

# The Research of Desiccation Rates Selected Protective Coating Used on Mould and Sand Cores

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## Abstract

Investigation results of the drying rate of the selected protective water coatings are presented in the paper. The water coating WC-R was subjected to examinations. The drying kinetics of this coating was determined. The coating was deposited on cores of the moulding sand of the matrix grain size being:  $d_L = 0.20$  mm; 0.24 mm; 0.34 mm. In addition, the kinetics of the coating drying process was determined for three conventional viscosities (15s; 22s; 34s). The coating viscosity was estimated by means of the Ford 4mm cup. Drying rates of the protective coating were examined by using the gravimetric technique (weight). Measurements were carried out in a continuous way under controlled conditions: constant ambient temperature and air humidity.

**Keywords:** Protective water coatings, Kinetics of drying, Gravimetric technique

## 1. Introduction

Protective coatings are widely used in foundry industry. These coatings fulfil several tasks. They are used to obtain smooth surfaces of a mould, to improve its strength, minimise reactions between moulds and metal and to obtain smooth casting surfaces. An application of such coatings protects against certain casting defects - veins, burn-on, sand buckles and others. In

addition, some coatings can beneficially influence the casting structure [1, 6–9].

The current environmental standards concerning an emission of volatile substances into the atmosphere are forcing applications of new – different technologies in foundry practice. In the field of protective coatings, in order to limit usage of easily vaporizing substances, coatings based on alcohols are substituted by the ones based on water.

Drying of a coating layer deposited on a mould under atmospheric conditions is rather slow. The amount of heat needed to water vaporising – heat of vaporisation - equals 2441 kJ/kg of water. This is nearly 4 times more than in case of alcohol. In addition, a volatility – an essential factor of a vaporisation rate – is 10-times larger for alcohol than for water [1]. The drying process kinetics depends on several factors: kind of coating, ambient temperature, air humidity. An application of multilayer coatings (deposited in layers on cores or moulds) requires knowing the drying time of each layer, since the consecutive layer should be deposited only when the previous one is dry or nearly dried. Drying times of protective coatings are relatively less known elements of the mould making and preparing it for pouring. Pouring liquid metal into the mould, on which the protective coating is not sufficiently dry, causes the formation of casting defects (sand buckles, veins, external blow holes or non-metallic inclusions). One of the methods of determining the protective coating drying times is the gravimetric technique (weight) [2 - 5].

## 2. Own investigations

### 2.1. Purpose and methodology of investigations

Several factors influence the drying process of the protective coating deposited on moulds or cores: ambient temperature, air humidity, air flow (exchange), as well as: coating viscosity and moulding sand matrix grain size. The aim of the performed investigations was the determination of the influence of the coating viscosity and the grain size of the moulding sand matrix on which the coating was applied - on the kinetics of the protective coating drying process. The gravimetric technique was applied for tracing drying processes. Measurements were performed continuously. Results recorded by the PS 3Y weight were entered in the computer. The experimental stand is presented in Figure 1.

Experiments were carried out at maintaining constant external conditions: temperature, air humidity, and airflow – it means possibility of exchanging water vapour from a coating to surroundings. Cores, on which coatings were deposited, were of the same dimensions. Figure 2 presents the core with and without the deposited coating.



Fig. 1. Experimental stand for investigating the drying process of protective coatings [3]



Fig. 2. The core – samples for testing, with and without the deposited coating

The protective coating WC-R of the Prec-Odlew Company was subjected to investigations. The coating was deposited on specially prepared cores made of a moulding sand with a furan binder. Moulding sands were prepared on the high-silica sand matrix from ‘Szczakowa’ of an average grain size:  $d_L = 0.34$  mm – ‘coarse’ sand;  $d_L = 0.24$  mm – middle sand;  $d_L = 0,20$  mm – ‘fine’ sand.

