

**DETERMINATION OF DIMENSIONS OF THE PATTERN
FOR THE MANUFACTURING OF PLASTER MOULDS FROM SHRINKAGE
OF CERAMIC BODY**

Plešingerová B.¹, Macáková J.², Klapáč M.²

¹ Department of Chemistry, Faculty of Metallurgy, Technical University, Letná 9, Košice,

² KERKOTHERM, a.s., Košice, Závod KACHLE, Pri Krásnej 2, Košice

**URČENIE ROZMEROV MODELU PRE VÝROBU SADROVÝCH FORIEM
ZO STANOVENIA ZMRAŠTENIA KERAMICKEJ HMOTY**

Plešingerová B.¹, Macáková J.², Klapáč M.²

¹ Katedra chémie, Hutnícka fakulta, Technická univerzita v Košiciach

² KERKOTHERM, a.s., Košice, Závod KACHLE, Pri Krásnej 2, Košice

Abstrakt

Metodika určenia presných rozmerov modelov pre výrobu sadrových foriem k výrobe keramických výrobkov tvarovaných liatím nie je normou daná. Pre určenie rozmerov modelov kachľových tvaroviek k výrobe foriem boli urobené laboratórne testy zmraštenia hmôr sušením a pálením a tieto výsledky následne preverené poloprevádzkovými testmi. Spracovávala sa hmota pripravená z 60 - 65 hm% granulátu z rozprachovej sušiarne a 40 - 35 hm% ostriva (nízkonasiakávohého šamotu). Spracovávaná suspenzia mala 80 - 83 hm% sušiny. Laboratórne testy boli realizované na sadrovej jedno dielnej a dvojdielnej forme o rozmeroch 103 x 103 mm. Hrúbka výrobkov sa pohybovala od 10 do 20 mm. Pri poloprevádzkových testoch sa použili väčšie dvojdielne formy rozmerov od 150 do 300 mm. Steny výrobkov dosahovali hrúbku od 10 do 30 mm. Po vysušení výrobkov a vypálení pri teplotách 990 až 1070°C sa vyhodnotili zmrašenie sušením, pálením a celkové zmrašenie vo vzťahu k veľkosti rozmerov výrobku vo forme.

Výsledky laboratórných testov ukázali, že zmrašenie hmoty určenej pre výrobu liatej keramiky s plným črepom nie je vhodné testovať odlievaním doštičiek do jednodielnych formiem a vyhodnocovaním zmrašenia vnútorných reliéfov na odliatku. Údaje zmrašenia reliéfov sú až o 0,6 % menšie ako zmrašenia vonkajších rozmerov odliatku.

Zmrašenia sušením a pálením vyhodnocované z vonkajších rozmerov výrobkov pripravených zo suspenzií s 80 % pevnej fázy a zastúpením granulát-šamot 65 : 35 v laboratórnych a poloprevádzkových podmienkach pri odlievaní do dvojdielnych foriem (na plný črep) sú porovnatelné. V priemere sú prevádzkové výsledky o 0,1 až 0,2 % vyššie ako laboratórne. Hodnoty celkového zmrašenia poloprevádzkových testov sú 2,7 - 3,2 %. Rozptyl meraní je vo vzťahu k požadovanej rozmerovej presnosti výroby kachľových tvaroviek veľký.

Kľúčové slová: rozmer modelov a foriem, zmrašenie keramickej hmoty, liatie

Abstract

The difference in dimension of the final ceramic products made by casting and of the casting mould depends on the properties of the body, namely on its shrinkage by drying and firing. The determination of dimensions of the patterns for the products cast into plaster moulds must be preceded by verification of the production technology, by a thorough testing of the body and by determination of changes in dimensions during drying and firing. The aim of this paper was to compare the results of laboratory and pilot-plant tests of determination of shrinkage by drying and firing of the body for stove-tiles made by casting. The final results of pilot-plant tests of shrinkage showed 0,1-0,2 % higher values than those of laboratory tests. This difference is mainly caused by the drying process.

Key words: dimensions of pattern, shrinkage of ceramic body, casting

1. INTRODUCTION

The worldwide trend in the production of stove tiles of complicated shapes and larger dimension is the technology of casting into the plaster moulds. The stove tiles are the covering shells of stoves and fire inserts. The stove tiles are not used separately, are components of the ceramic stove unit and so the tolerance in size of the stove tile pieces is $\pm 0,5\%$, sometimes only $\pm 0,2\%$, but at maximum 1 mm [1-3]. The requirements of size accuracy in case of stove tiles are more strict than in case of cast ceramic sanitary and chemical ware.

