INCREASE IN THE SERVICE LIFE OF FORMING SURFACES OF MOLDING UNITS. PART 2. STUDY OF THE EFFECT OF OPERATING PROPERTIES OF MOLDING UNITS ON THEIR OPERATING LIFE

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The effect is considered of such operating properties as the design of a molding unit and the method of drying gypsum molds, on the life of the forming surface of molding units. Avoidance of the disadvantages revealed combined with results obtained in part 1[2] of this work make it possible to increase the service life of molds by more than a factor of three

Keywords: gypsum, porous mold, molding unit, mold drying.

Apart from starting raw material quality, the operating characteristics of molding units affect the service life of gypsum molds, and this is confirmed by analyzing the operation of a mold manufactured from high quality German gypsum. Studies have shown that in spite of the best quality gypsum the service life of a mold increased in all by 50% (from 12 to 18 moldings).

The main criterion by which the degree of inadequacy is assessed is presence of cracks within its working surface (Fig. 1). As a result of work carried out, two main operating factors were established with a capacity to lead to the occurrence of this class of defects: mold design and its drying regime.

EFFECT OF MOLD DESIGN

In order to prepare large complexly shaped preforms by slip casting molds are used whose general form is presented in Fig. 2. The mold consists of the following main parts: a perforated metal frame *1*, within which there is a gypsum casting *2*, copying the outer profile of a preform; an upper support flange *3* and a lower flange *4*.

By analyzing the nature of crack distribution (see Fig. 1) it is possible to note that almost all of them start from the boundary of the gypsum with the metal support flange and then propagate through the mold surface. The main reason for this crack propagation in our opinion is the groove in the lower part of the support flange (see Fig. 2, position *5*) made by the intention of designers to function as a key for securing gypsum. The situation is aggravated by the fact that traditionally the forming surface of a gypsum mold is prepared as

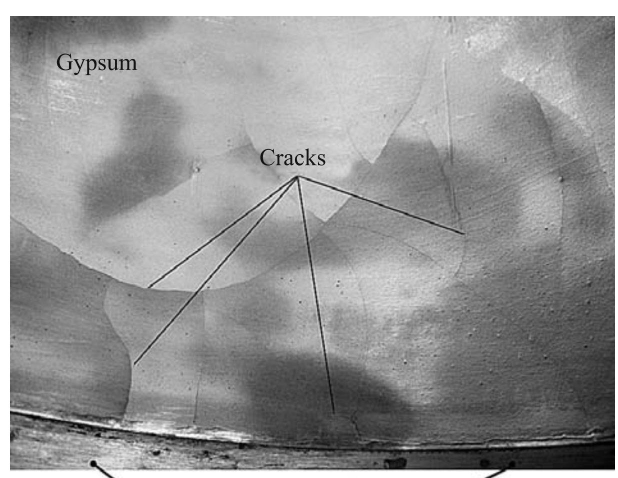

Fig. 1. Example of crack propagation in the working surface of a gypsum mold.

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[2] E. I. Sudal'tsev, D. V. Kharitonov, and A. A. Anashkina, "Increase in the service life of forming surfaces of molding units. Part 1. Study of the improvement of molding unit forming surface material quality," *Novye Ogneupory*, No. 2, 30 – 38 (2010).

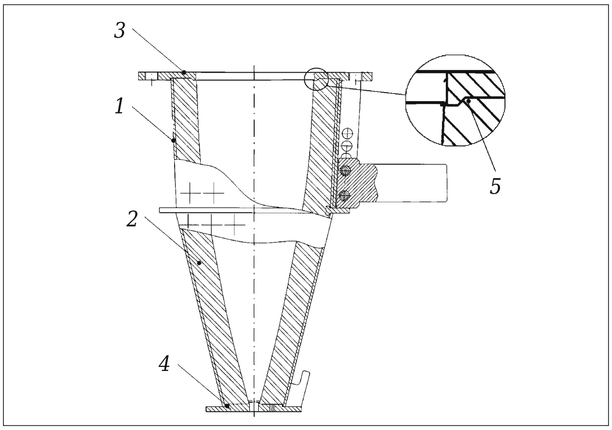

Fig. 2. Standard shape for preparing large complexly shaped ceramic preforms.

