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ISSN 0543-5846
METABK 54(1) 15-18 (2015)
UDC – UDK 621.746:621.747.002.2:658.532:621.001.6=111

THE INFLUENCE OF THE SHAPE OF WAX PATTERN ON THE KINETICS OF DRYING OF CERAMIC MOULDS

Received – Primljeno: 2014-03-05
Accepted – Prihvaćeno: 2014-09-15
Original Scientific Paper – Izvorni znanstveni rad

Multi-layer ceramic moulds are built of slurry and a refractory material forming their matrices. From the moment when the European Union introduced regulations concerning the environment protection requiring substitution of alcoholic binders by aqueous binders, several difficulties in making moulds occurred. The influence of selected factors on drying ceramic moulds applied in the investment casting technology was determined by the gravimetric method. It was found that each successive layer, of a similar thickness, is drying longer than the previous one. The drying time of layers forming a deep cavities is several times longer as compared with drying open surfaces (external). Extension scale of the drying time is a function of the slenderness of cavities.

Key words: wax pattern, ceramic molds, colloidal binder, drying rate, technological factors.

INTRODUCTION

The production process of multi-layer ceramic moulds consists in dipping the ready pattern set in slurry and then dusting the layers with highly fire-resistant material of a specified grain size [1 – 6].

Water-based colloidal silica binders are used now, but they lead to many problems in this technology. These problems relate mainly to the drying and hardening of layers applied one after another. The layer applied previously should be dry when the next layer is applied [7].

If the mould is not completely dry, it can crack, as a result of which its strength drops and the mould gets damaged. Unfortunately, a stage in the technology has not been well explored, namely the process of subsequent mould layers drying and hardening. Therefore an important element of the process is to define the drying time of subsequent layers. In laboratory conditions, the drying process can be monitored using one of several methods: gravimetric, electrical (resistance) or ultrasound.

Publications, both Polish and international, contain data about the kinetics of ceramic mould layer hardening with the use of a new, ultrasound measurement method [8].

An article has also been published about determining the impact of selected factors on the progress of drying ceramic moulds made of a colloidal binder using a gravimetric method [9], and also about a study of process of drying layers with forced air flow in openings and cavities of various lengths [10, 11].

SAMPLE PRODUCTION

In order to create conditions for studying the impact of wax pattern shape on the drying process, patterns shown in Figure 1 were produced. They are solids reflecting the internal surfaces of open cavities (tubes without bottoms) and closed ones (tubes with bottoms). The tubes were made of various lengths. Changing the tube length meant changing the internal slenderness of the cavity. Cavity slenderness is a shape parameter that plays a key role in the process of ceramic layer drying.

Wax patterns whose surfaces had previously been degreased had subsequent (three) layers of the slurry applied to them. In every case, they were dusted with matrix (Mullit I). Previously completed measurements [9] indicated that the grain size of the matrix used for dusting individual mould layers had no impact on the drying time of the layers applied.

The composition of the liquid ceramic mix determines the dynamic viscosity of the paste, which in turn impacts the thickness of individual ceramic layers [12 – 14]. As the paste viscosity increases, so does the thickness of the layers applied, which in turn determines the time of their drying.

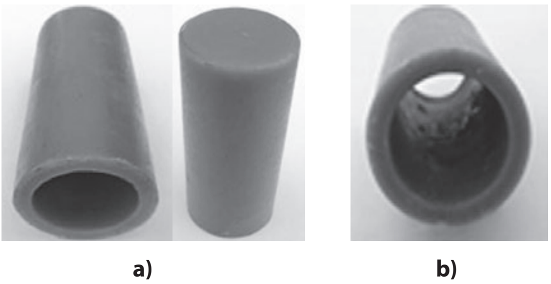
a)
b)

Figure 1 Wax patterns used in the study: a) tubes with bottoms; b) tubes with a through opening

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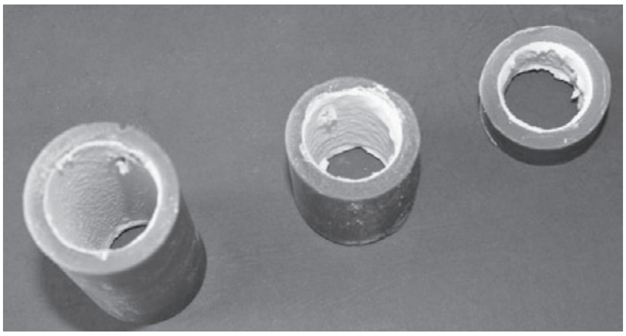

Figure 2 Wax patterns - slenderness of 1, 2, 3 with the inside layer applied to their surface - from the hook of the scales

MEASUREMENT BENCH DESCRIPTION

The drying of subsequently applied layers of the ceramic mould was studied using the gravimetric method with RADWAG electronic scales. The purpose here was to determine the drying time of individual layers for selected shapes of pattern surface, the slenderness and depth of cavities as well as drying in open and closed cavities.