The preparation of a patterns and moulds at the production of casting ceramic requires special attention. The total shrinkage of body must be taken into account, i.e. all changes in shape and dimensions going on in the body from the casting up to the end of the production process. Before determining the dimensions of the moulds the properties of the body and the changes in its composition and rheological behaviour relating to dimensional changes during drying and firing must be thoroughly tested. The final dimensions of the products reflect the particular parameters of the processed body (chemical and phases composition, granulometry of components, solids content in slip, viscosity, litre weight etc.) as well as the parameters of the subsequent technological operations in the production process - the way of moulding, drying and firing. It is well known that the wetter and finer the moulded body is, the bigger is the difference between the size of the final product and the pressing or casting mould. Wet products, i.e. those with higher humidity of the body tend more easily to bending and are more difficult to dry. The firing schedule, first of all the duration of exposure of the products to the maximum firing temperature, the granulometry and the composition, all these are factors influencing the shrinkage by firing.

There is no standard available prescribing how to determine the accurate dimensions of patterns for the production of ceramics by casting and the information about this problem in the literature on ceramics is only superficial [4,5].

The sensibility of the ceramic body to drying and the method of determination of shrinkage of plastic ceramic bodies by drying and firing as well as of total shrinkage is described in the standard ČSN 72 1073 [6]. This method is not applicable in the production of ceramics by casting, it is unsuitable for the determination of the dimensions of moulds.

The present paper is aimed at determination of shrinkage of products made of a given ceramic slip by casting into plaster moulds, the suspension being one intended for the manufacture of porous stove-tiles. The results of laboratory tests are compared with those of the pilot-plant tests.

2. EXPERIMENTAL PART

The ceramic slip was prepared from the fine granulate - spray-dried body (the plastic component of the body) and from fireclay refractory grog of low absorption capacity (chamotte) according to the recommendation of the company WBB - Ceramic Bodies (England) [7], a producer and supplier of ceramic bodies. The declared value of the dry shrinkage of the spray-dried body according to [7] is 3,8% and of the shrinkage after firing is 0,2%.

The particle size distributions of the solid components used for the preparation of the slip are shown in the Table 1. The weight ratio of the spray-dried body to the chamotte varied from 60 to 65 wt.% of the granulate : form 40 to 35 wt.% of chamotte. The content of solids in the slip varied from 80

to 83 wt.% (spray-dried body + chamotte + water). The litre weight 1960-1980 g/l recommended by the producer of the ceramic bodies was always kept. The litre weight of the slip was controlled after having the solid components thoroughly mixed up with water, namely after 24 hours at the earliest, and before each casting into plaster moulds.

Table 1 Particle size distributions of the solid components

Several series of 3 - 6 samples were cast into plaster moulds under laboratory conditions:

- a/ into a single-block mould (plate casting, samples thickness about 10 mm),
- b/ into a double-block (two-piece) mould (full-body casting, body thickness about 25 mm), the outer dimensions of the casting being 103 x 103 mm. In the mould, there were reliefs of a diagonal (103 mm long and 10 mm wide) and/or of a quadrangle (52 x 52 mm). The cast bodies were taken off the moulds after 90 - 120 minutes. They have been air-dried for 3 to 4 days and, after stabilisation of their dimension, additionally dried in a laboratory drier at 80°C. The value of the shrinkage by drying of the body was calculated according to the equation (1)

(1)

where Δl_D - the shrinkage by drying [%], l_0 - the dimension of the mould, l_D - the dimension of the dry body.

The firing of the green bodies was carried out in a 1 m³ electric kiln. The maximum temperature of the first firing was 1010°C/1 hour and during the second firing the temperature was 1070°C/1 hour. The total firing time was about 24 hours. The shrinkage by firing and the total shrinkage were calculated according to the following equations (2 and 3).

(2)

(3)

Δl_F - the shrinkage by firing [%], Δl_T - the total shrinkage [%], l_F - the dimension of the body after firing.

For the pilot-plant casting tests various two-piece moulds were used. Stove tiles of different shapes and functions were produced of dimensions from 150 to 300 mm and wall thickness of 10 - 30 mm. The wet castings have been air-dried for 3 to 4 days, then the drying was completed in a chamber drier at a temperature of 65°C. The green body were fired in a gas-heated chamber kiln (VULCANO, Fratelli Ficola, Italy). The maximum firing temperature was 990°C.

