www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (2299-2944)
Volume 18
Issue 4/2018

131 – 136

DOI: 10.24425/afe.2018.125182

25/4

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Investigations of the Thickness of Protective Coatings Deposited on Moulds and Cores

Ł. Jamrozowicz *, J. Kolczyk-Tylka **, A. Siatko
AGH, University of Science and Technology in Cracow, Faculty of Foundry Engineering,
Reymonta 23, 30-059 Cracow, Poland,
Correspondence contact: e-mail:* ljamroz@agh.edu.pl, ** Kolczyk@agh.edu.pl

Received 28.09.2018; accepted in revised form 13.12.2018

Abstract

This article presents measurements of the thickness of alcohol-based coatings on sand foundry cores and moulds. These coatings were applied using two methods, the dipping method and the painting method. For the purposes of the study, a zircon alcohol-based coating was prepared with three different levels of nominal viscosity; very thin at 10s, average at 20s, and thick at 30s. The coating was applied to a core made of quartz sand and furan resin. The cores were made of sand with three different grain sizes; d_L = 0.22 mm – fine sand, d_L = 0.33 mm medium sand, and d_L = 0.47 mm coarse sand. In the study, the thickness of the coating obtained to the core was measured immediately after application as well as after drying. Additionally, the extent of penetration into the intergranular spaces of the core matrix was measured. On the basis of this study, the impact of the grain size of the core matrix on the thickness of the coating and its penetration into the core was assessed. The thickness of coatings obtained using different application methods was also assessed.

Keywords: Protective coatings, Coating thickness, Coating viscosity, Core, Mold

1. Introduction

The casting production is a multistage and complex process. The main and superior aim is obtaining the ready product of the determined parameters and without defects. The casting quality in a large measure depends on the mould or core preparation. One of the preparation stages is covering the mould (core) surface by the protective coating [1,2]. The application of such coating improves the smoothness of the mould surface and due to that the casting surface becomes more smooth and less rough. In addition, the protective coating covering the mould surface layers minimizes reactions between the mould and liquid metal. The application of these coatings protects the casting against certain casting defects such as burn-on, veins, sand buckles and others. In addition, some coatings can favourably influence the casting structure [5-10]. The efficiency of the protective coating influence depends significantly on its thickness on the mould (core) during covering. Too thin coating will not provide the satisfactory protection. The thickness of the deposited coating depends on several factors: coating viscosity, way of deposition, number of deposited layers, grain size of the matrix out of which the core or moulds are made. There are many studies describing the course and drying kinetics of protective coatings [1,3,4,11,12]. However, research on determining the thickness of the coating formed on the core and the impact on the thickness of the above-mentioned parameters was not found.

2. Own investigations

2.1. Aim and the investigation methodology

The aim of the hereby study was the determination in which way such parameters as the coating viscosity, the way of its deposition and the grain size of the matrix of the moulding sand, influence the thickness of the deposited coating.
The alcoholic coating of three apparent densities 10s, 20s and 30s, were used in investigations. The viscosity measurements were done by means of the 'Ford's cup' of a clearance of 4 mm. Coatings were deposited on cores made of furan moulding sand. High-silica sand of three various matrix sizes:
'fine' sand – main fraction Fg = 85,3 % (0,2/0,16/0,32) - d_L = 0,22 mm, D50 = 0,24 mm (DIN)
'medium' sand – main fraction Fg = 90 % (0,4/0,2/0,32) - d_L = 0,32 mm, D50 = 0,39 mm (DIN)
'coarse' sand – main fraction Fg = 89,2 % (0,4/0,63/0,32) - d_L = 0,46 mm, D50 = 0,57 mm (DIN)
were used for making cores. Applied of coatings was done by dipping the core in the coating and also by painting.

The thickness of the coating in wet condition was measured directly after its deposition, by the device called the 'comb'. In addition, after drying the coating, its thickness on the core as well as its penetration into intergranular spaces were measured. In order to perform this last measurement the sample was cut out and the measurement was done by means of the microscope. The thickness of the coating was measured 4 times each time. The result presented in the graph is the arithmetic mean of the measurements. Maximum measurement error was +/- 10%.

Figure 1 shows the shape of the core to which the coating was applied, as well as the core with the coating already applied and across-section of the core.

