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Role of Sand Grains in Sorption Processes by Surface Layers of Components of Sand Moulds

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Abstract

The results of researches of sorption processes of surface layers of components of sand moulds covered by protective coatings are presented in the hereby paper. Investigations comprised various types of sand grains of moulding sands with furan resin: silica sand, reclaimed sand and calcined in temperature of 700^{o}C silica sand. Two kinds of alcoholic protective coatings were used – zirconium and zirconium – graphite. Tests were performed under condition of a constant temperature within the range 30 – 35^{o}C and high relative air humidity 75 - 80%. To analyze the role of sand grains in sorption processes quantitavie moisture sorption with use of gravimetric method and ultrasonic method were used in measurements. The tendency to moisture sorption of surface layers of sand moulds according to the different kinds of sand grains was specified. The effectiveness of protective action of coatings from moisture sorption was analyzed as well.

Knowledge of the role of sand grains from the viewpoint of capacity for moisture sorption is important due to the surface casting defects occurrence. In particular that are defects of a gaseous origin caused by too high moisture content of moulds, especially in surface layers.

Keywords: Castings defects, Moisture sorption, Surface layer, Furan moulding sands, Sand grains

1. Introduction

Sand grains is the main component of moulding sands undoubtedly. Because of availability of raw materials and low prices the greatest use of moulding and core sands is silica sand [1, 2].

Nevertheless, the proper selection of this basic component determines processes associated with preparing sand mould and phenomena occurring during pouring process and metal solidification [3]. Furthermore, it can be important from the viewpoint of moisture sorption by the surface layers of components of sand moulds.

Reclamation of used moulding sands has been commonly used in foundries. The process can be defined as a complex of technological operations leading to regaining the original condition at least one of the components of moulding sands [4]. Notwithstanding, only sand grains are reclaimed currently [5].

It should be considered that binder covered sand grains does not form a uniform layer on each grain. Moreover, in case of using reclaimed sand there is a possibility to remain an additional, fragmentary, not removed layer of binder. During preparing moulding sand (mixing process) this not removed layer is covered by essential layer of binder. It may be the reason why the moulding sands with reclaimed sand absorb moisture with a different intensity.

The knowledge of tendency to moisture sorption of surface layers of sand moulds according to the different kinds of sand grains is significant from the viewpoint of casting defects occurrence [6, 7]. In particular defects of a gaseous origin caused by too high moisture content of mould or protective coatings, when the mould is covered by them.

2. Investigation methodology

The role of sand grains in sorption processes by surface layers of components of sand moulds was performed for moulding sands with furan resin (Table 1) on the various types of sand grains: silica sand, reclaimed sand and calcined in temperature of 700^{o}C silica sand. Additionally, zirconium – graphite and zirconium alcoholic protective coatings were applied.

Table 1.
Composition of furan moulding sand

component	parts by mass
sand grains	100
furan resin FR75	1,2
hardener PU6	0,7

Analyses were performed by two investigation methods - quantitative measurement of a moisture sorption, proposed by N. Kaźnica and J. Zych, described in details in [6] and ultrasonic method [8 – 10], consisting of measurements of the transition time of ultrasonic wave through the special sample.

Quantitative measurement of a moisture sorption from surroundings under conditions of a constant temperature within the range 30 – 35^{o}C and a high relative air humidity within the range 75 – 80% is based on the continuously changes of weight of the sample. The changes of weigh are caused by increasing content of moisture inside the sample on account of a sorption process. In the tests gravimetric method was used.

a) b)

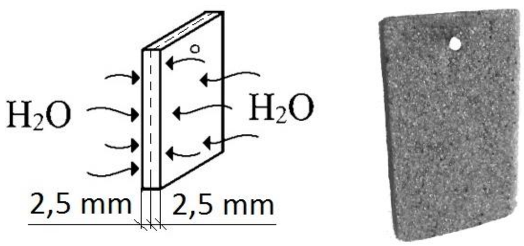

Fig. 1. a) Schematic presentation of a moisture exchange in thin – walled sample for quantitative moisture sorption
b) Sample for quantitative moisture sorption

Thin-walled samples (of a thickness of 5 mm) were tested. At a double-sided moisture exchange (which occurs during measurements) this corresponds with the conditions occurring in surface layers of sand moulds down to the depth of 2.5 mm (Figure 1).

