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# State of Spent Molding Sands in the Mold Large-Size Cast

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## Abstract

The results of investigations of spent moulding sands taken from the mould at various distances from the surface of the produced casting, are presented in the paper. The casting mould was made with an application of the cooling system of the metal core in order to increase the cooling rate of the ladle casting. As temperature measurements in the mould indicated the heat flow from the metal did not create conditions for the complete burning of a moulding sand. The analysis was performed to find out changes of spent moulding sands caused by degradation and destruction processes of organic binders. Conditions occurring in the casting mould were discussed on the bases of testing: ignition losses, dusts contents, pH reactions and the surface morphology of the moulding sand samples. Factors limiting the effective mould degassing were pointed out. Operations, possible for realization, which can limit the reasons of a periodical occurrence of increased amounts of casting defects due to changing gas evolution rates being the result of the technological process, were also indicated.

**Keywords:** Spent moulding sands, Organic binders, Thermal destruction, Ignition losses, Mechanical and thermal reclamation

## 1. Introduction

Spent moulding sands with organic binders, are burned to various degrees, after a casting was made. This problem is essential for companies producing high-dimensional castings, since amounts of applied moulding sands are very large and spent grain matrices, after their mechanical reclamation, are reused for preparing new moulding sands. When a casting is being knocked out individual zones of moulding sands are separated and this - in turn - can cause that the composition of moulding sands prepared with the obtained reclaim could be diversified. It should be mentioned, that the reclaiming devices are operating with a constant intensity and due to that the spent moulding sand of various fractions of partially burned binders will be purified to various degrees. The mechanical reclamation process partially averages the quality of the obtained reclaim, but can also create a situation in which the grain matrix will have different amounts

of binders on surfaces. This variable amount of organic binding materials can cause defects in various places of a casting. Too high resin amount increases a gas evolution rate of a moulding sand which can occur randomly in any place of a large casting [1]. Another factor worsening the effective mould degassing can be a large dusts content, since the dusts presence decreases the moulding sand permeability and decreases the effectiveness of the directional mould degassing. Also an excessive matrix refinement can - in large castings (ladles, ingot moulds) - worsen gases migrations in the mould. The solution of such situation is creation of systems carrying away of gases from moulds, especially from cores, where mainly occur unfavorable conditions related to gases flows as well as to increased thermal influences of metals on moulding sands reproducing the casting inner surface. The system realizing this task was presented in paper [2].

## 2. Investigation methodology

Investigations showing the binder burning process in a high-dimensional casting are presented in the hereby paper. Samples of spent moulding sands were taken from different places of the mould during the casting knocking out. For comparison purposes the analysis of the spent moulding sand of an averaged composition was also performed.

### 2.1. Materials taken for tests

The state of the spent moulding sand taken during the casting knocking out is presented in this publication. On account of the casting shape, materials for tests were taken from three places of various moulding sand burning degrees. The ladle casting is presented in Figure 1, while the sampling places are shown in Figure 2.

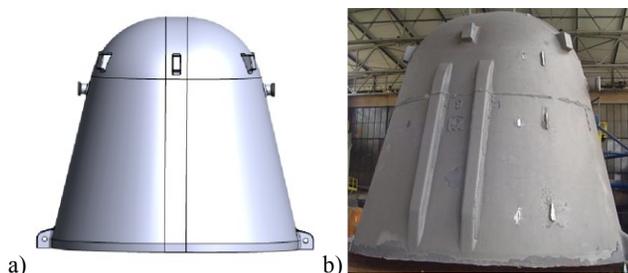


Fig. 1. Casting of the ladle: a) Three-dimensional ladle model, b) Casting after knocking out

The weight of the presented casting (made of cast iron) was equal 18500 kg, while for making the ceramic mould 58000 kg of moulding sands was used. The urea-formaldehyde resin modified by furfuryl alcohol, hardened by mixture of organic (from sulphonic acids group) and inorganic acids (modified by special additions) is applied by the Company for making the casting mould. The reclaimer obtained by the mechanical reclamation is used as the matrix. The system realising this task was presented in paper [3, 4].

Samples for tests were taken from the mould of one of the casting. Three samples were taken.

Sample PI – situated very near the casting, which due to the liquid metal influence lost its binding properties. The material taken from the mould was in a loose state. Burned moulding sand consisted of matrix grains covered by glossy coatings indicating that the pyrolysis effect occurred, i.e. degassing of organic substances under oxygen-free conditions and carbonisate formation (process coke).

