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Kinetics of Gases Emission from Surface Layers of Sand Moulds

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Abstract

Gas emission from casting moulds, cores and coatings applied for sand and permanent moulds is one of the fundamental reasons of casting defects occurrence. In the previous studies, gas emission was measured in two ways: normalized, in which the evolving gas volume was measured during heating of the moulding sand sample in a sealed flask, or by measuring the amount of gas from sand core (sample) which is produced during the pouring of liquid metal. After the pouring process the sand mould is heated very unequally, the most heated areas are layers adjacent to the liquid metal. The emission of gas is significantly larger from the surface layer than from the remaining ones. New, original method of measuring kinetics of gas emission from very thin layers of sand moulds heated by liquid metal developed by the authors is presented in the hereby paper. Description of this new method and the investigation results of kinetics of gas emission from moulding sand with furan and alkyd resin are shown. Liquid grey cast iron and Al-Si alloy were used as a heat source in the sand moulds. Comparison of the kinetics of gas emission of these two kinds of moulding sands filled with two different alloys was made. The momentary metal temperature in sand mould was assigned to the kinetics of gas emission, what creates a full view of the possibility of formation of casting defects of the gaseous origin. Moulding sand with alkyd resin is characterized by larger gas emission; however gases are emitted slower than in the case of moulding sands with furan resin. This new investigation method has a high repeatability and is the only one which gives a full view of phenomenon's in the surface layer which determines quality of the casings. The obtained results are presented on several graphs and analyzed in detail. They have a great application value and can be used in the production of iron as well as light metal alloy castings.

Keywords: Moulding sand, Surface layer, Gases, Kinetics of gas emission, Moulding sands, Chemical binders

1. Introduction

An influence of a high temperature of liquid metal on the sand mould causes the volume increase of gases (air), which are filling the mould cavity and intergranular pores. This leads to decomposition or/and gasification of organic components of moulding sands and protective coatings. Protective coatings are applied for nearly all moulds and cores produced from moulding sands with binders. Gases emitted during the mould pouring and castings solidification constitute one of the main reasons of a large group of casting defects. There are several sources of gases. In the sand mould technology these are the most often organic binders, additions to moulding sands, water in classic wet sands and in moulding sands with hydrophilic binders. In the metal mould technology the protective coatings, deposited to improve the mould durability, are gas sources.

In several technologies gases can be originated from protective coatings, which in baseline contain - the most often - more than 60% of water or alcoholic diluents and additions of various modifiers changing their rheological properties and delaying their sedimentation.

Two groups of methods are applied for assessing the gas evolution susceptibility from various foundry materials. One group is related to investigations under laboratory conditions [1 ÷3, 8-10, 15, 16], the other one to investigations performed under conditions being close to the ones occurring directly in the mould [1, 4 ÷ 7, 11-14, 17]. In the first case the tested material sample (e.g. moulding sand) is heated in the leak-proof flask, placed in the tubular furnace. The gas volume, emitted during heating the moulding sand sample (to the selected temperature), is measured [3]. In the second method [1] and its newer versions [4 ÷ 7] the moulding sand sample - forming a certain kind of a core - is poured in the mould with liquid metal. During heating the amount of gases emitted from the sample is measured.

As all measuring methods the described above have their advantages and disadvantages. None of the described methods - in their actual solution variants - allows to determine the gases emission kinetics as the function of the instantaneous moulding sand temperature. In addition, there is a justified fear that during measurements the volume of emitted gases is summed up with the growing volume of heated air, which fills the measuring flask (in the laboratory test), or fills 'voids' in the porous sample (intergranular pores).

The new method, belonging to the group of direct methods, is presented in the hereby study. The sources of potential measuring errors were eliminated and conditions of investigating the gases emission kinetics as the function of the moulding sand temperature were developed. The courses of the volume changes of the emitted gases are recorded in the real time. In addition, the new approach to assessing the moulds poured with liquid metal is presented. Thin-walled cores, corresponding to the surface layer of the moulding sand in the mould, are applied

2. Investigation methodology

The emission of gases from the mould poured with liquid metal concerns mainly layers being in a direct contact with the casting, i.e. surface layers of the mould cavity or core. Therefore, when analysing the gas evolution rate of moulding sands, the assessing should be performed under conditions occurring in the surface layer. The surface layer is heated to the temperature similar to the liquid metal temperature, and the gasification process occurs at a very limited oxygen access. Aiming to create similar conditions of experiments the new concept of investigations (presented in Fig. 1) was developed [17].