The samples using in researches were covered by zirconium and zirconium – graphite coatings by immerse. Viscosity of those coating measured by Ford cup was 18 s. The number of layers of the protective coatings was the same for each type of sand grains and was equal 1 and 2. After application of each coating layer sample was dried at temperature of 50^{o}C for 20 minutes.

Ultrasonic method consisted of measurement of transition time of longitudinal ultrasonic wave passing through the sleeve shape sample (Figure 2). The sample was placed between the ultrasonic heads inside the measuring chamber. The chamber assured maintaining constant temperature (30 – 33^{o}C) and humidity level (78 – 80%). Whereas the rows of openings determined ensuring equal conditions inside and outside the sample as well.

a) b)

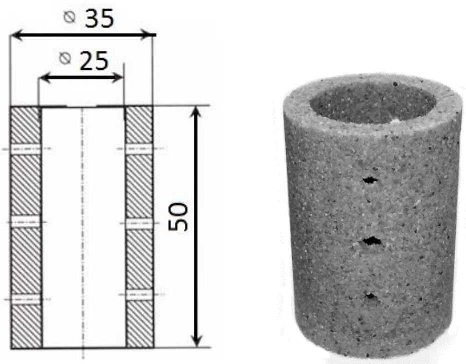

Fig. 2. a) Schematic presentation of sample for ultrasonic measurements
b) Sample for ultrasonic measurements

In analogy to the quantitative measurement of moisture sorption the samples using in ultrasonic method were covered by protective coatings and dried after each application layer at temperature of 50^{o}C for 20 minutes before placing in the test chamber.

Ultrasonic technique allows to tracking changes in moulding sands elasticity and associated changes in their strength. In the described researches observed changes are caused by the impact of moisture.

3. Analysis of the results

The performed investigations concerned the analysis of the role of sand grains in moisture sorption process by surface layers of components of sand moulds.

Table 2.
Characterization of sand grains

kind of sand grains / characterizing parameter	silica sand	reclaimed sand	calcined silica sand
numbers of sieves, where the main fraction is	0,40/0,315/0,20	0,20/0,315/0,40	0,40/0,315/0,20
the average grain size d_L based on a grain number d_L [mm]	0,338	0,268	0,315
main fraction index F_g [%]	92,36	87,46	91,61

a) b) c)

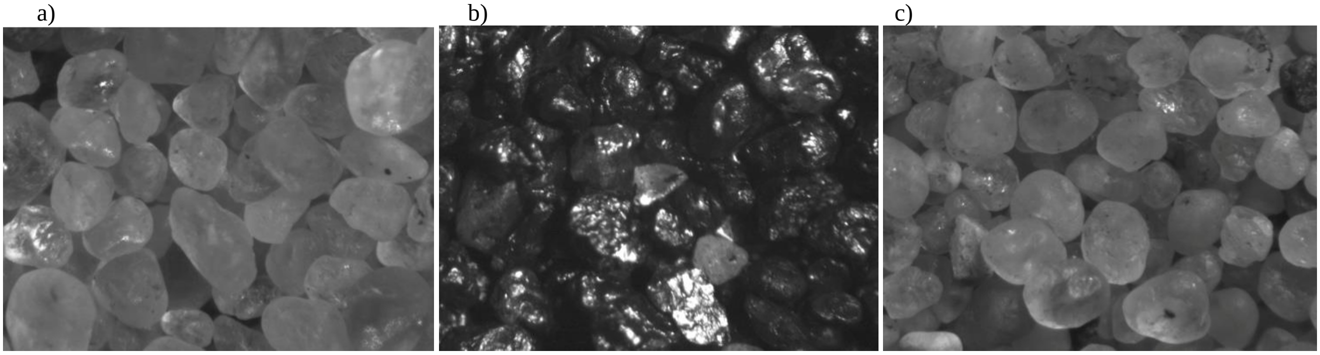

Fig. 3. Sand grains of moulding sand: a) silica sand, b) reclaimed sand c) calcined silica sand