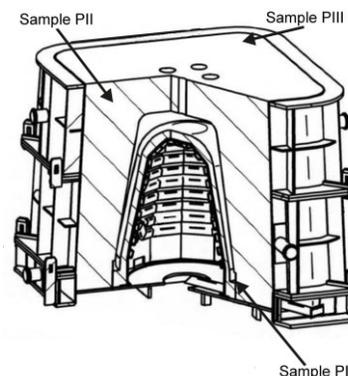


Fig. 2. Places in the casting mould from which materials were taken

Sample PII – from the middle part between the casting and moulding box. This material was taken as bound sand (in chunks). The moulding sand from the sampling zone was not burned, but since it was taken from the area which was under the liquid metal influence, it was hot.

Sample PIII – from the moulding box corner. This material was taken in a form of chunks, the moulding sand was bound and without any influence of a liquid metal temperature (sand was cold).

Sample PIV – prepared from the above materials mixed in the ratio: 1-1-1. This material has to represent the averaged - not selected - moulding sand which is left after the casting knocking out.

### 2.2. Mass decrements in dependence of the temperature - ignition losses

The most important criteria of assessing the quality of spent moulding sands with organic binders or the reclaim, are ignition losses [5, 6]. The sampled materials were subjected to investigations of the temperature influence on the degradation and destruction of a binder applied in the moulding sand (furan resin). Samples of materials PII and PIII were crushed and sieved through the 0.8 mm sieve, before testing. Materials in a loose form were roasted in the silite furnace. Investigations of the temperature influence on the degradation and destruction state were carried out on two 30 g samples, weighted into quartz crucibles. The results presented in this paper are average values of two reclaim samples, which were heated for 2 hours in the furnace at a temperature of 950°C.

### 2.3. Sieve analysis

The sieve analysis was performed for two 50 g samples. Sieving was done on the laboratory sieve shaker LPeZ-2e. The obtained results were elaborated by the LabaSit program.

## 2.4. Analysis of fractions technologically unsuitable for the grain matrix

An important factor influencing the moulding sand quality is the grain matrix state (sand, reclaim) in respect of dusts content (fractions technologically unsuitable – particles size less than 0.1 mm). This parameter was determined on 100 g samples blown through by the air flowing with a velocity of 1 m/s for 4 minutes in the fluidizing column of a diameter of 50 mm. The results presented in this paper are the arithmetic mean from two samples.

## 2.5. Determination of the pH value

The determination of the tested material pH value was done for 50 g sample to which 50 cm<sup>3</sup> of distilled water was added, mixed and left for 1 hour.

The pH value of the obtained solution was determined by means of the microcomputer pH-meter CP-105. The measurement was performed after the calibration of the device, to avoid an eventual error related to electrode properties. Two buffer solutions of the strictly determined pH values are needed for this calibration: e.g. for contaminated acidic waters of pH 7 and pH 4.

## 3. Analysis of the results

It was shown in other publications of the author [2, 7, 8], that the burning state of a moulding sand depends on a temperature, time and air, necessary for the complete burning of the binder. In case of the binder applied by the Company (resin FR 75A mixed with hardener PU-6 according to the ratio recommended by the producer - resin/hardener=2) a temperature of app. 520°C is required for the binder complete burning (destruction) in the oxygen atmosphere [2]. The temperature distribution in the core is shown in Figure 3, while in Figure 4 the temperature distribution in the mould of another casting, in dependence on the distance from the metal and from the place at the casting height. The presented example of the temperature distribution in the casting shows the burning state of the moulding sand which, as it was mentioned above, is used - after the mechanical reclamation - for making several high-dimensional castings.

Temperature changes presented in the diagram indicate that despite large amounts of the liquid metal the area of heat influencing a moulding sand is limited.

It can be noticed, that only a moulding sand which is very close to the casting can undergo a destruction process, being the organic binder burning (exceeding temperature of 520°C), if a sufficient amount of air is contained in the mould and intergranular spaces. The further from the casting the lower temperature and the worse conditions for the complete resin burning. Of course, more favorable conditions for better burning of a moulding sand are from the core side. Moulding sand burning zones in the mould are also changing with the mould height, which is illustrated in Figure 4. This results from variable conditions of heat dissipation, which are more favorable in the upper and lower part of the mould.