The mould, in which the thin-walled core of a sleeve shape (with a bottom) and of walls thickness of app. 8.0 mm is placed, is poured with liquid metal. Metal surrounds this core from all sides and the emitted gas is directed to the measuring system (shown in Fig. 1). The innovatory solution of the measuring methodology, in relation to other solutions known from the references [1, 4 ÷ 7, 11-14], is placing two temperature sensors: one in the core and another one in the casting and decreasing the core thickness. On-line monitoring of the temperature and amounts of emitted gases allows to determine such dependencies as: $dV/dt = f(T_{core})$, $dV/dt = f(T_{cast.})$. Thus, it is possible to determine and describe at which core temperature gases are the most intensively emitted and in which state is metal at that time (liquid, solid).

The developed method allows to determine the influence of protective coatings on the gas emission from the surface layer of the mould, which provides the possibility of forecasting the surface quality of castings.

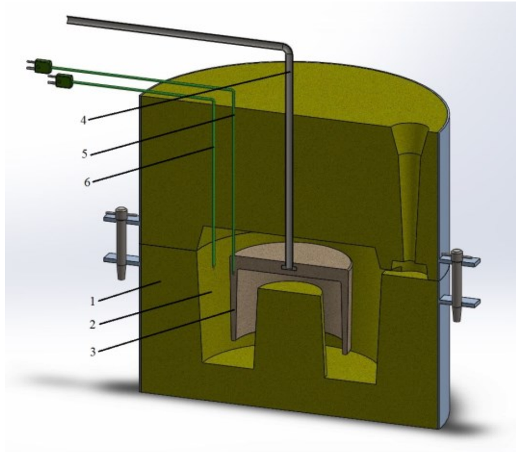

Fig. 1. Conceptual diagram of the laboratory stand for testing the gas emission from the mould surface layer : 1- sand mould, 2 – cavity mould, 3 – core, 4 – collecting gases system, 5 – thermoelement 1 (in core), 6 – thermoelement 2 (in mould cavity)

3. Results of own investigations

The aim of the performed investigations of gas evolutions from surface layers was to determine the influence of some technological parameters on the course and amount of emitted gases. The influence of a binder kind, alloy kind and applying of protective coatings was determined. Two kinds of binders: furan resins and alkyd resins were tested (The moulding sands had the following binder: 1) furan resin - 1.10%, hardener – 0.45%.; 2) alkyd resin – 1.3%, hardener – 0.33%). Moulds were poured with Al-Si alloy and with cast iron. The cross-section of the test casting is shown in Figure 2.

Fig. 2. Cross – section of test casting made at investigations of the gas emission from surface layers of the mould

Temperature changes of the casting and the sample (core), after pouring the mould with AlSi7 alloy of a temperature of 750°C, are shown in Figure 3. It can be noticed that the thin-walled core is heated to the metal temperature. Equal temperatures are maintained for a few minutes, between 100 and 400 seconds from the moment of the mould pouring start.

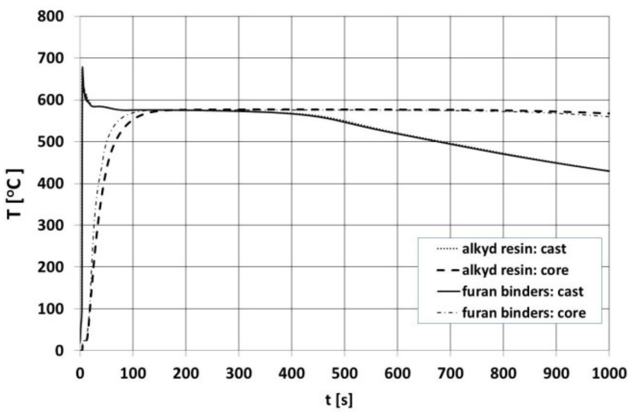

Fig. 3. Courses of the metal temperature changes (cooling) and the core temperature changes (heating) during the gas emission test

Similar effect is observed in casting moulds during the casting production process. In the surface layer of the mould the moulding sand temperature reaches the metal temperature. The heating rates of moulding sand layers in the tested sample at the mould pouring with cast iron and AlSi7 alloy are presented in Figure 4. These rates will decide on the gas emission kinetics from the moulding sand subjected to heating. In case of cast iron the maximum rate reaches nearly 450°C/s. At such high dynamics of heating, gases will be also emitted rapidly. This high dynamics indicates that the mould should be constructed in such way as to have the possibility of fast removing of generated gases.

