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## EFFECTIVENESS OF PROTECTIVE ACTION OF COATINGS FROM MOISTURE SORPTION INTO SURFACE LAYER OF SAND MOULDS

The results of investigations of the sorption process of surface layers of sand moulds covered by zirconium and zirconium - graphite alcohol coatings are presented in the paper. Investigations comprised two kinds of sand grains (silica sand and reclaimed sand) of moulding sand with furan resin. Tests were performed under conditions of a high relative air humidity 75 - 85% and a constant temperature within the range 28 – 33°C. To evaluate the effectiveness of coatings protective action from moisture penetration into surface layers of sand moulds gravimetric method of quantitative moisture sorption and ultrasonic method were applied in measurements.

The optimal number and kind of coatings from the viewpoint of protection from moisture sorption were specified for furan moulding sands with quartz sand and reclaimed sand as well.

Knowledge of proper coatings selection is important due to protection from high air humidity and its adverse effects. What is more, it can allow to select the proper storage conditions of casting moulds waiting for being poured with liquid metals. This can limit the occurrence of surface defects which are caused by too high humidity of casting moulds, especially in surface layer.

*Keywords:* moisture sorption, surface layer, furan moulding sands, protective coatings

### 1. Introduction

Coatings for moulds and cores are widely known products of the casting technology. They are defined as multi-component layers deposited on surfaces of moulds and/or cores, characterised by variable consistency (liquid, semi-liquid, powdery) and fulfillment of several tasks [1 – 3]. Their tasks are: improvement of moulds surface smoothness and its strength, which causes improvement of a casting surface quality; protection against certain casting defects, such as pitting, veins, buckles or burn-on; changes of the structure of the upper casting layer [4 – 7]. These tasks constitute the basis of dividing coatings due to their aims into [8]:

- passive – for obtaining good quality casting surfaces, without surface defects such as pitting and burn-on, but without any interference into the chemical composition of the casting skin;
- active – for changes of properties of the surface layer of the casting due to introducing into it certain components;
- reinforcing – for improving properties related to moulds and cores strength.

Nevertheless, the subject literature does not take into account the protection against humidity. It seems essential from the point of view of forming surface defects, which are caused by too high moisture content of moulds or protective coatings when the mould is covered by them. This concerns defects of a gaseous origin.

### 2. Investigation methodology

Assessments of the operation effectiveness of protective coatings against the moisture penetration from surroundings into moulds surface layers were performed for moulding sands with furfuryl resin on the high-silica sand grains and on the reclaimed sand grains. Zirconium and zirconium - graphite alcoholic protective coatings were applied.

Analyses were performed by two investigation methods – ultrasonic [9], consisting of measurements of the longitudinal ultrasound wave rate passing through the special sample and of the quantitative measurement of a moisture sorption, proposed by N. Kaźnica and J. Zych, described in details in [10].

#### 2.1. Quantitative measurement of a moisture sorption

Thin-walled samples (of a thickness of 5 mm) were used in the quantitative method of the moisture sorption measuring. At the two-sided moisture exchange - which occurs during measurements - this reflects conditions which exist in surface layers of moulding sand moulds, down to the depths of 2.5 mm.

In order to obtain identical initial conditions, before starting investigations, each sample was dried in the moisture balance at a temperature of 50°C for 15 minutes and then in 5-minutes cycles up to obtaining the constant mass. When the mass was stabilized the sample was covered (by immerse) by zirconium and zirconium - graphite alcoholic protective

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coatings. After each covered layer sample was dried at temperature of 50°C for 20 minutes.



Fig. 1. Sample covered by zirconium – graphite coating to investigations of moisture sorption from surroundings

In that way prepared sample was placed in a test chamber. The chamber could maintain a constant, high temperature of surroundings (28 – 33°C) and the relative air humidity (75 - 85%). The sample placed in the measuring chamber was simultaneously suspended on the electronic balance in a way allowing moisture sorption by its surface from surroundings. Mass changes, with the accuracy up to  $10^{-3}$  g, were continuously measured during the whole investigation period, i.e. 12 hours and recorded by means of a computer every 30 seconds.