The coating deposition was carried out by immersing the core in a coating of a determined viscosity. The coating viscosity was determined by means of the Ford 4mm cup. Three viscosities were used: 15 s; 22 s and 34 s. Time of core immersing ( $t_1$ ) was - 30 s, and coating draining time ( $t_0$ ) - 60 s. Such prepared cores were tested.

During tests the influence of the viscosity and the moulding sand grain size on the kinetics of drying were determined. Drying times of the first and the second layer of the coating were measured. Also the viscosity influence on the coating thickness was determined (the first and second layer). The coating thickness was measured by means of the micrometric screw; the coating was deposited on specially prepared aluminium plates. Such plate with the deposited coating is shown in Figure 3.

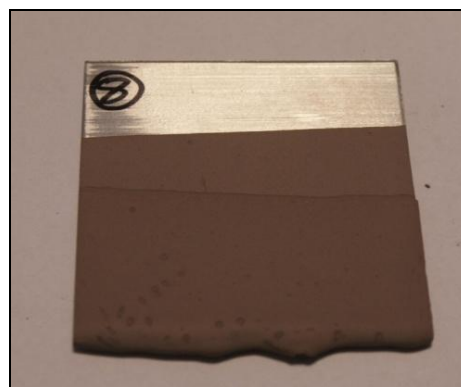


Fig. 3. Plate for measuring the coating thickness with the deposited coating

## 2.2. Kinetics of the protective coating drying

Examples of results of the drying processes of the protective coatings are presented in Figures 4 and 5. A drying degree of the coating was determined using the equation:

$$S_{wp} = \frac{m_{p(0)} - m_{p(x)}}{m_{p(k)} - m_{p(0)}} \cdot 100\%$$

where:

$S_{wp}$  - coating drying degree

$m_{p(x)}$  - coating mass in the given moment

$m_{p(0)}$  - coating mass in the initial moment ( $t = 0$ ) - coating contains a diluent

$m_{p(k)}$  - coating mass after drying - coating does not contain a diluent

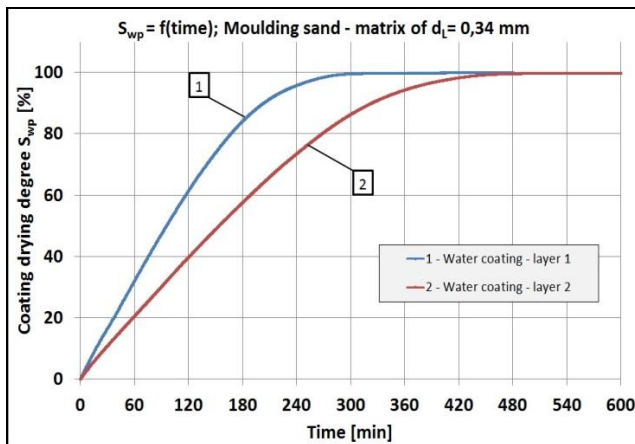


Fig. 4. Drying process of the protective water coating deposited on the moulding sand core of grain sizes  $d_L = 0.34$  mm. Coating viscosity (Ford cup)  $L_p = 22$  s., ambient temperature  $T = 22$  °C, air humidity  $W = 20$  %

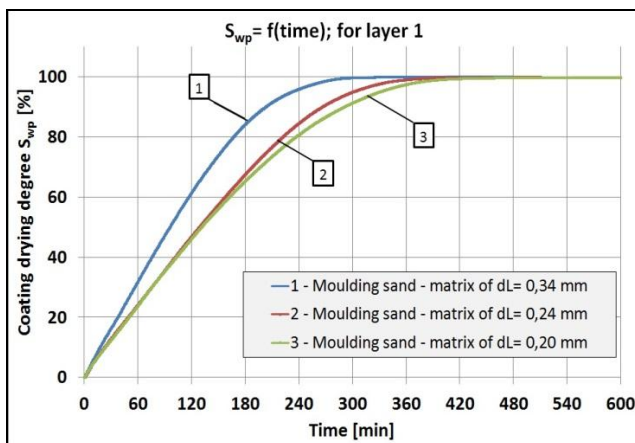


Fig. 5. Drying process of the protective water coating deposited on the moulding sand core of three grain sizes  $d_L$ . Coating viscosity (Ford cup)  $L_p = 22$  s., ambient temperature  $T = 22$  °C, air humidity  $W = 20$  %