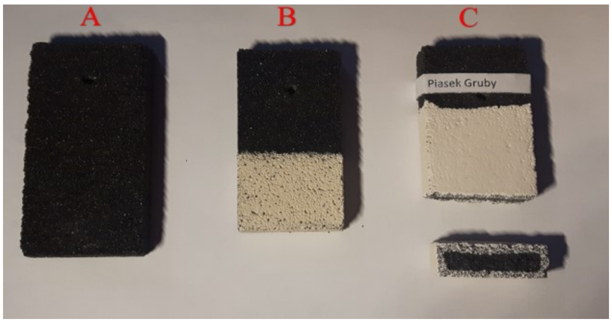

Fig. 1. A – the prepared core before application of coating, B – the core after application of the coating, C – the core after being cut in half, showing the penetration of the coating in the intergranular spaces

2.2. Results of investigations

Figures 2 – 4 show the coating applied to the core, as well as the penetration into the intergranular spaces. The photo was taken with a laboratory microscope with 10x enlargement. Figure 2 illustrates the penetration of a coating with a nominal viscosity of 10s applied to the core by dipping. It can be seen that along with an increase in the grain size of the core matrix, the penetration increases, while the thickness of the coating which arises on the core is similar. In the case of the coating with a nominal viscosity of 30s (Fig. 3), also applied to the core by dipping, the situation is similar, in that along with an increase in grain size the penetration increases. The results are similar in the case of a coating with a nominal viscosity of 20s (Fig. 4) applied to the core by painting. However, in this case it can be seen in the photos that the degree of penetration is lower.

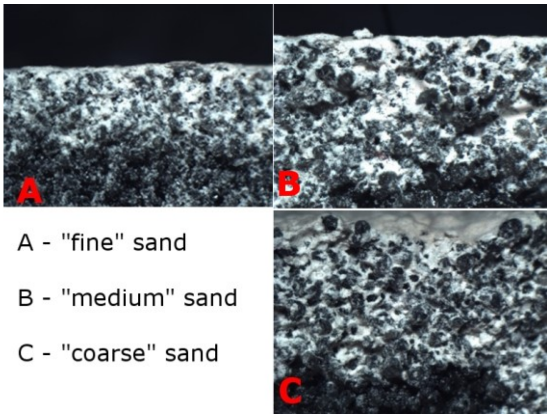

Fig. 2. Penetration of the coating into the intergranular spaces depending on the matrix grain size – coating with arbitrary viscosity 10s. coating was applied by dipping, magnification 10x

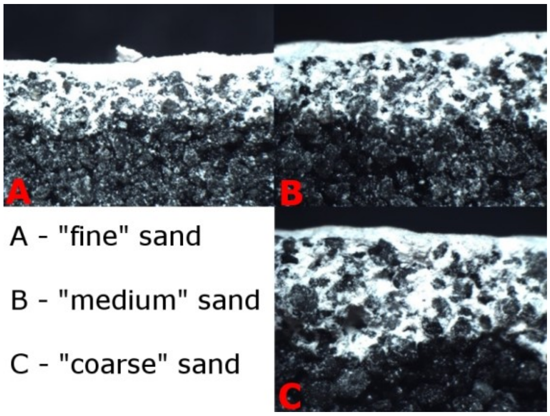

Fig. 3. Penetration of the coating into the intergranular spaces depending on the matrix grain size – coating with arbitrary viscosity 30s. coating was applied by dipping, magnification 10x

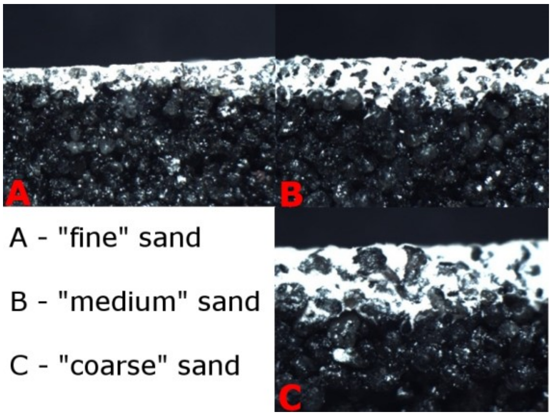

Fig. 4. Penetration of the coating into the intergranular spaces depending on the matrix grain size – coating with arbitrary viscosity 20s. coating was applied by painting, magnification 10x