## 2.2. Ultrasonic method

Samples of a sleeve shape of a wall thickness 5 mm (Fig. 2), were used in the ultrasonic method. Preparing of samples and covering by protective coatings were analogical to the methodology of quantitative measurement of a moisture sorption. Appropriately prepared sample was placed between ultrasonic heads in the test chamber for a period of 12 hours. Closing the face surfaces of the sample by heads, determined rows of openings ensuring the same conditions inside as well as outside the sample.



Fig. 2. Sample covered by zirconium coating to ultrasonic investigations

Under constant, high temperature (30 – 32°C) and the relative air humidity (75 – 80%) transition time of ultrasonic wave through the sample was measured. Results were recorded by means of a computer every 30 seconds. The wave rate passing through the moulding sand with protective coating was determined on this base.

## 3. Analysis of the results

The performed investigations concerned the assessment of the effectiveness of protective operations of alcoholic coatings (applied for moulds and cores) against a harmful influence of moisture present in surroundings.

### 3.1. Quantitative measurement of a moisture sorption

The moisture sorption process by surface layers of moulds made of furan moulding sands on the high-silica sand grains and on the reclaimed sand grains is presented as the time function in Figures 3 and 4.

The process proceedings for each analysed moulding sand with or without protective coatings were very similar. The only differences occurred in the intensity of building up of curves, it means in the curve inclination angle to the axis OY.

It was found, that in case of furan moulding sand on the high-silica sand grains (Figure 3) the zirconium as well as zirconium-graphite coating protects efficiently against moisture contained in the surrounding air, however only when there is one layer of the coating.

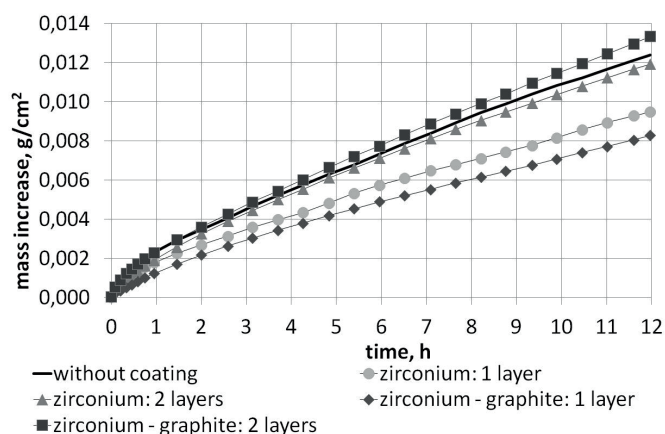


Fig. 3. Proceeding of the moisture sorption from surroundings by surface layers of moulds made of furan moulding sands on the high silica sand grains

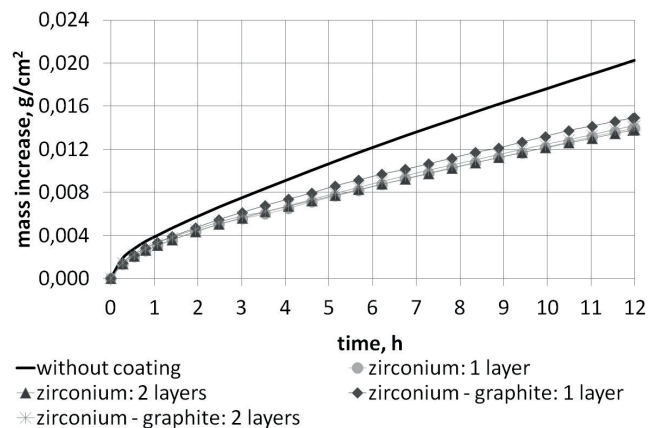


Fig. 4. Proceeding of the moisture sorption from surroundings by surface layers of moulds made of furan moulding sands on the reclaimed sand grains

Two layers of the alcoholic zirconium coating protect the mould surface layer only insignificantly, while two layers of the zirconium - graphite coating even slightly negatively influence the protective operation. However differences in both cases (two layers) are so small in comparison with the moulding sand without any coating, that the statement that the number of protective coating layers larger than one does not influence significantly the protection of moulds surface layers against the air of a high moisture content, can be risked.

In case of the furan moulding sand on the reclaimed sand grains (Figure 4) the intensity of the moisture sorption from surroundings is much smaller when samples are covered by protective coatings than when samples are without coatings. Differences between the kind of coatings (zirconium or zirconium - graphite) and the number of layers (one or two) are insignificant. It can be said that the application of the coating protects the furan moulding sand on the reclaimed sand grains against a harmful influence of the air humidity.