In case of the drying processes presented in Figure 4 the character of changes is similar, however it is possible to notice differences in the drying rate between the first and the second layer. The first layer dries after approximately 300 minutes, while the second after approximately 480 minutes. The difference is probably due to the penetration (soaking) of the first layer by a diluent during depositing the second layer. The longer distance causes that the process of a diluent removal is more difficult and - in consequence - longer.

The course of drying the protective coating deposited on cores made of matrices of various grain sizes  $d_L$  are shown in Figure 5. The drying process is the fastest in case of the coating deposited on the moulding sand with a matrix of  $d_L = 0.34$  mm and equals 300 minutes, while the slowest - for the sand with a matrix of  $d_L = 0.20$  mm (approximately 420 minutes). When the coating is deposited on the moulding sand of a middle grain size the drying time equals approximately 390 minutes. Thus, from these tests explicitly results that, the grain size has the significant influence on the drying time of the coating deposited on cores

Figure 6 presents the influence of the matrix grain size of the moulding sand on the drying times of both layers of the protective coating. In order to determine the end of the coating drying, on the bases of the drying process pathway, the kinetics of the process, which means the first derivative of the drying degree ( $dS_w/dt$  [%/min]) was detected. It was assumed that the end of the process was the moment when the drying rate was below 0.25 %/min. Analysing the results presented in Figure 6 one can notice, that in case of the first layer of the coating the matrix grain sizes significantly influences its drying time - the larger grains the shorter drying time. The difference in the drying time of the coatings deposited on samples of  $d_L = 0.2$  mm, and of  $d_L = 0.34$  mm, equals approximately 120 minutes. For the coating second layer this influence is much smaller. With the grain size increase the drying time is also shorter but this difference is small, only 10 - 20 minutes. Differences in the coating drying times, at various grain sizes of matrices result from the coating layer thickness on the core surface and its penetration into intergranular spaces, which - in turn - influences the process of the diluent removal during drying. A thinner layer, larger intergranular spaces - easier the diluent removal process and shorter drying time. In case of the second layer there is no penetration of intergranular spaces and therefore drying times are similar.

The dependence of the conventional coating viscosity, determined by means of the Ford 4mm cup, on its drying time is presented in Figure 7. It can be noticed, when analysing the diagram, that with the conventional viscosity increase (diluent content decrease) the drying times of the first and second coating layer become longer and longer. Whereas the intensity of this time prolongation is different for individual layers. In case of the second layer the intensity was higher and when the viscosity was increased from 15 s to 34 s the drying time became longer by 200 minutes, while in case of the first layer, such viscosity increase caused the time prolongation by only 75 minutes.

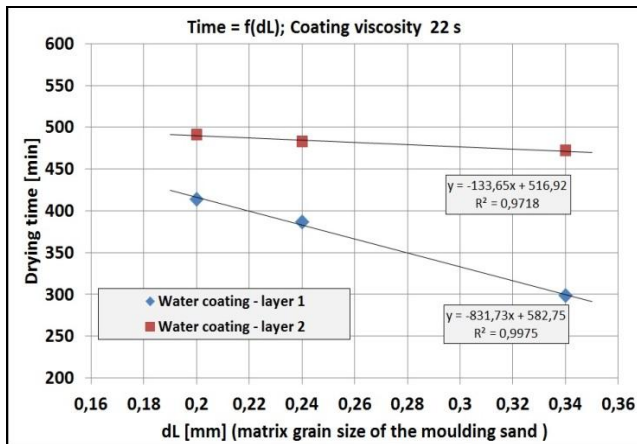


Fig. 6. Influence of the matrix grain size of the moulding sand on the drying time of the protective coating. Coating viscosity (Ford cup)  $L_p = 22$ s, ambient temperature  $T = 22$  °C, air humidity  $W = 20$  %

