SAT-LCR-P-2-CT(R)-11

FEATURES OF COORDINATION OF SHRINKAGE PROCESSES OF CERAMIC MASSES AND ENGOBE COATINGS IN BRICK PRODUCTION

Assoc. Prof. Olena Khomenko, PhD
Department of Chemical Technology of Ceramics, Glass and Building Materials
Ukrainian State University of Chemical Engineering, Ukraine
E-mail: elenahtks@ukr.net

Prof. Tsvetan Dimitrov, PhD
Department of Chemistry and Chemical Technologies
University of Rousse "Angel Kanchev "- Razgrad Branch
E-mail: tz_dimitrow@abv.bg

Abstract: *Applying engobe coatings to the surface of ceramic bricks is a reliable way to diversify the product range and improve its quality. But such a coating effect is provided in the case when they are coordinated with ceramic masses by shrinkage processes during drying and firing. This work presents the results of research on the shrinkage processes of engobe coatings and ceramic masses when engobes are applied to freshly formed and dried semi-finished products. The probability of the occurrence of internal stresses between the ceramic mass and the coating was analyzed and the maximum permissible deviations of their shrinkage indicators were established. It is noted that with a discrepancy of 13–15% of air and fire shrinkage of masses and engobes, internal stresses are not critical and do not lead to defects in the form of cracks or chips. At the same time, the difference in shrinkage of 17–20% caused the appearance of deep and numerous cracks on the surface of the products. The most versatile composition of the engobe coating is offered, which can be suitable for engobing both face and clinker bricks.*

Keywords*: Slip, Engobe, Grinding, Clay, Cullet, Fluidity, Roasting, Sintering, Water Absorption, Frost Resistance*

INTRODUCTION

Building bricks are the most common and popular material used for the construction and cladding of buildings. The products have high physical and mechanical properties, provide an optimal indoor climate and do not emit toxic substances.

The application of engobe coatings on the surface of ceramic bricks is a reliable way to diversify the product range and improve quality (Khomenko, O., Tsyhanenko, L., Tsyhanenko, H., Borodai, A., Borodai, D. & Borodai, S., 2023). Correctly selected to the ceramic base, engobe coatings, in addition to the decorative effect, also perform a protective function – they reduce the porosity of products by creating a dense outer layer, which in turn leads to a slowdown in the destruction of the structure under the influence of environmental factors (Dal Bó, M., Bernardin, A. M. & Hotzac, D., 2014).

The complexity of developing engobe coating compositions for ceramic bricks lies in the fact that two ceramic materials with different structures need to be combined in one product - coarse-grained ceramic brick shards and a fine engobe coating. These materials differ in porosity and hardness due to different degrees of sintering at the same firing temperature. For example, ceramic bricks usually have a water absorption of 5–12%, depending on their intended use (clinker or facing). Engobe coatings should form a dense hard layer with a water absorption of 1–2% and reduce the likelihood of moisture penetration into the interior of the product (Khomenko, O., Datsenko, B., Sribniak, N., Nahornyi, M. & Tsyhanenko, L., 2019).

Refractory clays, leans and sintering additives are commonly used for the manufacture of engobe coatings. Clays ensure the adhesion of the coating to the ceramic substrate and the manufacturability of the products before the firing stage. Leans additives (quartz sand, fireclay) help to control shrinkage processes. The higher density of engobe coatings compared to ceramic base is achieved by using a significant number of melts, in particular, broken glass (Nandia, V.S., Raupp-Pereira, F., Montedo, O.R.K. & Oliveira, A.P.N., 2015), which ensures liquid-phase sintering of the coating layer. Engobes in the form of a slips are applied to the surface of the ceramic semi-finished product and the product is fired once (Yatsenko, N.D. & Rat'kova, É.O., 2009).