Figures 5 – 7, in turn, show the impact of grain size of the core matrix on the thickness of the coating that arises on the core. The cores were dipped in coating of a nominal viscosities of 10s (Fig. 5), 20s (Fig. 6) and 30s (Fig. 7). Measurement of the coating was taken immediately after application – while wet and after drying, and the degree of penetration of the coating into the intergranular spaces was also measured. In the case of the coating of a viscosity of 10s (Fig. 5), it can be seen that the coating which arose on the core is quite thin, merely 0.15 mm and for practical purposes does not increase together with an increase in the grain size of the core matrix. In contrast, the penetration of the core is high, amounting to 3.5 mm, and along with an increase in the grain size of the core matrix this increases to about 4 mm. The situation is similar in the case of the coating with a viscosity of 20s (Fig. 6). However, for this viscosity the thickness of the layer which arises on the core is twice as great, amounting to 0.3 mm. In contrast, the penetration of the coating into the intergranular spaces of the core matrix $d_L = 0.22$ mm is lower, amounting to 1.6 mm, and also increases along with an increase in grain size, amounting to 2.4 mm for a grain size of $d_L = 0.47$.

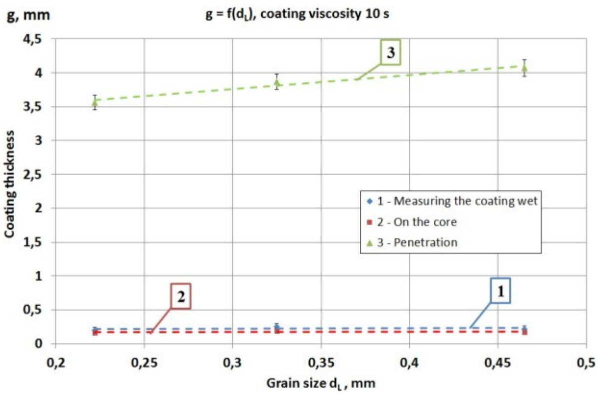

Fig. 5. Thickness of the protective coating depending on the core grain size. Coating with arbitrary viscosity 10s was applied by dipping

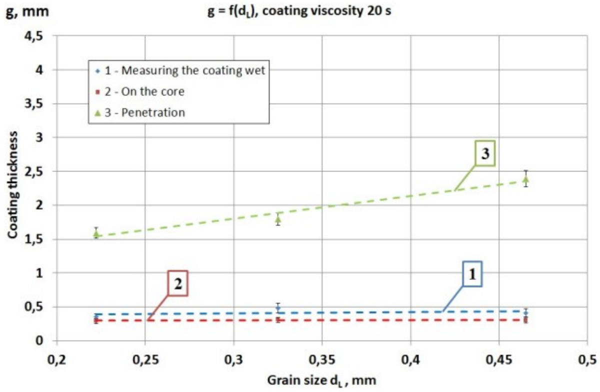

Fig. 6. Thickness of the protective coating depending on the core grain size. Coating with arbitrary viscosity 20s was applied by dipping

For the coating with a nominal viscosity of 30s (Fig. 7), the thickness of the coating which arose after application to the core, regardless of the grain size of the core matrix, amounted to 0.45 mm. In contrast, the penetration of the coating into the intergranular spaces also increased with an increase in grain size of the core matrix, amounting to 1.2 mm for a grain size of d_L = 0.22 mm, while for a grain size of d_L = 0.47mm, the penetration of the coating amounted to 2.1 mm.

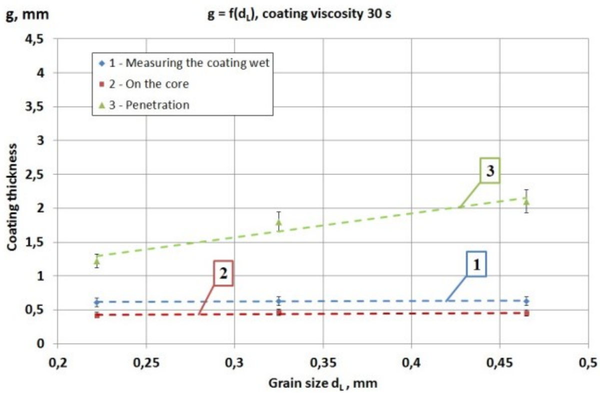

Fig. 7. Thickness of the protective coating depending on the core grain size. Coating with arbitrary viscosity 30s was applied by dipping