3.1. Analysis of the sand grains

Each kind of investigated sand grains is characterized by a high homogeneity, what is confirmed by the main fraction index F_g (Table 2). Nevertheless, based on visual assessment of Figure 3a-c differences in shapes of grains are observed. The most spherical shape is characteristic for the calcined silica sand, while the most angular are grains of the reclaimed sand.

This results from the treatment the used moulding sand was handled. The treatment led to obtaining reclaimed sand. Changes in surface of grains as a result of various kinds of mechanical and thermal reclamation of moulding sands with furan resin are presented by R. Dańko in [11].

The size of grains is characteristic for the reclaimed sand as well – definitely the smallest one from investigated kinds of sand grains. The average grain size d_L of the reclaimed sand is slightly more than 20% lower than the silica sand. This is due to a number of elementary operations such as grinding, rubbing or crushing. The change of grains size is inextricably connected with the change of intergranular spaces (pores) size. It may has an influence on moisture sorption from surroundings and the moisture transport through the moulding sands.

3.2. Quantitative measurement of a moisture sorption

The results of investigating the moisture sorption from surroundings for furan moulding sands on the three kinds of sand grains are presented in Figures 4 – 6.

It was found that characteristics of the moisture sorption for each moulding sand, regardless of the kind of sand grains or the protective coatings, had similar pathways. The only differences occurred in the curve inclination angle to the axis OY, it means in the intensity of building up of curves.

It is concluded, on the base of Figure 4, that under conditions of a high air humidity moulding sand on the reclaimed sand indicates the highest sorption ability, whereas moulding sand on the calcined silica sand – the lowest. The differences (in sorption ability) are almost three times and they are the result of physic – chemical state of the sand grains used for preparing moulding sand.

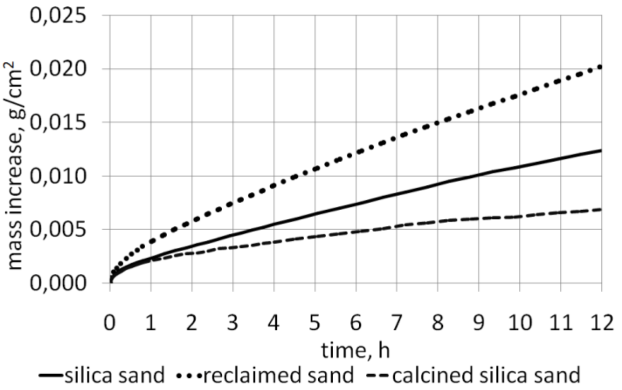

Fig. 4. Proceeding of the moisture sorption by surface layers of sand moulds made of furan sand with various sand grains

Moisture sorption by surface layers of sand moulds covered by the protective coatings is presented in Figures 5 i 6.

Moulding sand on the reclaimed sand indicates the highest sorption ability. Kind of protective coatings (zirconium or zirconium - graphite) and number of layers (1 or 2) does not influence significantly on the intensity of the process. In case of moulding sands on two remaining kinds of sand grains the differences in amount of water penetrated through the surface layers are noticed. They depend on kind of the protective coatings and the number of layers.