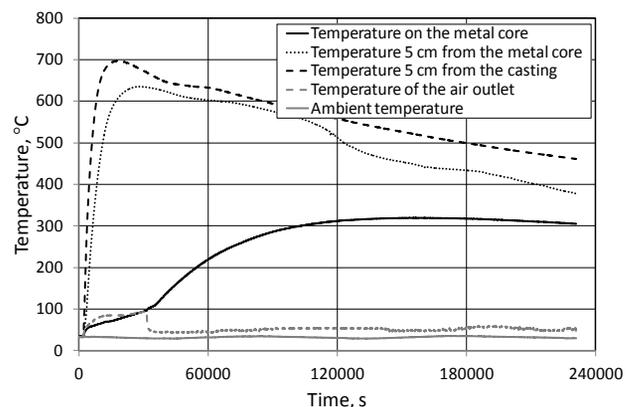


Fig. 3. Temperature distribution in the mould for the casting example (ladle)

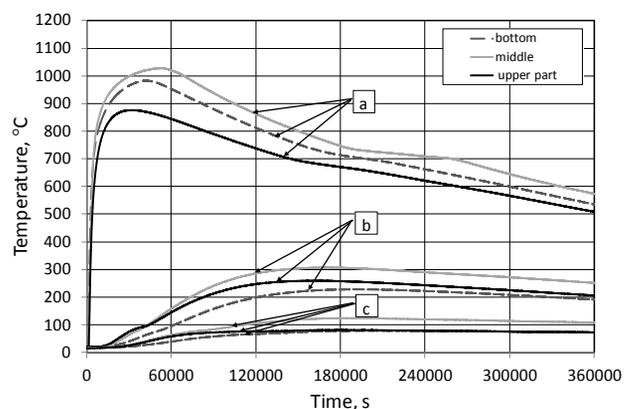


Fig. 4. Temperature distribution in the mould, for the casting example (ingot mould): a) temperature at the casting (2 cm), b) temperature at the moulding sand (20 cm), c) temperature at the moulding box (40 cm)

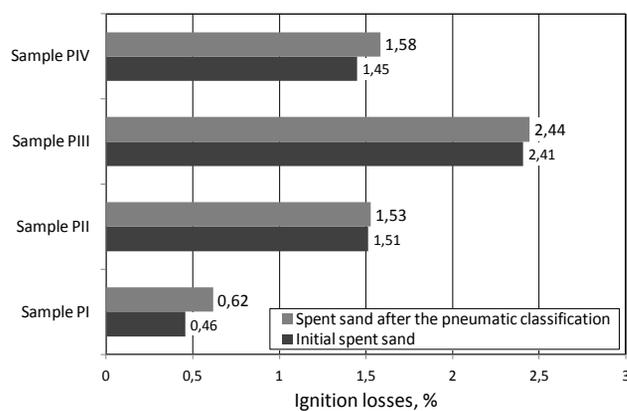


Fig. 5. Ignition losses of the spent moulding sand before and after the pneumatic classification, in dependence of the sampling place in the mould

Ignition losses of the tested materials before and after the pneumatic classification in the cascade air classifier, are shown in

Figure 5. A presence of dusts in a form of fine matrix fractions and also binders of a high degree of thermal degradation, causes that the ignition losses are smaller at the same weight of tested samples. The pneumatic classification process dedusts from the total mass of tested materials not active binders and fine matrix fractions, which - in turn - causes that resin of a smaller degradation degree remains in larger amounts. The largest differences in ignition losses can be seen in moulding sands taken near the casting, where the resin degradation degree is the highest.

Ignition losses of dusts collected after the pneumatic classification of the tested materials are presented in Figure 6. A moulding sand near the moulding box undergoes the lowest thermal degradation. Therefore dusts originated from the refinement of the moulding sand - from the tested zone - are characterized by the highest ignition losses (they contain the most of resin, which was not thermally degraded).