The measurement using the scales consisted in suspending the wax pattern sample with the ceramic layer applied and recording - with the use of a computer working with the scales – changes (decreases) of the sample mass. The measurement was carried out throughout the duration of ceramic layer drying.

Drying process studies were carried out while the following conditions were maintained: air humidity W= 45 – 50 %, ambient temperature T= 22 – 24 ^{o}C.

IMPACT OF SURFACE CAVITY SLENDERNESS OF THE PATTERN ON THE DRYING TIME OF CERAMIC LAYERS

The investment pattern method is mainly used to produce castings that are highly complex, frequently with geometrically complicated surface, and this additionally hinders the drying process. Study [9] has shown that there is a lot of variety in the rate of internal and external surface drying. Interior surfaces, particularly those pointing down, are much slower to dry [15].

The application of individual layers of ceramic moulds to an increase in the thickness and the drying time as well. The impact of slenderness on the drying time of ceramic mould layers was assessed using tube-shaped wax patterns, Figure 2. The drying duration of internal surfaces applied to wax patterns of tubes with bottoms (closed) and with a through openings (open) was studied. The wax pattern, i.e. a tube of the following dimensions: H = 84,0 mm, D = 35,5 mm, d = 25,5 mm (slenderness 3), was covered with three slurry, one after another, with the finest grained matrix (Mullit I). Figure 3 presents the course of internal surface drying for a wax model of a tube with a through opening of various slenderness, equal to 1 (H = 21,0 mm, D = 35,5 mm, d = 25,5 mm), 2 (H = 42,0 mm, D = 35,5 mm, d = 25,5 mm) and 3. The drying degree was calculated using the following equation:

$$\eta = \frac{m_p - m_x}{m_p - m_k} \cdot 100\ \% \qquad (1)$$

m_p – initial mass of the sample / g.
m_k – final mass of the sample / g.
m_x – sample mass at time “x” / g.
η – drying degree / %.

Figure 4, in turn, presents the course of drying three subsequent layers of ceramic slurry applied to the internal surface of a wax pattern of a tube with a bottom and the slenderness of 1.

The research completed allows a quantitative determination of the impact of surface cavity slenderness on the speed and time of mould drying. When the opening is through, the impact of slenderness becomes apparent when S > 2, Figure 3. What is characteristic of layers applied to a wax pattern is that the first one is always the thinnest. The time it needs to dry is clearly shorter than the remaining layers need, Figure 4.

The application of subsequent layers of slurry with a water-based binder causes the previous, already dried layers to get moist again. This extends their drying

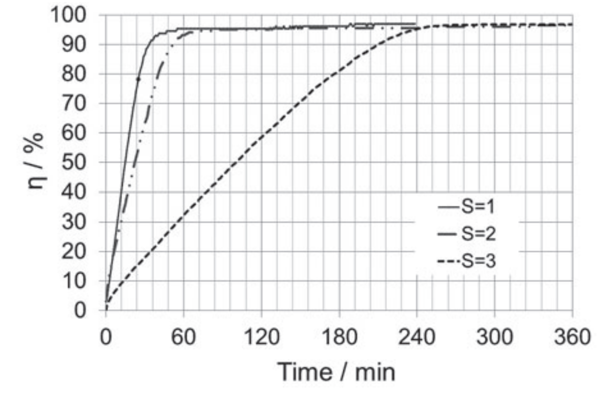

Figure 3 The drying process of the first ceramic layers : internal surface of a tube with a through opening, matrix Mullit I; opening slenderness S = 1, 2 and 3

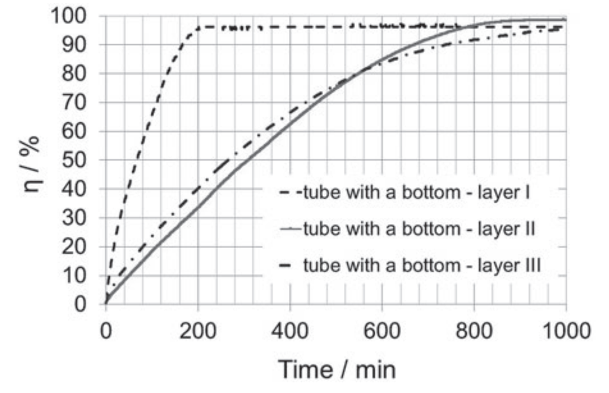

Figure 4 The drying process of subsequent ceramic layers: internal surface of a tube with a bottom, matrix Mullit I; opening slenderness S = 1

times, often even several times, Figure 4. This phenomenon is observed even if the cavity slenderness is small, e.g. if S = 1, as shown by Figure 4.