Brick mass on the base low-melting clays and loams is prepared by rough processing (Khomenko, O.S., Datsenko, B.M. & Fomenko, G.V., 2022), the technological properties of which vary widely depending on the raw material deposit and the specifics of the production process. Bricks are mainly formed by plastic moulding (extrusion), and engobes can be applied by watering or spraying to freshly moulded or dry semi-finished products.

Therefore, the composition of an engobe coating should always be developed only for a specific production (Governatori, M., Cedillo-González, E.I., Manfredini, T. & Siligardi, C., 2022), taking into account all technological factors (composition of the ceramic mass, humidity, air and fire shrinkage, ability of the engobe to sinter at the temperature of brick firing, etc.)

And one of the main factors in the technological process is the matching of ceramic bricks and engobe coating in terms of shrinkage.

EXPOSITION

The aim of this study was to investigate the shrinkage processes of ceramic semi-finished products and engobe coatings of different compositions during drying.

The following tasks were set: to prepare engobe coatings with different clay content and determine their shrinkage; to prepare brick samples from ceramic mass of a given composition and determine their shrinkage; to compare the air shrinkage of engobes and ceramic samples and establish permissible deviations.

For the manufacture of ceramic brick samples, a typical composition of the mass was chosen, which included, wt%: red highly plastic clay – 50, sandy loam – 50. The raw materials belong to the Sursko-Pokrivske deposit (Ukraine) of low-melting clay. The properties of the ceramic mass and samples from it are shown in Table 1.

Table 1 – Properties of ceramic mass and fired samples *

Name of the indicator	Properties after heat treatment	
	at 70ºC	at 1000ºC
Air shrinkage, %	7.3	-
Fire shrinkage, %	-	5.8
Water absorption, %	-	14.5

* the samples were prepared in the laboratory in a plastic way without the use of vacuum

Engobes were prepared in the form of a suspension with a moisture content of 42–46% by fine wet grinding to a residue of 0.5% on a with mesh size 63 μm mesh sieve. To determine the shrinkage during drying samples in the form of 3x3x0.5 cm tiles were made by casting into gypsum moulds and applied to prepared moulded ceramic brick samples to visually assess of the coatings. Table 2 shows the compositions of the experimental engobie coatings.

Table 2 – Experimental compositions of engobe coatings, wt.%.

Component name	Composition number										
	1	2	3	4	5	6	7	8	9	10	11
Refractory clay	80	50	50	65	65	50	60	35	35	20	40
Quartz sand	10	10	40	10	25	25	20	25	40	40	30
Broken glass	10	40	10	25	10	25	20	40	25	40	30

The fundamental choice of the stage of applying an engobe coating to a ceramic substrate is based on the ratio of their shrinkage processes. It is possible to apply engobe to freshly moulded ceramic products and to products dried in a thermal unit. It is advisable to consider both mechanisms of interaction between the engobes and the ceramic base.

Peculiarities of applying engobe coatings to freshly moulded ceramic semi-finished products.

Engobe coatings are applied to a freshly moulded product before it is dried. The ceramic semi-finished product coming out of the moulding press has a moisture content of 20–22% and is coate with an engobe slip with a moisture content of 40–45%. The advantage of this method is that both the ceramic product and the engobe layer will shrink simultaneously, which means that the difference in shrinkage processes will be relatively small. A negative factor is that the semi-finished product is sensitive to soaking, and if the moisture content of the engobe slip is not selected correctly, deformation, goes limp and prolongation of drying time are possible, with greater sensitivity of the products to the drying regime.

Fig. 1 schematically depicts the shrinkage processes of the engobe coating and the ceramic substrate that occur during drying when the engobes is applied to a freshly moulded ceramic sample.