Figures 8 - 10 show the impact of grain size of the core matrix on the thickness of the coating which arises on the core when the coating is applied by painting. In this case, the thickness of the coating which arises is virtually the same, regardless of the grain size of the core matrix. For the coating with a nominal viscosity of 10s (Fig. 8), the thickness of the coating which arises is g = 0.13 mm, for the coating with a viscosity of 20s (Fig. 9) g = 0.18 mm, and for the coating with a viscosity of 30s (Fig. 10) the thickness of the layer increases slightly from g = 0.15 mm for fine sand to g = 0.25mm for coarse sand.

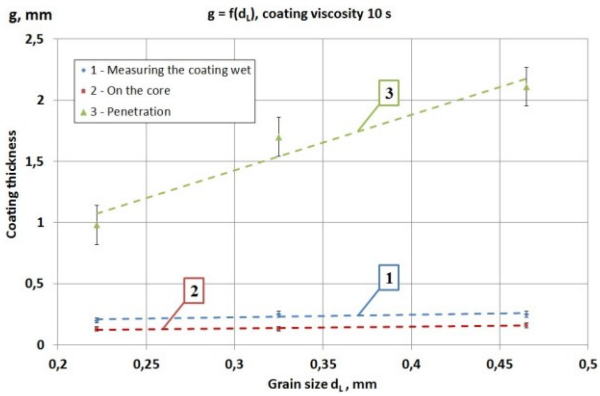

Fig. 8. Thickness of the protective coating depending on the core grain size. Coating with arbitrary viscosity 10s was applied by painting

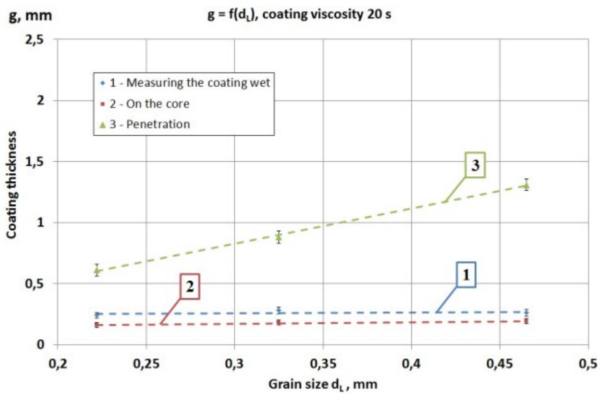

Fig. 9. Thickness of the protective coating depending on the core grain size. Coating with arbitrary viscosity 20s was applied by painting

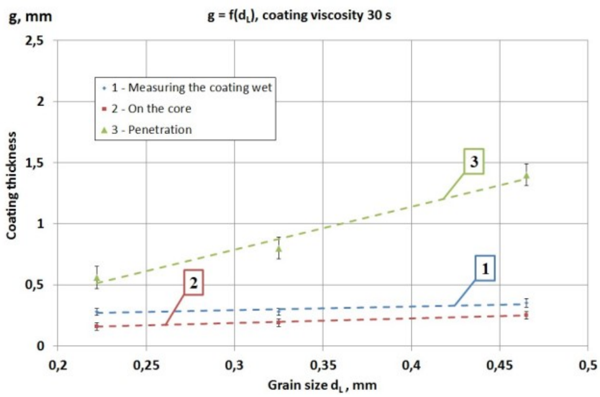

Fig. 10. Thickness of the protective coating depending on the core grain size. Coating with arbitrary viscosity 30s was applied by painting

In contrast, the penetration of the coating into the intergranular spaces of the core matrix along with an increase in the grain size, as in the case of coatings applied by dipping, also increased. For the coating with a viscosity of 10s (Fig. 8), a change from a grain size of d_L = 0.22 to 0.47 resulted in an increase in penetration depth from 1 mm to 2.1 mm. For the coating with a viscosity of 20s (Fig. 9), penetration increased from 0.6 mm to 1.3 mm, and for that with a viscosity of 30s (Fig. 10), the respective change was from 0.55 mm to 1.5 mm.