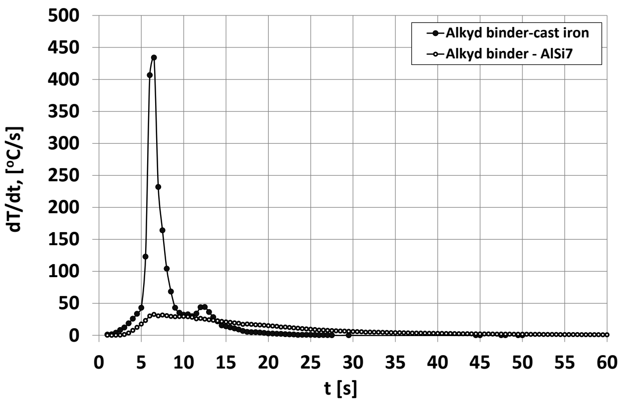

Fig. 4. Comparison of the core heating rate at the mould pouring with AlSi7 alloy and with grey cast iron

Some moulding sands with chemical binders are applied for moulds and cores at casting Al alloys as well as ferrous alloys. The developed investigation methodology allows comparisons of the course as well as the kinetics of gases evolution from moulds poured with any kind of alloy.

The courses of gases emissions from the sample of furan moulding sand when it was poured with Al alloy and with grey cast iron are shown in Figure 5. The volume of gases which are evolving when the mould is poured with cast iron is more than 5-times larger than when the mould is poured with Al alloy. The results presented in Figure 5 concern the so-called specific gas generation, it means they are referred to 1% of a binder in the tested moulding sand ((cm^3/g)/%).

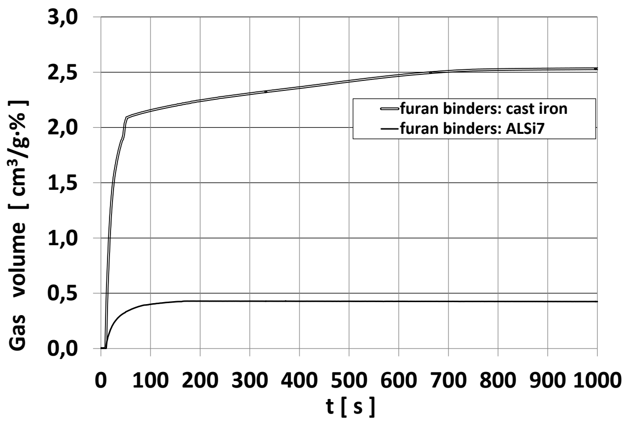

Fig. 5. Comparison of volumes of gases (referred to 1% of a binder) emitted from the sample when the mould was poured with AlSi7 alloy and grey cast iron

From the point of view of the possibility of the casting defects formation not only the total volume of emitted gases is important, but also their emission kinetics. When the gas emission process is rapid the casting defects of a gaseous character will occur more often. The new investigation method allows to trace the kinetics of gases evolutions in relation to the moulding sand temperature (core) (Fig. 6) and in relation to the casting temperature (Fig. 7).

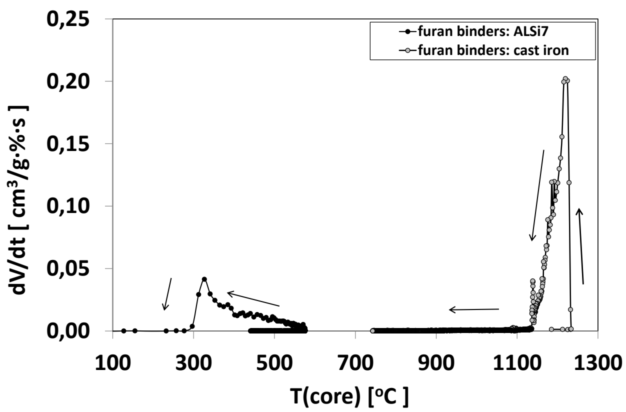

Fig. 6. Gases evolution from sand cores when the mould was poured with cast iron and with AlSi7 alloy

When the real casting moulds are poured with liquid metal the oxygen-free (reducing) atmosphere is formed very fast in the surface layer. Thus, organic binders are burned to a small degree only, while mainly they are gasified. When the cavity mould is poured with cast iron, thin layer of the mould (and cores) is rapidly heated (see Fig. 4). Also a gasification of the furan binder occurs at a very high temperature of moulding sands (cores). In the tested case it was within the temperature range: 1150 ÷ 1250°C (Fig. 6). When moulds are poured with AlSi7 alloy the gas generation from a binder is much slower and does not reach high rates. At pouring with cast iron the maximum value of dV/dt is close to 0.20 (cm^3/g•%)/s, while at pouring with AlSi7 alloy - this rate is less than 0.05 (cm^3/g•%)/s, that is approximately 4 - times smaller (Fig. 6). The kinetics of gases evolutions related to the casting temperature is shown in Figure 7. It can be noticed, that in case of cast iron gases are emitted within the period when the cast iron solidification process occurs ($T_{eutectic}$ =1154°C).