When comparing amounts of moisture which underwent sorption from surroundings in 12 hours by samples of furan moulding sands on various matrices (Figure 5) a significant advantage of the moulding sand with the reclaimed material is noticed. A larger water amount was taken in by samples covered by protective coatings. Only in case of two layers of zirconium - graphite coating these values are similar for moulding sands with both kinds of matrices.

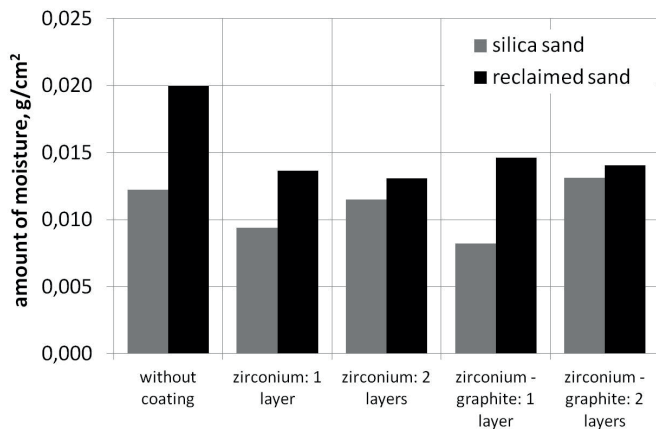


Fig. 5. Amount of moisture sorped from surroundings during 12 hours

The differences in amounts of water taken in from the air are due to various kinds of matrices. It is generally known, that sand grains after the reclamation have on their surfaces remains of binders and hardeners. Amounts of these remains can influence the mechanisms of taking in moisture from surroundings and - in consequence - its amount too.

### 3.2. Analysis of the sand grain

When performing a visual assessment of grain sizes of the sand grains, on the basis of Figures 6 and 7, it was found that high-silica sand had grains of a higher homogeneity.

It is also confirmed by the main fraction index  $F_g$  given in Table 2. What's more, the grains shape seems to be nearer to spherical than in case of the reclaim, which grains are rather angular.



Fig. 6. Sand grains – silica sand

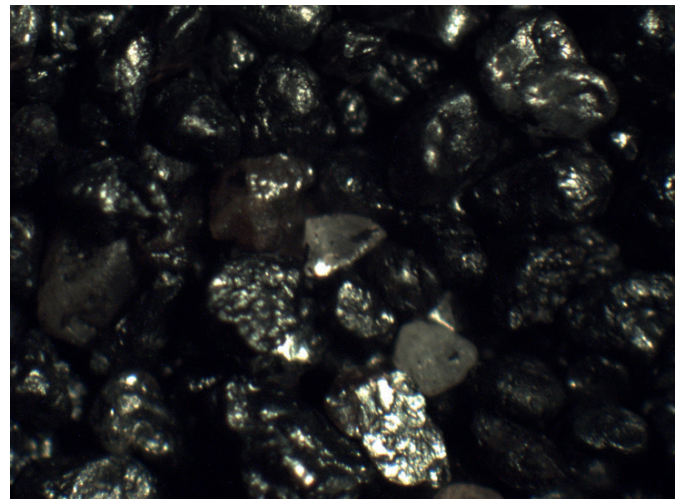


Fig. 7. Sand grains – reclaimed sand

TABLE 1  
 Mesh fractions recalculated in [%] from the sieve analysis

Number of sieve	Mesh fractions recalculated [%]	
	silica sand	reclaimed sand
1.6	0,00	0,00
0.8	0,25	0,12
0.63	5,20	1,66
0.4	40,29	16,81
0.32	32,40	26,92
0.2	19,67	43,73
0.16	1,64	6,28
0.1	0,55	4,34
0.071	0,00	0,14
0.056	0,00	0,00
bottom	0,00	0,00
sum	100,00	100,00

TABLE 2

Characterization of sand grains

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

This, in turn, in connection with a finer fraction (indicated by the sieve analysis results given in Table 1 and such parameters as sieve numbers on which the main fraction was collected and the average grain size dL based on a grain number given in Table 2) is the reason of smaller diameters of intergranular pores. However in connection with Figure 5, where it is clearly seen that the moulding sand with the reclaimed sand takes in more moisture from surroundings, it can be stated that the size of pores in the furan moulding sand either does not have or have a negligible influence on processes of water sorption from surroundings.