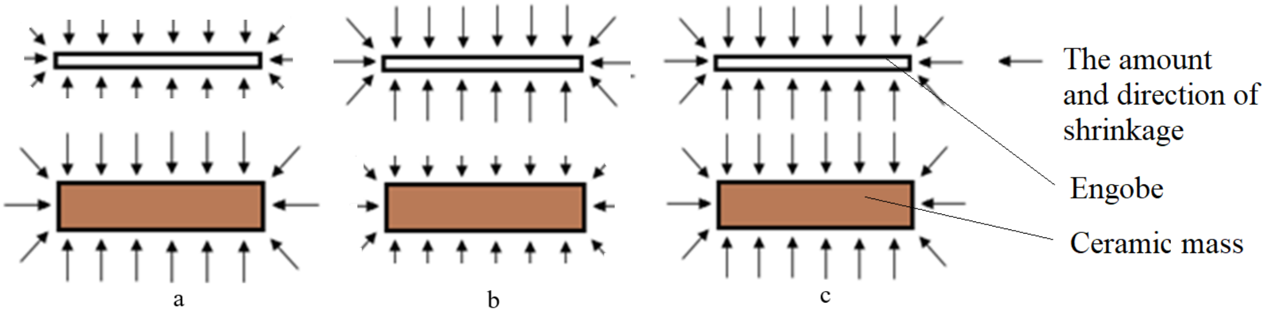

Fig. 1 – Schematic representation of the shrinkage processes of the engobe coating and the ceramic substrate when the coating is applied to a freshly moulded sample: a – shrinkage of the engobe is less than that of the ceramic mass, b – shrinkage of the engobe is greater than that of the ceramic mass, c – shrinkage of the engobe and the mass are equal

In this case, the air shrinkage of the ceramic semi-finished product and the engobe applied to it occurs simultaneously. Moreover, it is possible that the shrinkage of the engobe is less than that of the ceramic mass (Fig. 1a), which will be observed if an increased amount of desiccant components is introduced into the composition of the engobe. It is also possible that the engobe has an increased content of clay components (in particular, refractory clay), in which case the shrinkage of the coating layer will be higher (Fig. 1b) than that of the ceramic semi-finished product. However, the most rational option would be to carefully select the composition of the engobe coating with shrinkage rates close to those of the ceramic mass (Fig. 1c).

If we analyse the shrinkage of the experimental engobes, all three variants of interaction between the engobe coating and the ceramic base are observed (Fig. 2).

It has been established that for samples No. 1, 5, 7–11, there is a rather large discrepancy in the air shrinkage of the engobe and the ceramic mass, both upward and downward (Fig. 2). For compositions 1 and 10, the difference in air shrinkage values reaches to 65%, which indicates a high probability of cracks on the engobed surface of the product during the drying stage. Indeed, a visual assessment revealed that after drying, cracks of varying degrees and locations appeared on samples No. 1, 5, 7–11 (Table 3), which correlates with the differences in shrinkage between the mass and the engobe (Fig. 2).

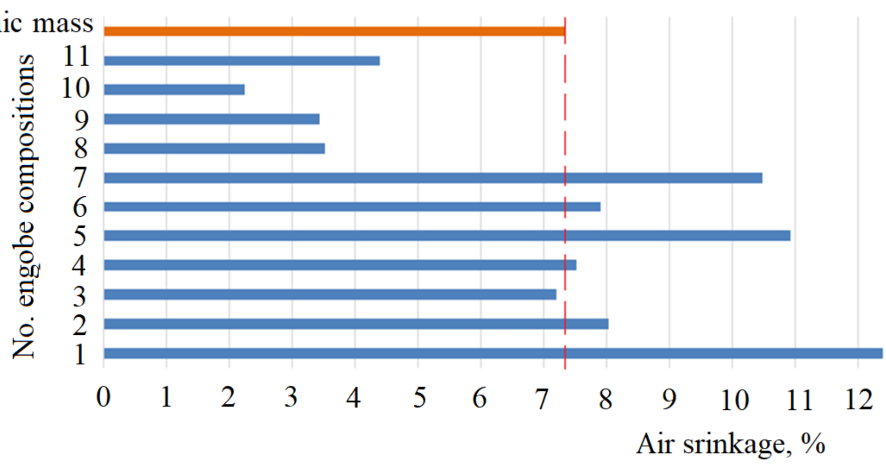

Fig. 2 – Comparison of the air shrinkage of engobe coatings and ceramic mass when applying engobe to a freshly moulded ceramic semi-finished product

