
[24] Zych, J., Mocek, J. & Kaźnica, N. (2017). Kinetics of Gases Emission from Surface Layers of Sand Moulds, *Archives of Foundry Engineering*, in print.