When comparing the results of thickness measurements of the coating which arises on the core applied by the painting method to the results when this coating is applied by dipping, it can be seen that regardless of the viscosity of the coating, the thickness of the layer obtained is at least two times thinner when the coating is applied by painting. Figure 11 presents the results of measurements of the thickness of the coating layer on the core depending on the viscosity of the coating when using different application methods. Similar results are obtained regarding penetration of the coating into the intergranular spaces (Fig. 12) for painted cores; regardless of the viscosity of the coating, the thickness was at most half of the thickness of the coating when applied by dipping.

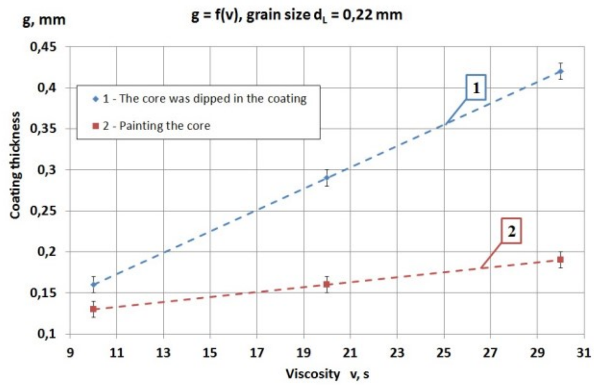

Fig. 11. Influence of viscosity on the thickness of the coating for different methods of its application to the core. The matrix grain size d_L = 0,22 [mm]

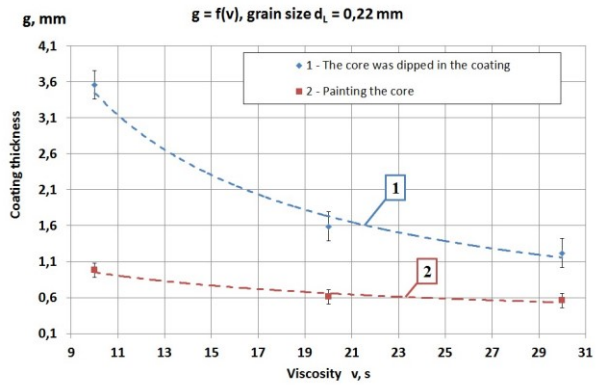

Fig. 12. The effect of viscosity on the measure of penetration of the coating for various methods of its application to the core. The matrix grain size d_L = 0,22 [mm]

Figure 13 presents the impact of the viscosity of the coating on the thickness of the layer which arises on sand cores with a variety of grain sizes. The coating was applied in these cases by the dipping method. For the range of viscosities studied, the change in the thickness of the coating was virtually linear. Along with a change in nominal viscosity from 10s to 30s, the thickness of the coating layer increased from 0.19 mm to 0.46 mm for a core matrix with a grain size of d_L = 0.33 mm. For the remaining two grain sizes, the values for the thickness of the coating are lower by 0.01 – 0.04 mm, that is to say that the differences are not significant, meaning that the grain size of the core matrix for the range of grain sizes studied has virtually no impact on the thickness of the coating which arises o the core.

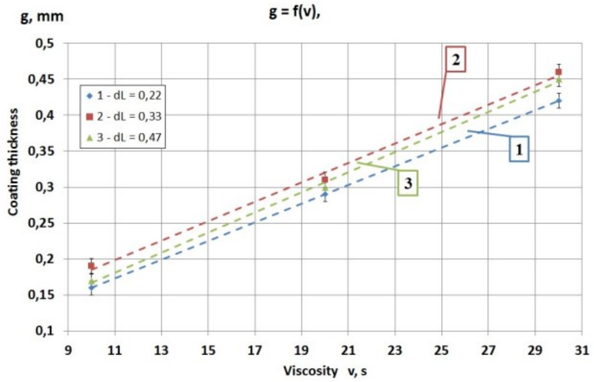

Fig. 13. The influence of the viscosity on coating thickness for the different grain size of the matrix. The core was dipped in the coating