Figure 8 presents the dependence between the conventional viscosity and the layer thickness. The coating thickness measurements were done by depositing coatings on specially prepared aluminium plates (Fig. 3). In case of the first layer, along with the coating viscosity increase the layer thickness increases. However, this increase is small, of the order of 35 – 40  $\mu\text{m}$  when the viscosity changed from 15s to 34 s. For the second layer its thickness increase is much larger and equals 200  $\mu\text{m}$ . In addition, regardless of the coating viscosity, the second layer thickness is more than twice larger than the first one.

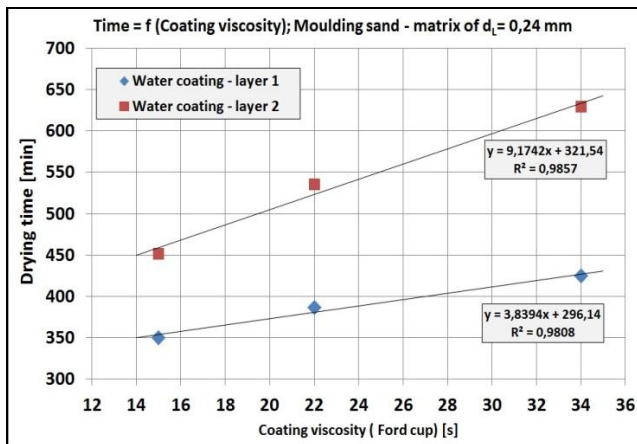


Fig. 7. Coating viscosity influence on its drying time. Moulding sand – matrix of  $d_L = 0.24$  mm, ambient temperature  $T = 22$  °C, air humidity  $W = 20$  %

Since examinations of the layer thickness (Fig. 8) were performed on aluminium plates, effects of the coating penetration into the plate did not occur neither during depositing nor during drying. The situation is different when the coating is deposited on moulds or cores. In such cases the coating penetrates intergranular

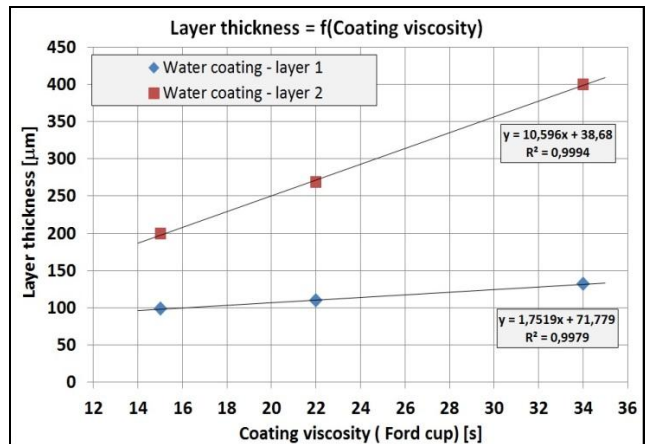


Fig. 8. Coating viscosity influence on the layer thickness. Ambient temperature  $T = 22$  °C, air humidity  $W = 20$  %

spaces. In order to observe this effect, cores with deposited coating, after drying, were examined by means of the optical microscope. Figure 9 presents cores prepared for microscopic investigations. Sample a) – core of the moulding sand on the matrix of  $d_L = 0.34$  mm, b) – core of the moulding sand on the matrix of  $d_L = 0.24$  mm, while c) – core of the moulding sand on the matrix of  $d_L = 0.20$  mm. The differences in the penetration (filtration) depth of the coating into the intergranular spaces can be seen in this Figure. Sample a) – core of large grains - the coating filtration is much deeper than for sample c) – core of small grains. In addition differences in the coating thickness on the core surface are seen. For sample c) the coating is thicker than for sample a).