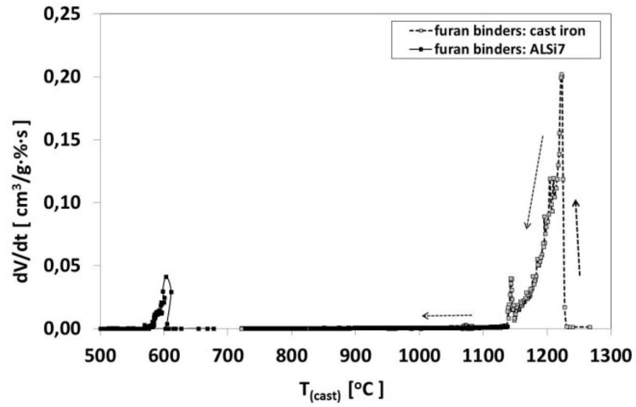

Fig. 7. Intensity of gases evolutions from sand cores related to the instantaneous casting temperature

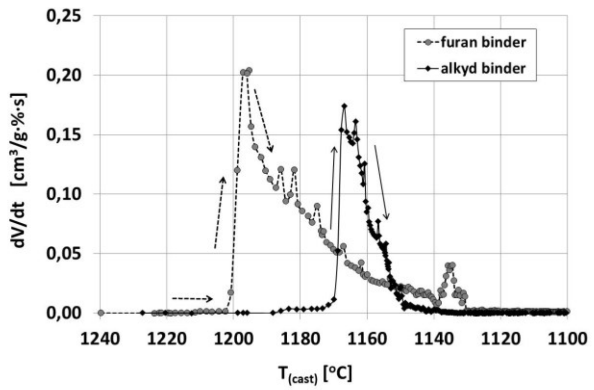

Fig. 8. Intensity of gases evolutions from cores of moulding sands with furan and alkyd resins, as a function of $T_{(casting)}$

The comparison of gas evolution rates from the furan and alkyd moulding sands when moulds were poured with cast iron, was also performed (Fig.8). The furan moulding sand decomposes earlier (at higher temperature) than the alkyd moulding sand. Volumes of gases emitted from cores covered and not covered by the protective coating (zirconium alcoholic coating, $th_{coating}$ = 1,0 mm), are compared in Figure 9. Sample with the coating was dried at a temperature of T = 50°C for 15 minutes and then in 5-minutes cycles up to obtaining the constant mass. It can be seen that the protective coating significantly increases the amount of gases evolving from surface layers of the mould. This effect was already shown in the previous work of the authors [17].

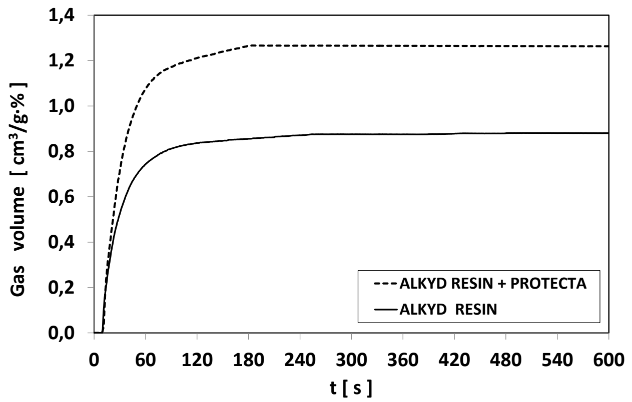

Fig. 9. Evolution of gases from the mould produced of the alkyd moulding sand: without and with the protective coating

4. Conclusions

The performed investigations allow to draw several conclusions.

- The developed, new investigation method of the kinetics of gases evolutions from moulding sands allows to test - under laboratory conditions - processes occurring in the mould layers adhering to the casting.
- Processes are proceeding very fast in surface layers of the mould, especially when moulds are poured with ferrous alloys.
- Maximum gases emission rate from furan moulding sands occurs in the period when metal in the mould is in the liquid and semi-solid state.
- Protective coatings, also in the 'after drying' state, increase the gas generation from surface layers of the mould.

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