### 3.3. Ultrasonic investigations

Decreases of the rate of the ultrasound wave passing through the sample are shown in the time function in Figure 8 for the furan moulding sand on the high-silica sand grains and in Figure 9 for the reclaimed sand grains.

For all analysed pathways, concerning samples with protective coatings, the similar character which can be divided

in two stages, was observed. The first stage is characterised by a large rate decrease which can be the result of the shock related to changes of the storage conditions. The second stage, it means a slow increase or stabilisation is a reflection of a moulding sand behaviour under conditions of a high air moisture content and a temperature.

Samples made of furan moulding sands without protective coatings are characterised by a slightly different behaviour. In the first stage of the process they indicate a sudden rate decrease, which (analogous as in samples with coatings), reflects a sudden change of surrounding conditions. However in the second stage a fast rate increase is observed, similar to the initial one. This can suggest that the change of the surrounding conditions, mainly moisture content increase, does not significantly influence a material structure, which is reflected in the rate of the ultrasound wave passing through the sample. However the fact that the furan moulding sand is taking moisture from surroundings can not be denied, since it is clearly seen in Figures 5 – 7. Such situation can be explained by the mechanism of the moisture sorption by the moulding sand. If this sand is taking in water from surroundings and its result is not specially seen in changes of ultrasound wave rates passing through the sample, it means that moisture is only adsorbed on a surface and is not penetrating deep into the material and intergranular pores.

It results from ultrasonic investigations of surface layers of samples made of moulding sands on high-silica sand grains (Figure 8), that the sample with zirconium – graphite coating indicates larger rate decreases of the passing ultrasound wave than the sample with the zirconium coating, which indicates its higher sensitivity to changes of the surrounding conditions – a high moisture content of the air. The sample with one layer of the zirconium coating is characterised by a behaviour the most similar to the moulding sand without any coating. It seems to indicate also the highest efficiency in protecting moulding sands moulds against a moisture influence since there are the smallest fluctuations of rates of the ultrasound wave passing through the sample. Nevertheless, the obtained

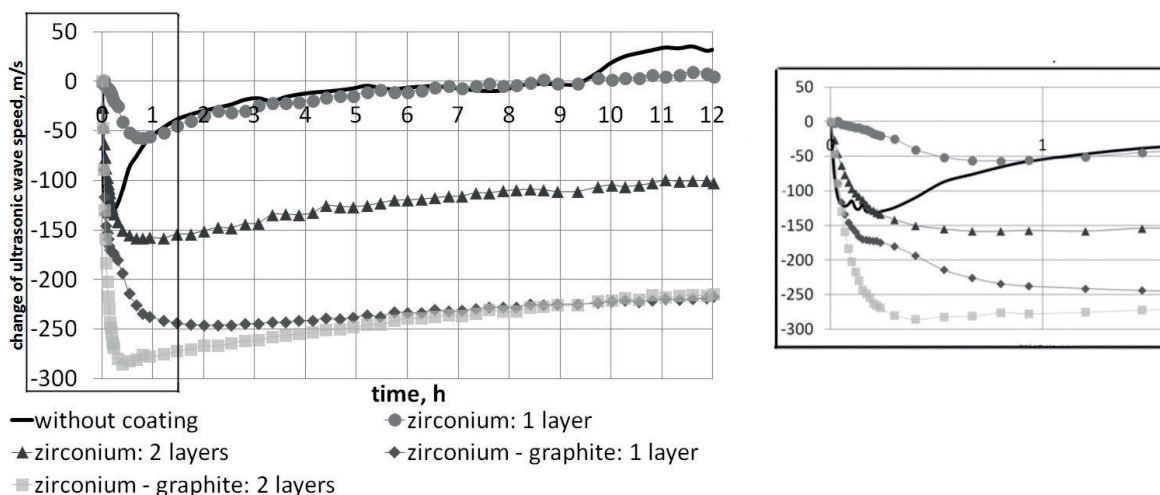


Fig. 8. Rate decrease of the ultrasound wave passing through the sample in the time function, for surface layers of moulds made of furan moulding sands on the high – silica sand grains