Table 3 – Visual analysis of defects in prototypes

Name of the defect	Numbers of research engobes										
	1	2	3	4	5	6	7	8	9	10	11
Cracks on the entire surface	+++	one*	-	-	+	one	++	+	+	+	+
Cracks along the edge	+	-	-	-	-	-	+	+++	+++	+++	++
Surface chips	-	-	-	-	-	-	-	-	-	one	-

*one – single manifestations, "+" – presence and intensity of the defect, "-" – absence of the defect

The nature of the crack location was different (Fig. 3), depending on the direction in which the shrinkage of the engobe and the ceramic mass differ.

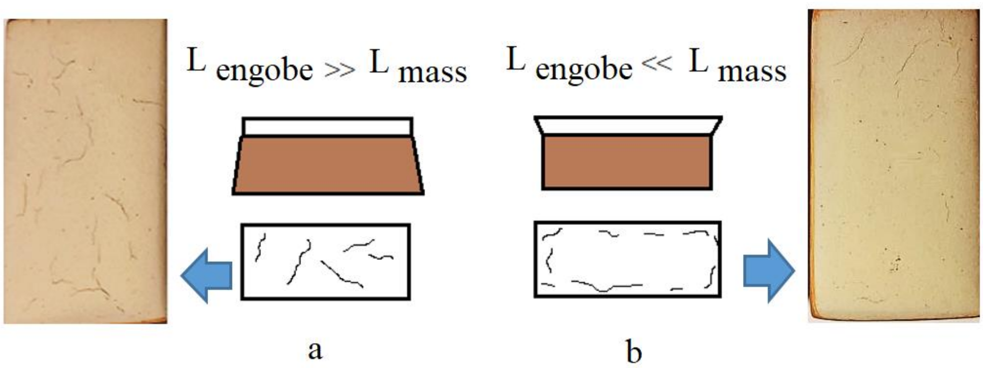

Fig. 3 – Schematic representation of defects in engobe coatings with differences in their shrinkage (L) with the ceramic mass: a – engobe No. 1, b – engobe No. 11

For example, for engobe No. 1, deep and large cracks are observed over the entire surface of the sample. The engobe layer shrinks, but the ceramic shard does not allow the engobe layer to shrink due to shrinkage, and actually "breaks" the thin coating layer. On the contrary, in sample No. 11, the ceramic mass shrinks more, so the cracks appear closer to the edges of the sample, when the engobe envelops the shard, refracting at the edges.

For engobes No. 2 and 6, one small crack was observed on each sample, with a difference in shrinkage between the mass and the engobes of up to 13%. There are no defects at all on samples 3 and 4. Looking at Fig. 2, we can see that the difference in shrinkage between the engobe and the ceramic mass is 2–3%.

Peculiarities of applying engobe coatings to dried ceramic semi-finished products.

Applying engobe to a dried ceramic semi-finished product also has advantages and disadvantages. When angobic slurry is poured onto dry ceramic samples, the engobe slurry dries quickly, it adheres firmly to the ceramic base, the samples are almost immediately ready for the next technological operation. However, as for shrinkage processes, their control becomes more complicated, since now the ceramic mass has almost no air shrinkage (Fig. 4), while the engobe layer has air shrinkage, and its varies widely depending on the composition.