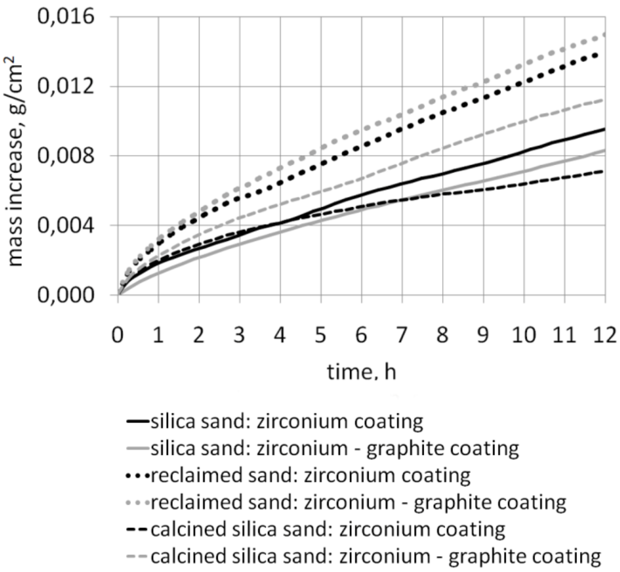

Fig. 5. Proceeding of the moisture sorption by surface layers of furan sand moulds covered by one layer of protective coating

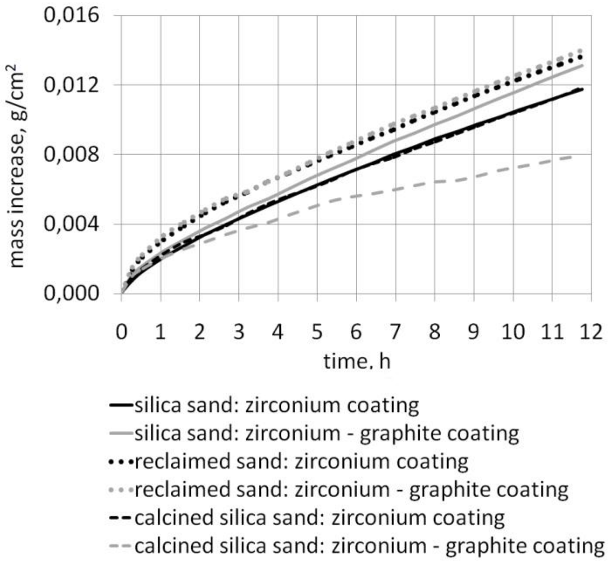

Fig. 6. Proceeding of the moisture sorption by surface layers of furan sand moulds covered by two layers of protective coating

Analyzing Figure 7, it is concluded that using the calcined silica sand as a sand grains of furan moulding sand causes a reduction in moisture sorption. On the other hand, simultaneous application of alcoholic coatings does not have an essential impact on the increase of protection against the air of high moisture content.

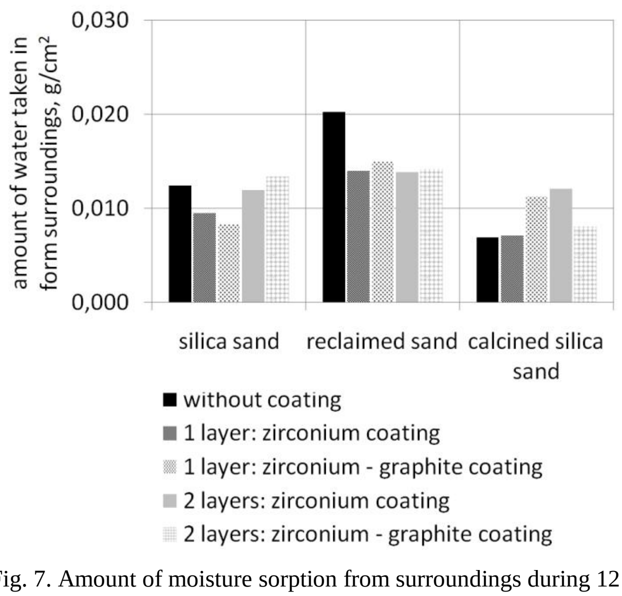

Fig. 7. Amount of moisture sorption from surroundings during 12 hours under condition of a high air humidity (75 – 80%)

Application of 1 layer of the protective coatings on sand moulds made from silica sand grains protects them against a harmful influence of the air humidity. Increasing the number of layers protect the mould surfaces only insignificantly or even has a slightly negatively influence on the protective operation.