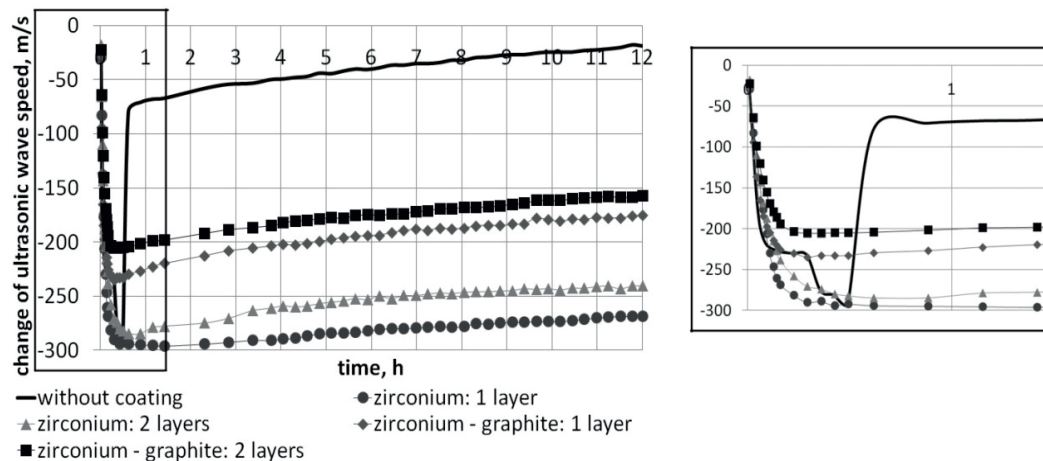


Fig. 9. Rate decrease of the ultrasound wave passing through the sample in the time function, for surface layers of moulds made of furan moulding sands on the reclaimed sand grains

values are not convergent with the results achieved in the test of the quantitative description of the moisture sorption from surroundings by surface layers of moulds. These discrepancies can be explained by various mechanisms of the water sorption by moulds elements covered by various coatings.

On the other hand, in the furan moulding sand on the reclaimed sand grains (Fig. 9) a clear segregation of coatings is observed, on account of the value of rate decreases of the ultrasound wave passing through the sample. Similar values have samples covered by zirconium coatings (one or two layers) oscillating within a range from -300 to -250 m/s. The second group constitute samples with zirconium – graphite coatings, where decreases of the longitudinal wave rates are within a range from -200 to -150 m/s. The obtained results do not agree with Figure 6, presenting the moisture sorption process. In a similar fashion as in case of furan moulding sands on high-silica matrices with coatings, these differences can be a result of the moisture sorption mechanism. In other words, when there are protective coatings, despite that they are taking in less moisture from surroundings than moulding sands without coatings, water is sorped deep into a material and circulates in intergranular pores, while when a moulding sand is not covered by coatings water adsorbs on surfaces only.

#### 4. Conclusions

The investigation results concerning the effectiveness of alcoholic protective coatings (zirconium and zirconium – graphite), against moisture from surrounding penetration into surface layers of moulds made of furan moulding sands, are presented in the hereby paper.

On the basis of the performed investigations, concerning amounts of a moisture sorption from surroundings, it was found that:

- moulding sand with furfuryl resin on the high-silica sand grains takes less moisture than the sand on the reclaimed sand grains, also when protective coatings were applied.
- For moulding sands on the reclaimed sand grains the

number of layers (1 or 2) and the kind of alcoholic coating (zirconium or zirconium – graphite) is not essential in the context of the moisture sorption from surroundings. The application of the protective coating decreases the water amount sorption from the air.

- The most efficient for furan moulding sands on the high-silica sand grains is the application of one layer of the protective coating. Its kind is of no importance.
- Whereas, on the basis of ultrasonic investigations it was found, that:
- furan moulding sands without protective coatings indicated smaller sensitivity to a high air humidity than sands with coatings.
- Probably the mechanism of joining water particles to surfaces of moulding sand moulds and their elements changes when protective coatings are applied.

The knowledge of the proper selection of the coating and its layers will influence the efficiency improvement of protecting sand grains of moulding sands against moisture. The need of the continuation of such research should be emphasised.

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