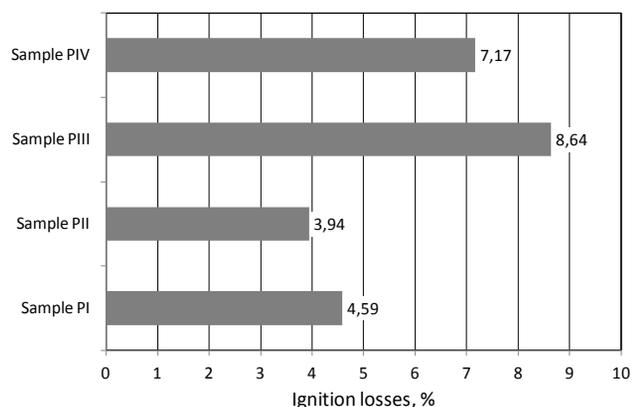


Fig. 6. Ignition losses of dusts collected after the pneumatic classification, in dependence on the collection place in the mould

The results of ignition losses of the tested materials are presented in Figure 7.

The percentage of technologically unsuitable fractions in dependence on the mould thermal degradation - determined for 100 g samples in the fluidization column - is presented in Figure 8.

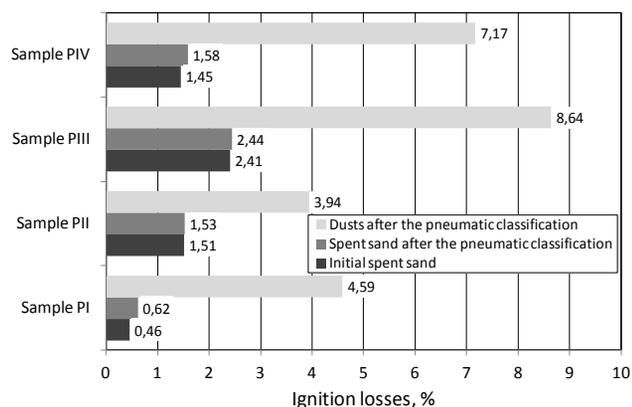


Fig. 7. Comparison of ignition losses of the tested materials, in dependence on the collection place in the mould

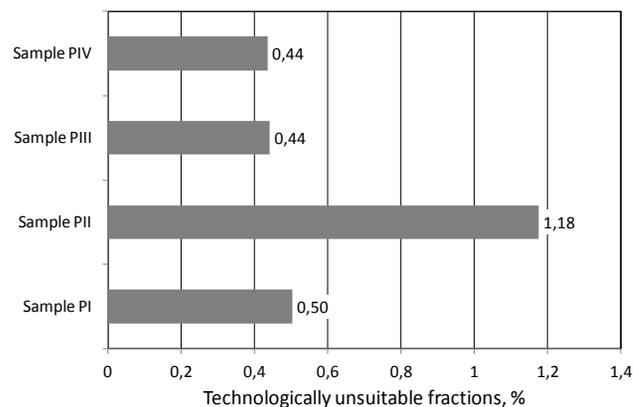


Fig. 8. Technologically unsuitable fractions, in dependence on the collection place in the mould

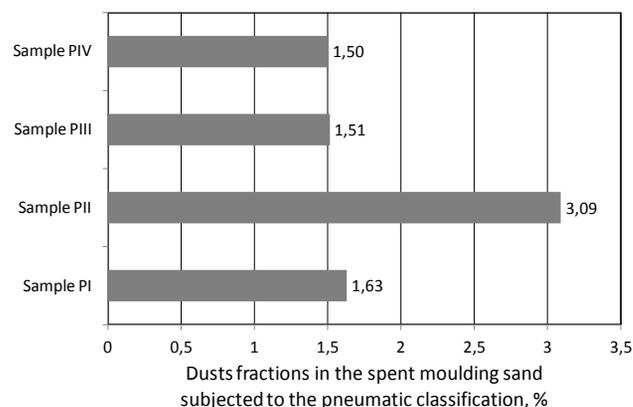


Fig. 9. Dusts fractions in the spent moulding sand subjected to the pneumatic classification, in dependence on the mould collection place

Materials taken for investigations were also subjected to pneumatic classification in the cascade classifier. The percentage dusts fractions in the moulding sand in dependence on their thermal degradation in the mould, are presented in Figure 9. The largest amounts of dusts were found in the mould middle part in case of investigations in the fluidization column as well as in the cascade classifier. The resin which was very near the casting underwent - to a considerable degree - the complete degradation (sample was taken from a zone of various degradation degrees).