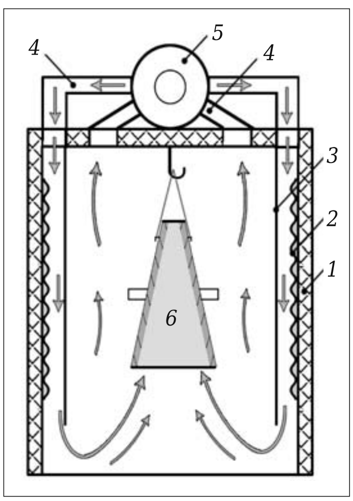

Fig. 3. Diagram of the heating cabinet for drying molds: *1*) body with heat insulation; *2*) heating elements; *3*) metal screen; *4*) air duct; *5*) fan; *6*) mold.

follows. The perforated metal frame is covered outside with paper, the molding pattern is installed, and the space formed is filled with gypsum paste; after gypsum solidification the pattern is extracted and the paper is removed. As a result of this a monolithic structure is prepared within which on one hand the perforated openings of the metal frame are entirely filled with gypsum, and on the other hand the support flange is connected rigidly with the gypsum. With repeated drying of the mold cyclically there is warm-up (to 45 – 50°C) and cooling of the monolithic structure obtained. Here the gypsum and the metal frame of the mold undergo different volumetric changes, that finally leads to quite rapid breakage of the gypsum part of the mold.

As confirmation of the effect of the mold structure on crack formation it is possible to provide the following fact (according the ZAO Kirov Farfor data): a mold for manufacturing objects for sanitary engineering purposes, made from German gypsum without any frame, withstood up to 140 moldings. For use of this method in minimizing the effect of design disadvantages the following experiment was carried out. In a mold for manufacturing OTI 1111 objects (preform height 300, base diameter 200 mm), before applying gypsum the groove in the support flange was removed and the perforated frame of the mold was glued with paper from within. Here gypsum of domestic production was used. During June – August 2009 twenty preforms were prepared using this mold, that exceeded by 65% the mean statistical index for operation of similar molds (12 preforms). Apart from this markedly favorable effect of applying gypsum to the mold, made by the method described above, another is observed, i.e. extraction of gypsum from the metal frame is carried out by several point knocks into perforation holes, that prevents deformation of the metal and increases the service life of the frame itself.

EFFECT OF MOLD DRYING REGIME

In view of the fact that in preparing molds and molding of preforms the gypsum mold is impregnated with moisture (for preforms of quartz and lithium aluminosilicate glass from slips the amount of water absorption is 7 – 8% of the slip volume, and in preparing molds the amount of absorbed water reaches 110%), a requirement arises for drying it.

Due to a partial change in the range of components, differing in size and weight characteristics and produced in small batches, use of traditional drying approaches for mold drying in the ceramic industry is economically undesirable. As a rule in similar cases there is use of use of an electric heating cabinet of periodic operation (Fig. 3), whose operating principle is based on forced circulation of heated air. Ideally the heated air should be fed from below into the cavity of the mold and effectively dry the gypsum. However, checking the temperature distribution over the inner and outer surfaces of a mold during primary (directly after mold gypsum application) and intermediate drying (Fig. 4*a*, *b*) showed low efficiency of the heating cabinet used. It may be seen in the diagrams presented that the heat carrier, washing over the outer surface of a mold, warms it unevenly, and it does not provide convection of the heat carrier over the inner cavity of the very wet part of the gypsum mold, and in fact the temperature of the outer and inner surfaces of the mold only become identical towards the last instant of the drying regime. For this reason mold drying occupies considerable time: 80 – 90 h with primary drying and 15 – 17 h with intermediate drying; drying is associated with significant electric power consumption: 515 kWh is expended in the first drying and it is 90 kW·h in the second.

It may also be noted that the hot heat carrier, washing over the mold from below upwards heats its support flange, from which the main mass of cracks commence (see Fig. 1). Often in order to accelerate cooling of the heating cabinet after completion of the drying regime its door is opened. Suction of cold air creates additional thermal shock in the support flange, that worsens the situation even more.