The research completed sheds light on the role of the shape of the mould (pattern) surface. Moulds dry in a completely different way in closed cavities (openings) and in open ones. For example, as shown in Figures 3 and 4, the drying duration of the first layer in an open cavity with the slenderness of 1 is less than 60 minutes, while the drying time of a cavity of the same slenderness, but closed, is about 200 minutes, that is almost 3,5 times longer. This example demonstrates the huge role that the shape of the external surface of the pattern, i.e. the shape of the ceramic mould, plays in the drying process.

The results of the remaining studies are presented in Figures 5 and 6. An analysis of the results obtained justifies a general statement that ceramic mould dries faster in through openings. The main reason for this is the easier exchange of air receiving the evaporating water with the surroundings.

This slight natural movement of air is greater in through cavities and supports faster evaporation. Other publications by the authors [9, 15] have demonstrated that the direction in which cavities face (downward or upward) also plays a significant role in the speed with which ceramic layers dry. Closed cavities pointing upward dry much faster than those pointing downward. In this study, too, the air flow inside the cavities and its exchange with the environment played a major role.

Slenderer ceramic moulds dry much slower. In the case of internal surfaces of closed cavities (tubes with a bottom) in which direct contact with the surroundings is limited, the mass loss (drying) is much slower, cf. Figures 5 and 6.

Inside a cavity which is a hollow closed at one end, air humidity rises as a result of water evaporating from the slurry of the mould. The increased humidity of air above the evaporating surface, i.e. air saturation with water vapour, slows down further water evaporation from the layer of the ceramic mould. Such conditions prolong the drying process, which is running much slower, and this in turn has an unfavourable impact on the production of a multi-layer ceramic form, because it extends the technological process. If air flow is forced, this accelerates the mass exchange (drying), but researching this subject requires a different methodology.

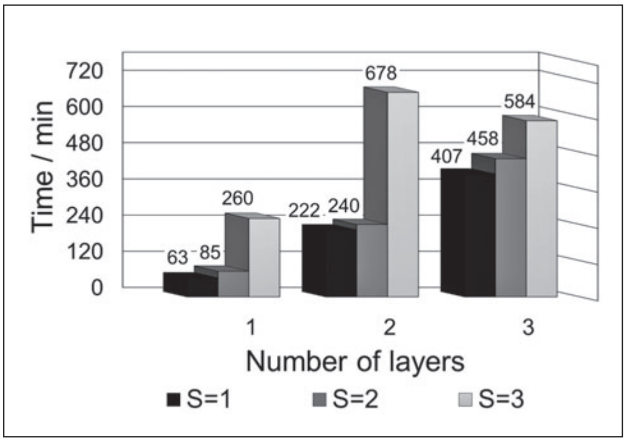

Figure 5 Comparing the drying time of three layers of slurry, the internal surface of a tube with a through hole (without a bottom), matrix Mullit I; opening slenderness S = 1, 2 and 3

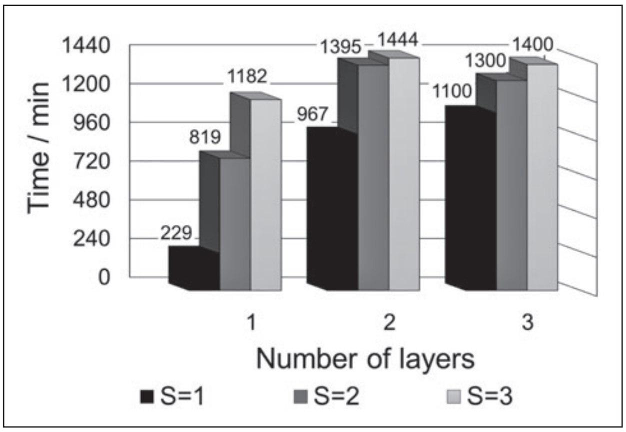

Figure 6 Comparing the drying time of subsequent layers of slurry, the internal surface of a tube with a closed hole (with a bottom), matrix Mullit I; opening slenderness S = 1, 2 and 3

CONCLUSIONS

Ceramic moulds are of a multi-layer structure, which is due both to the anisotropic nature of the material used to make them and to the technology of their production. The thickness of individual mould layers depends on the dynamic viscosity and the composition of the liquid slurry as well as the method of applying the layers.

The research completed indicates that the drying time of ceramic layers formed on a wax pattern is significantly influenced by, apart from their thickness itself, also the shape of the pattern (mould).

All types of cavities (open, closed, pointing downward or upward) are difficult to dry. Their shape, characterized *inter alia* by their slenderness, determines the pace and duration of drying.

This study has shown that deep cavities closed on one side are particularly difficult to dry if water-based binders (colloidal silica) are used, and such cavities frequently require several times longer durations to dry than cavities of similar dimensions, but open (holes without a bottom).

Acknowledgements

The research was performed within the AGH project 11.11.170.318 task 4.

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Note: The responsible translator for English language: “ANGOS” Translation Office, Krakow, Poland