However, in case of moulding sand on the reclaimed sand significant protective action is observed. Moreover, the number of layers and the kind of coatings protect surface layers of sand moulds similarly.

3.3. Ultrasonic investigations

Decreases of the rate of the ultrasonic wave passing through the sample are shown in the time function in Figures 8 – 10 for the furan moulding sand on the silica sand grains, reclaimed sand and calcined silica sand. Investigations were performed under condition of a high air humidity and a temperature for samples covered by protective coatings.

For all analysed pathways the similar character is observed. The character can be basically divided into two stages. The first stage is characterised by a large decrease of the rate of the ultrasonic wave passing through the sample and the second stage when the rate increases more or less intensively. The first decrease can be the result of the shock related to changes of the surroundings conditions (high increase of an air humidity and a temperature). The gradual increase of the rate proves adaptation to the new conditions. The more intense curve growth, it means the lower rate decrease, indicates the lower sensitivity to moisture content of the air.

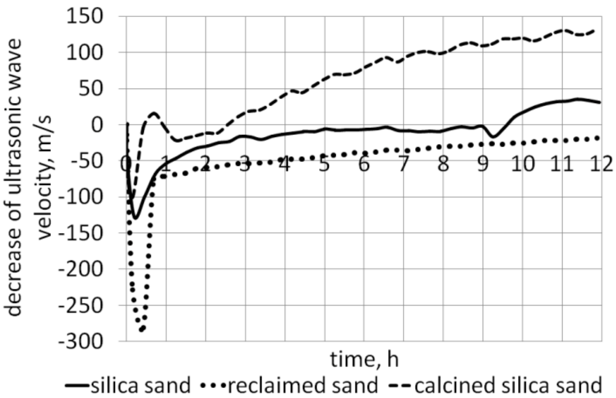

Fig. 8. Decrease of the rate of the ultrasonic wave passing through the sample in the time function, for surface layer of furan sand moulds

It results from Figures 8, that surface layers of samples made of moulding sand on the calcined silica sand indicates the higher resistance to a high moisture content in the air. It should be noticed that the smallest water amount was taken in by this kind of moulding sand (Figure 4). Moreover, the largest sensitivity to a high air humidity shows moulding sand on the reclaimed sand, which contains the largest amount of water (Figure 4). These divergences in moulding sands behaviour under conditions of a high air moisture content and a temperature can be probably explained by the treatments which the silica sand has been subjected.

Decreases of the rate of the ultrasonic wave passing through the sample are shown in the time function in Figure 9 for the surface layers of sand moulds covered by one layer of protective coating and in Figure10 for two layers.

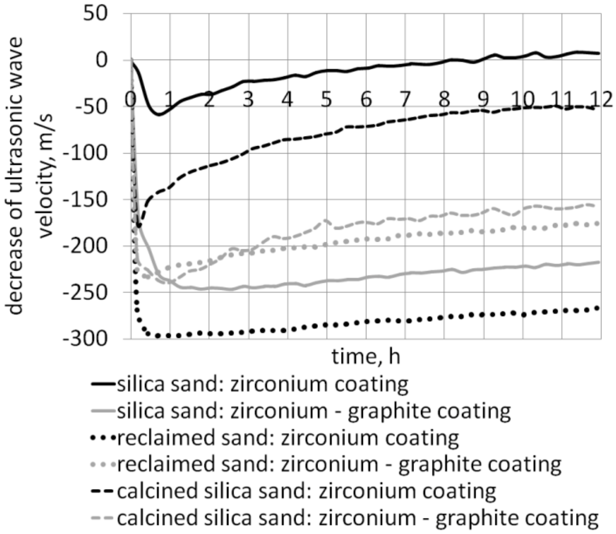

Fig. 9. Decrease of the rate of the ultrasonic wave passing through the sample in the time function, for surface layer of furan sand moulds covered by one layer of protective coating