The results of laboratory and pilot-plant tests of shrinkage by drying and firing as well as of total shrinkage of stove-tiles relating to the dimensions of the plaster moulds are shown in Tables 1 -3.

3. RESULTS AND DISCUSSION

The composition of the slip may only be changed within the exactly determined limits in the production process. In this limit range must be characterised the behaviour and the properties of the slip and of the body.

The variable content chamotte as grog and the fluctuating content of solids in the slips was intentional. Tables 2 and 3 show the results of shrinkage by drying and firing of the casting samples under laboratory conditions. The great differences in changes of the dimensions in Tables 2 and 3 are caused especially by the variable content of the water in the slips and by the variable ratio of the spray-dried body to chamotte too. Of course, lower values of shrinkage by drying are due to higher content of chamotte in the slip. The results in Table 3 show that there is a close connection between the shrinkage of the body after casting and the content of the water in the slips. It is interesting, that less shrinkage has been measured with the samples cast from thinner slips, i.e. from those with low solids content. These slips showed better castability. In spite of the differences in the contents of the solid phases and the different castabilities of the slips too, no changes of the litre weight were found in these slips. The values of the shrinkage by drying of the outer dimensions of the samples prepared by means of casting into single-block mould (Table 2), are greater than the shrinkage of the reliefs i.e. of the quadrangle edges and of the length of the diagonal. The shrinkage by drying of the outer dimensions is in the average 2,49 %, in case of a 40-35 wt.% chamotte content of the body. In case of the inner dimensions the shrinkage is often 0,6 % lower. The shrinkage by firing as shown by the results in Table 1, is dependent on the firing schedule. The green bodies contract by 0,05 - 0,15 % during the firing at a temperature of 1010°C. During the repeated firing at a temperature of 1070°C values of the shrinkage by firing increased to 0,2 %. The values of the inner and outer linear changes are comparable.

Table 2 The results of the laboratory tests of shrinkage of samples cast into single-block moulds;

fired in a 1m³ electric kiln

* double fired

Table 3 The results of the laboratory tests of shrinkage of samples cast double-block mould; fired in a 1m³ kiln

* double fired

If the samples were cast into double-block mould there was no difference between the shrinkage of the inner dimensions of the reliefs and outer dimensions of the samples (Table 3). The range of shrinkage by drying is rather wide, the average value is 2,57 %. The value of shrinkage by firing is about 0,15 % after firing at a temperature of 1010°C and after repeated firing at a temperature of 1070°C it increased by about 0,1 - 0,15 %. The double firing reduces the dimensions of the green body by about 0,25 %.

The results of pilot-plant tests of determination of shrinkage by drying of products made by casting from a slip of a 64 wt.% content of granulate and 36 wt.% of chamotte (Table 4) show in average a shrinkage higher by 0,15 % in comparison with the results of laboratory tests of bodies containing 65 wt.% of granulate and 35 wt.% of chamotte and about 80 % of solids in the slip (Table 3). The values of shrinkage by firing are similar (0,18 - 0,2 %) despite the fact that under factory conditions the firing temperature of the samples was about 20 °C lower. The total shrinkage by drying and firing shows values close to $2,9 \pm 0,2$ % the dimension of the mould. When measuring tiles of larger sizes a smaller range of values of shrinkage by drying was found.

4. CONCLUSION

It is obvious from the test results that it is inconvenient to determine the shrinkage of cast-moulded full-body product by means of casting of plates into single moulds and evaluation of shrinkage of inner reliefs. The values obtained for the shrinkage of the relief are as much as 0,6 % lower than those of shrinkage of outer edges of the casting. The shrinkages of outer edges of products made from slips with a solids content of about 80 wt. % and a granulate -chamotte ratio of 65 : 35, observing the recommendations of the manufacturer of the semi-products for the body (the company WBB) concerning the parameters of the slip, produced values in laboratory test from 2,55 to 2,95 % and in pilot-plant test from 2,7 to 3,2 %. The average value of total shrinkage is 2,9 %. The range of measured values, however, is too wide with regard to the required accuracy in size of the stove-tiles.

The convenient way of determination of shrinkage of cast-moulded products and the relating determination of the dimensions of the patterns and moulds is to adhere to the following terms and conditions:

- constant initial properties of the casting slip,
- keeping the technological instructions of preparation of the slip, casting, drying and firing,
- using test moulds of dimensions and shapes very similar to the product to be made.

The total shrinkage of the body must be determined in the same way as in the expected technological process.

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