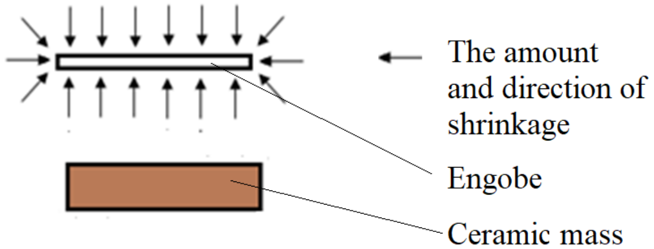

Fig. 4 – Schematic representation of the shrinkage processes of the engobae and ceramic substrate when applying the coating to a dry sample

All the processes associated with air shrinkage of the ceramic mass have already taken place, and the air shrinkage of the engobe layer occurs on the surface of the already dry ceramic substrate. A comparison of the air shrinkage of both materials in this coating model is shown in Fig. 5.

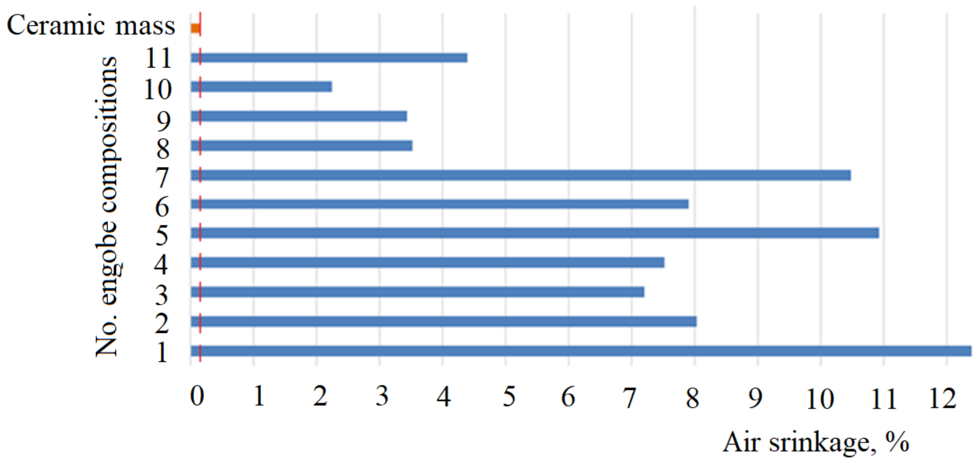

Fig. 5 – Comparison of air shrinkage of engobe compositions and ceramic mass when applying engobe to a dry ceramic semi-finished product

Assuming that the residual moisture remains in the ceramic mass, which will give another 0.2–0.5% (approximately) of air shrinkage. The shrinkage of the experimental engobes varies from 2.2% for engobe No. 10 to 12.5% for engobe No. 4, which is 2.5–16 times higher than the final air shrinkage. Therefore, during visual analysis, cracks of varying degrees of intensity were found on many samples (Table 4, Fig. 6), most of which appeared or intensified after the firing.

The most optimal composition in terms of the set of properties is engobe No. 4, which can be adapted in the future for applying to dry semi-finished products. Engobes No. 8, 9 and 10, although they have a low shrinkage, are technologically difficult to work with - due to the high content of leans cjmponents, eangobe slips are prone to sedimentation.

Table 4 – Visual analysis of defects in the prototypes

Name of the defect	Numbers of research engobes										
	1	2	3	4	5	6	7	8	9	10	11
Cracks after drying	+++	++	+	one	+	++	++	-	-	-	+
Cracks after firing	+++	+++	++	+	++	++	+++	++	+	-	+++

*one – single manifestations, "+" – presence and intensity of the defect, "-" – absence of the defect

CONCLUSION

Thus, the probability of internal stresses appearance between the ceramic mass and the coating was analysed and the maximum permissible deviations of their shrinkage were established. With a difference of up to 13‒15 % in air and fire shrinkage of masses and engobes, internal stresses are not critical and do not lead to defects in the form of cracks or chips. At the same time, a difference in shrinkage of 17‒20% and above causes deep and numerous cracks on the surface of the products. The most versatile composition of the engobe coating is No. 4, which can be applied to both freshly moulded and raw ceramic semi-finished products and is not prone to cracks and delamination in both the dried and fired states.

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