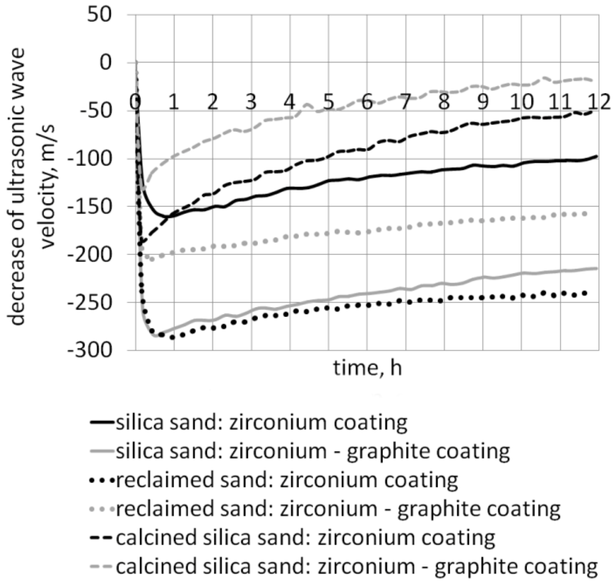

Fig. 10. Decrease of the rate of the ultrasonic wave passing through the sample in the time function, for surface layer of furan sand moulds covered by two layers of protective coating

It is clearly presented that one layer of zirconium coating protects against the negative influence of moisture moulding sands on the silica sand and the calcined silica sand the most. For moulding sand on the reclaimed sand one and two layers of zirconium coatings were applied. That causes substantial decreases of the rate of the ultrasonic wave passing through the sample what means increase of sensitivity to the air humidity.

A comparable protective effect for one layer of zirconium – graphite coating applied on samples made of moulding sand on the calcined silica sand as well as on the reclaimed sand is observed. Increasing the number of layers of this kind of coating significantly improves the protective effect for moulding sand on the calcined silica sand, while the moulding sand on the reclaimed sand is not significantly affected.

On the other hand, the most adverse effect in the case of increasing the number of zirconium coating layers for moulding sand on the silica sand is achieved. Substantial decreases of the rate of the ultrasonic wave passing through the sample are observed.

4. Conclusions

Defining the role of the sand grains of furan moulding sands in process of moisture sorption from the surroundings are presented in hereby paper. On the basis of the performed investigations, concerning amounts of a moisture sorption from surroundings by surface layers of sand moulds, it was found that:

- the use of various types of sand grains in the furan moulding sand affects its behaviour under condition of a high humidity and a temperature;
- The different tendency to moisture sorption of particular types of sand grains depends on the treatments the silica sand has been subjected;
- The greatest tendency to moisture sorption form surroundings is characteristic for surface layers of sand moulds made of moulding sands on the reclaimed sand, while the lowest tendency for moulding sands on the calcined silica sand;
- The application of the alcoholic protective coatings reduces the amount of moisture sorption by moulding sands on the reclaimed sand, regardless of the type of the protective coatings or the number of layers. Nevertheless, application of the protective coatings is reflected in a significant reduce of the rate of the ultrasonic wave passing through the moulding sand;
- The application of protective coatings on moulding sands on the calcined silica sand does not have or has negative influence on the amount of moisture sorption from surroundings. On the other hand number of applied layers of the protective coatings changes the rate of the ultrasonic wave passing through the moulding sand;
- The sand mould on the silica sand exhibits the intermediate properties in the context of moisture sorption from surroundings between moulding sands on the reclaimed sand and moulding sands on the calcined silica sand;
- The most insensitive to the harmful action of moisture is furan moulding sand on sand grains of calcined silica sand.

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