The obtained results presented in Figure 9, suggest that in the middle part of the mould there is a binder of a significant thermal degradation (binder which was not burned, but simultaneously did not have initial properties of a binder prepared for making a mould). The probable decomposition of polymers into monomers generates large amounts of a weakly bound binder, which - due to crumbling - generates significant amounts of dusts (large mass fraction of dusts in tested samples).

The results of pH values of tested materials before and after the pneumatic classification are shown in Figure 10.

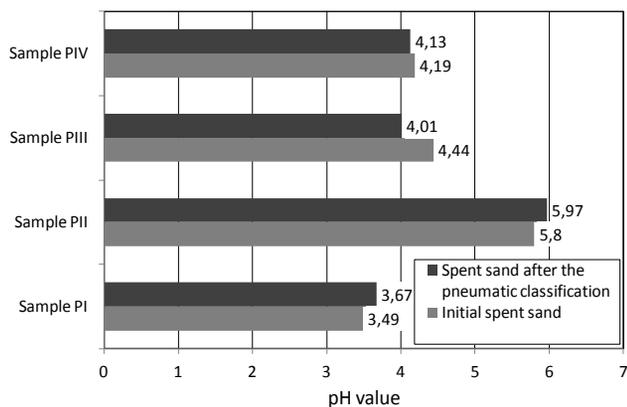


Fig. 10. pH values of the spent moulding sand before and after the pneumatic classification in dependence on the sampling place

It was found that the pneumatic classification process influences the pH value in a different way, depending on the binder thermal degradation in the mould. Samples of the spent moulding sand subjected to high temperatures (at the casting and in the middle) after the pneumatic classification were characterized by higher pH values (reaction was less acidic), while in samples taken at the moulding box the dedusting process increased acidity of the tested materials (smaller pH values). Simultaneously, it should be noticed that the moulding sand at the casting was characterized by the smallest pH. Figure 11 illustrates the combined list of pH reactions of all tested materials.

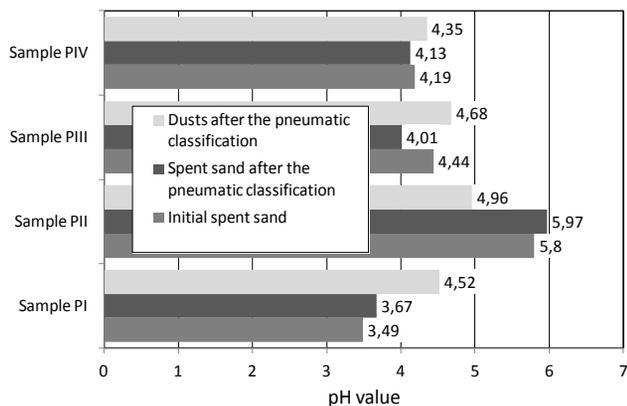


Fig. 11. pH values of the spent moulding sand before and after the pneumatic classification and dusts in dependence on the sampling place

Changes of the average arithmetic diameter of grain matrix in dependence of the sampling place, before and after the pneumatic classification, are presented in Figure 12. It can be noticed that, the further from the casting the spent moulding sand was sampled the larger grain size of the matrix. The spent binder destruction and degradation processes occurring on grain surfaces are seen clearly in the sieve analysis regardless of such small amount of a binding material. The pneumatic classification procedure (dedusting of technologically unsuitable fractions) also increases grain sizes of matrices for each tested material.

Table 1.

Selected parameters of the sieve analysis of the tested materials

Material	Calculated values of the sieve analysis				
	$d_a$ [mm]	$S_i$ [cm <sup>2</sup> /g]	$F_g$ [%]	GG [%]	Main fraction
Sample PI initial	0,398	64,33	93,46	62,28	0,40/0,32/0,20
Sample PI after classification	0,409	61,17	94,45	63,96	0,40/0,32/0,20
Sample PII initial	0,431	58,26	93,13	65,71	0,40/0,32/0,20
Sample PII after classification	0,435	57,48	92,73	64,56	0,40/0,32/0,20
Sample PIII initial	0,447	57,50	89,18	63,40	0,40/0,32/0,20
Sample PIII after classification	0,461	56,02	87,41	60,16	0,40/0,32/0,20
Sample PIV initial	0,430	58,76	92,62	64,47	0,40/0,32/0,20
Sample PIV after classification	0,449	57,02	88,71	61,39	0,40/0,32/0,20