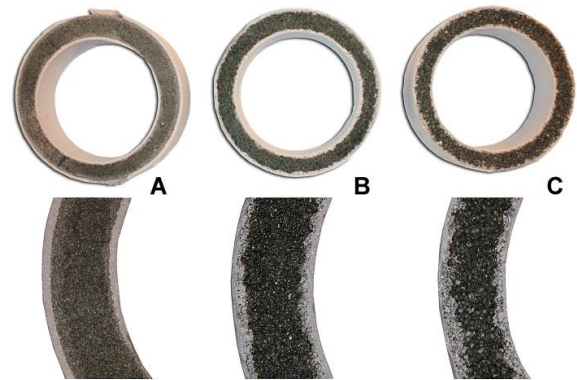


Fig. 9. Samples prepared for microscopic examinations

Figures 10–12 present photographs of coatings made by means of the toolroom optical microscope. Magnification was 30 times. Differences in the coating thickness and the depth of the coating filtration into intergranular spaces of the moulding sand matrix are much more accurately seen than in Figure 9. During taking photographs the measurements of the coating thickness were also made. Cores of the moulding sand on the matrix of a grain size  $d_L = 0.20$  mm (Fig. 10) had the coating thickness from 0.4 to 0.6 mm, while the coating filtration of intergranular spaces was 0.1–0.2 mm. For cores of the moulding sand on the matrix of a grain

size  $d_L = 0.24$  mm (Fig. 11) the measured coating thickness was smaller and equalled 0.3 – 0.4 mm, while the filtration depth significantly increased to be within 0.5 and 0.7 mm. In turn, for cores on the matrix of  $d_L = 0.34$  mm (Fig. 12) the coating thickness was still smaller and equalled 0.15 – 0.35 mm, and the measured filtration depth was still larger, of the order: 0.7–1 mm.



Fig. 10. View of the coating deposited on the core of the moulding sand on the matrix of  $d_L = 0.20$  mm, magnification 30x

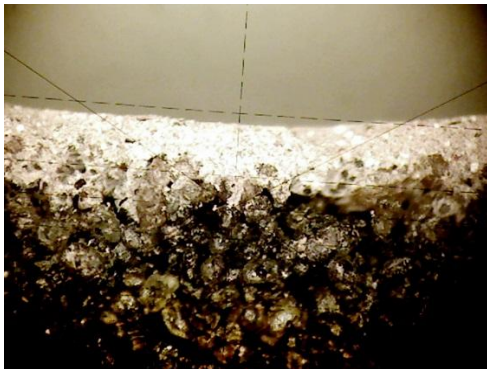


Fig. 11. View of the coating deposited on the core of the moulding sand on the matrix of  $d_L = 0.24$  mm, magnification 30x



Fig. 12. View of the coating deposited on the core of the moulding sand on the matrix of  $d_L = 0.34$  mm, magnification 30x

### 3. Conclusions

The performed examinations of the influence of the coating viscosity and grain size of the moulding sand matrix on the drying process of the protective water coating, deposited on cores and moulds, allow to present the following conclusions:

- The drying time of the first coating layer is shorter than of the second layer,
- The viscosity and grain size of the moulding sand matrix influence the coating drying time, at constant climatic conditions (ambient temperature, humidity, air not flowing),
- With the increase of the conventional viscosity from 15s to 34s (diluent content in the coating decreases) the coating drying time increases. The intensity of the drying time prolongation is higher for the second layer.
- With the increase of the coating viscosity the thickness increase of the coating layer is also observed.
- At increasing the moulding sand matrix grain size from  $d_L = 0.2$ mm to  $d_L = 0.34$ mm, the drying time of the first layer of the coating is significantly shortened (by approximately 120 minutes), while the drying time of the second layer changes by only 10–20 minutes.
- The depth of the penetration of the moulding sands intergranular spaces by the coating is the larger the larger are matrix grain sizes of the moulding sand.

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