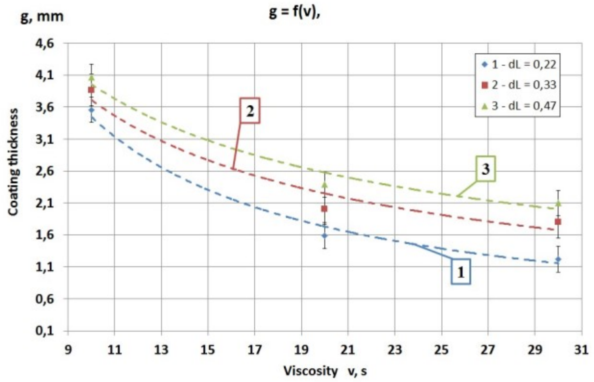

Fig. 14. The influence of the viscosity of the size of the penetration for the different grain size of the matrix. The core was dipped in the coating

In turn, Figure 14 shows the impact of the viscosity of the coating on its penetration into the intergranular spaces for a variety of grain sizes. Along with an increase in the viscosity of the coating, the depth of penetration decreases. The greatest penetration was observed for a grain size of d_L = 0.47 mm. For a core matrix with a grain size of d_L = 0.33 mm, the penetration values were lower by 0.2-0.3 mm, while for a core matrix with a grain size of d_L = 0.22 mm the values were lower by 0.5 – 1 mm. The greatest change in the depth of penetration occurred when the viscosity of the coating changed from 10 to 20s; within this range, regardless of the grain size of the core matrix, the penetration decreased by half. Further increase in the viscosity of the coating to 30s resulted in only a slight change in penetration, amounting to only 0.3 – 0.5 mm.

In the case of coatings applied to the core by the painting method (Fig. 15), it was also observed that along with an increase in the viscosity of the coating the thickness of the coating increased. With a change of viscosity from 10s to 30s, the thickness of the coating which arise on the core increased from 0.16 mm to 0.25 mm. The greatest thickness of the coating was obtained on a core with a grain size of d_L = 0.47 mm. For the remaining grain sizes, the thickness of the coating which arose was lower by 0.03 – 0.05 mm. In turn, along with an increase in viscosity, the penetration decreased (Fig. 16). As was the case with the dipping method, when the coating was applied by the painting method the greatest changes in penetration occurred with the change in viscosity from 10 s to 20 s, amounting to about 0.5 mm. An increase in viscosity to 30 s resulted in a decrease in penetration of 0.1 mm. The greatest penetration of the coating was observed for the core matrix with a grain size of d_L = 0.47 mm, and the lowest for a grain size of d_L = 0.22 mm.

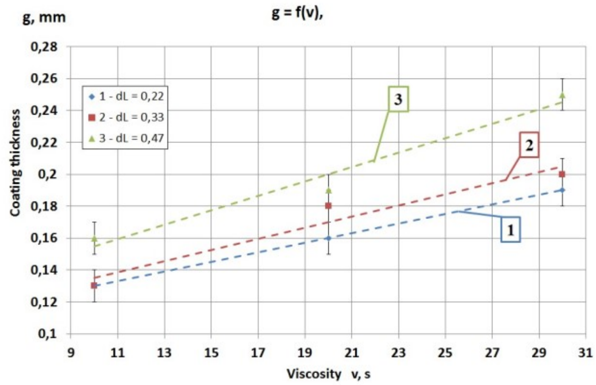

Fig. 15. The influence of the viscosity on coating thickness for the different grain size of the matrix. The core was painted with a coating

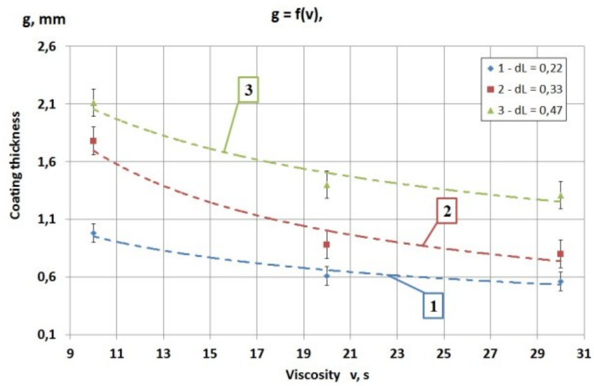

Fig. 16. The influence of the viscosity of the size of the penetration for the different grain size of the matrix. The core was painted with a coating

3. Summary and conclusions

After studying the impact of the method of applying a coating to a core or mould on its thickness, it was determined that:

- The thickness of the coating which adheres to the core is not dependent on the grain size of the core matrix but rather on the viscosity of the coating.
- An increased in the nominal viscosity of the coating from 10 s to 30 s results in an increase in the thickness of the coating on the core from 0.15 mm to 0.45 mm
- The thickest coatings were obtained by using the dipping method, while the thinnest were obtained using the painting method.
- Applying the coating on the core using the dipping method resulted in the even distribution of the coating over the core, while the painting method resulted in visible streaks.
- The penetration of the coating into the intergranular spaces in turn depends on the grain size of the core matrix and on the viscosity of the coating.
- An increase in the grain size of the core matrix resulted in deeper penetration into the intergranular spaces, while an increase in the viscosity of the coating resulted in shallower penetration.
- The deepest penetration occurred when using the dipping method and the shallowest when using the painting method.
- Within the studied range of viscosity, an increase in the viscosity resulted in a linear increase in the thickness of the coating on the core. In turn, the greatest change in the extent of penetration was observed with a change in viscosity in the range between 10 and 20 seconds, within which the penetration dropped by half. A further in increase in viscosity to 30 seconds resulted in only a slight drop in the penetration of the coating.

In order for the coating to fulfill its task, the thickness of the coating applied to the core or mould depends on the type of alloy and the wall thickness of the casting. For castings with walls less than 100 mm, the coating should have a thickness of 0.2 - 0.5 mm, while for walls above 100 mm, the coating thickness should be above 0.6 mm. The choice of method for applying the coating depends on the core size and the size of the mould. Small cores are dipped in the coating. However, large moulds and cores are painted. Therefore, to obtain the right coating thickness, large forms and cores should be painted 2-3 times.

Acknowledgments

The research received founding from NCBIR no. POIR 01.01.01-00-0042/17

References

[1] Lewandowski, L.J. (1997). *Materials for foundry molds*. Kraków. Wydawnictwo „Akapit”.
[2] Seeger, K. (2012). Application of water coverings in manual forming. *Przegląd Odlewnictwa*. 7-8, 322-326. (in Polish).
[3] Zych, J. & Snopkiewicz, T. (2011). Drying and strengthening of protective coatings after deposition on casting moulds and sand cores – new investigation methods. *Przegląd Odlewnictwa*. 9-10, 506-512.
[4] Zych, J. (2006). Application of the novel ultrasonic method in the on line research of the setting, and hardening process of ceramic materials. *Inżynieria Materiałowa*. 27(3), 680-683.
[5] Holtzer, M., Bobrowski, A., Drożyński, D. & Mocek, J. (2013). Investigations of protective coatings for castings of high-manganese cast steels. *Archives of Foundry Engineering*. 13(1), 39-44.
[6] Jakubski, J., Dobosz, St.M. & Jelinek, P. (2005). The influence of the protective coating type on thermal deformation of casting cores. *Archives of Foundry*. 5(15), 164-169.
[7] Jakubski J., Dobosz St. (2006). The influence of the protective coating on thermal effects in core sands Wpływ powłoki ochronnej na zjawiska cieplne w rdzeniach odlewniczych. *Archives of Foundry*. 6(18), 453-458. (in Polish).
[8] Kubicki, J. & Kochmańska, A. (2001). Multicomponent protection coatings on hightemperaturecreep resisting cast steel obtained from paste. *Archives of Foundry*. 1(1). (in Polish).
[9] Kochmańska, A. & Kubicki, J. (2009). Efficiency of protective coatings on high creep resistant cast steel. *Archives of Foundry Engineering*. 9(2), 129-132.
[10] Wróbel, J. (2014). Research on the quality of zirconium protective coatings in terms of their suitability for molds and sand cores for cast steel. *Przegląd odlewnictwa*. 64(9-10). (in Polish).
[11] Jamrozowicz, Ł. Zych, J. & Kolczyk, J. (2015). The drying kinetics of protective coatings used on sand molds. *Metalurgija*. 54(1), 23-26.
[12] Jamrozowicz, Ł., Zych, J., Kolczyk, J. & Wróblewski, D. (2014). The Role of the Surface Shape of the Mould in the Process of Drying of Selected Protective Coatings. *Archives of Foundry Engineering*. 14(spec.2), 39-44. (in Polish).