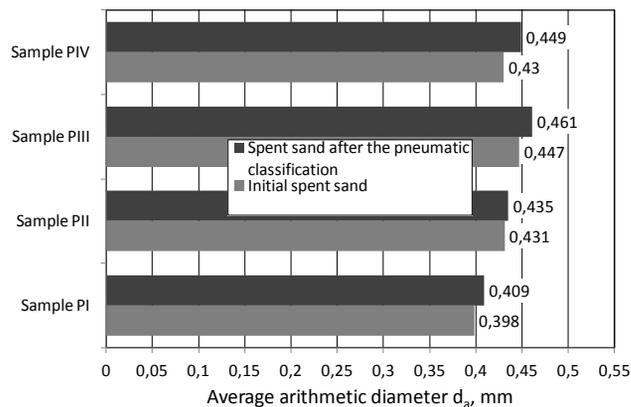


Fig. 12. Average arithmetic diameter  $d_a$  of matrix grains

The morphology of grain surfaces in dependence of their processing is shown in Figure 13.

A moulding sand after being knocked out from the mould undergoes mixing and therefore the sample PIV was analyzed. In Figure 13a, presenting the burned spent moulding sand, significant amounts of a thermally degraded binder and small particles of a burned binder can be noticed on grain surfaces. Figure 13b presents the same spent moulding sand after its mechanical reclamation. A lower binder content is seen on the reclaim surface (binder remains only in inequalities of matrix grains surfaces). The presence of bright grains can indicate averaging of the composition, mixing grain matrices from individual burning zones of moulding sands in the mould.

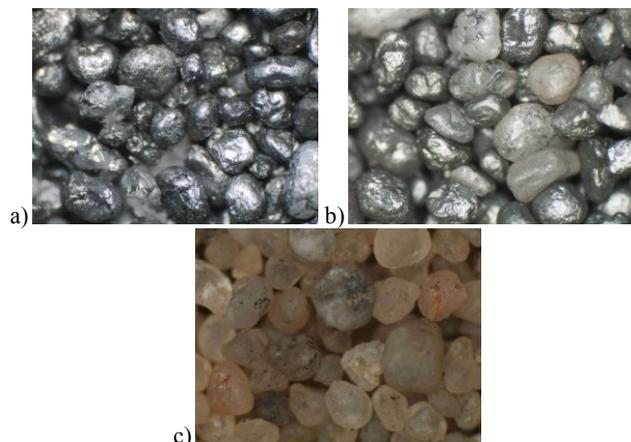


Fig. 13. Morphology of matrix grains in dependence of the processing: a) Knocked out burned moulding sand, b) Spent moulding sand after the mechanical reclamation, c) Spent moulding sand after the mechanical reclamation and the additional thermal reclamation, in a temperature of 520°C

The grain matrix after the thermal treatment is shown in Figure 13c. If the state of the reclaim after its thermal reclamation is compared with the spent burned moulding sand or with the reclaim obtained after its mechanical reclamation, it can be seen that using the thermally reclaimed matrix warrants the constant and repeatable moulding sand composition in the next cycle. In this way, eventual differences in a moulding sand composition are avoided, a gas evolution rate is limited and much better conditions of the mould degassing are created (less organic binder, means a lower gas evolution rate).

## 4. Conclusions

Presented above investigations indicate to which degree the spent moulding sand undergoes the thermal degradation and destruction, during a casting production. For a wide assortment of ladles and ingot moulds (of various shapes and dimensions) the basic problem, related to the segregation of spent moulding sands in respect of its burning, is exposed. This creates problems of the proper waste management. Utilizing such heterogeneous materials for the successive production cycle can become a factor creating risks of casting defects due to various binder contents in a moulding sand.

However, as long-term investigations indicate, the mechanically reclaimed materials have various ignition losses depending on the material, which was sent for the mechanical reclamation from the previous cycle of the mould and casting making. The best solution, from the point of view of the repeatability of moulding sand preparation, will be the application of the thermal reclamation, which would remove residues of spent

binders regardless of the state of the heat influence. The above is confirmed by the observations of the moulding sand state reproducing the core, where the moulding sand layer placed on the metal core undergoes much more intensive burning but the installed systems of cooling and carrying away of gases generated by resin burning limit the defects formation on the inner, working surface of a ladle (or ingot mould).

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