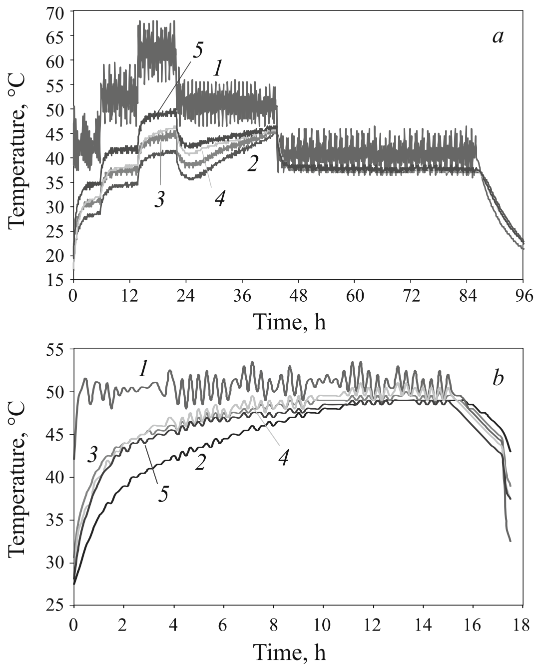

Fig. 4. Temperature distribution with primary (*a*) and intermediate (*b*) drying of a mold for preparing preforms of article OTI 1111 in a drying cabinet: *1*) heat carrier; *2*) top of mold from inside; *3*) nose part of mold from outside; *4*) bottom of mold from inside; *4*) bottom of mold with outside.

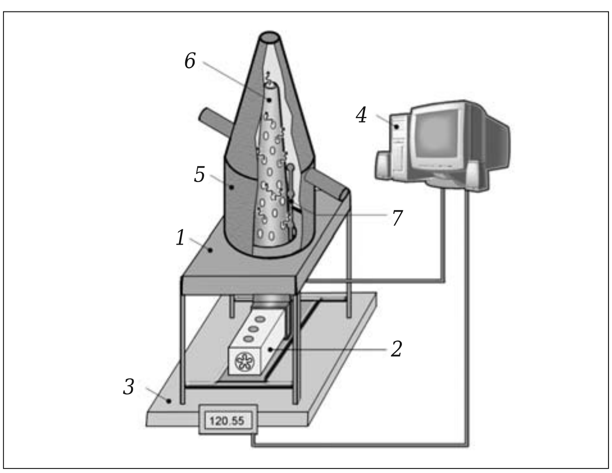

Fig. 5. Diagram of a device fro drying gypsum molds: *1*) heavy-duty stand; *2*) fan; *3*) load-bearing measurements platform; *4*) control and measurement system; *5*) mold (preform); *6*) air distributor; *7*) thermocouple.

Proceeding from the data obtained, in order to overcome the revealed disadvantages the supply of heat carrier was accomplished within the inner cavity of the mold. For this an effective device was proposed for mold drying (Fig. 5) using a standard heating fan and electronic scales. The completion of mold drying is achievement of its constant weight. An example of primary and intermediate mold drying is shown in Fig. 6*a*, *b*.

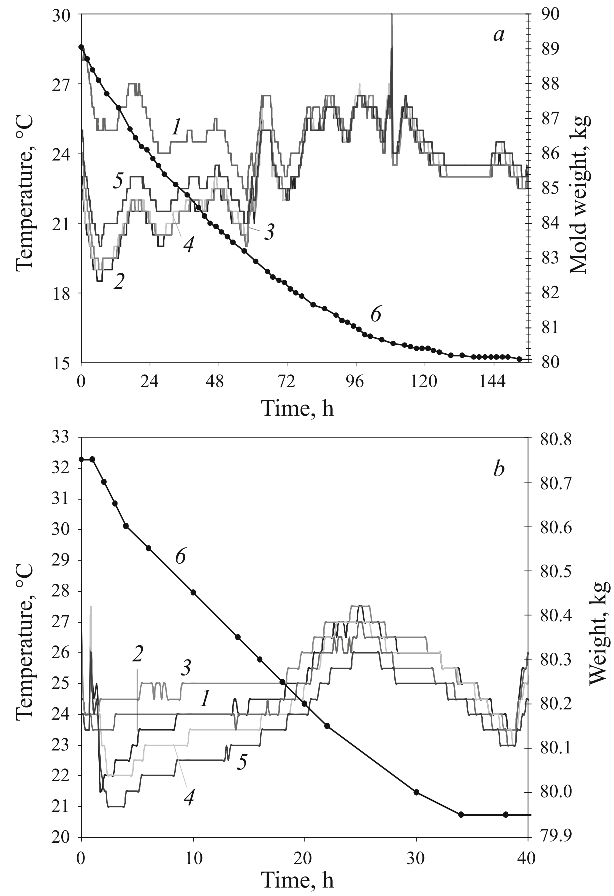

Fig. 6. Temperature distribution during primary (*a*) and intermediate (*b*) drying of a mold with a heating fan without use of a heated air flow with control of mold weight: *1*) heat carrier; *2*) top of mold from inside; *3*) nose of mold from outside; *4*) bottom of mold from inside; *5*) bottom of mold from outside; *6*) mold weight.

It follows from these curves that the temperature distribution over the inner and outer surfaces of the mold occurs almost uniformly. Here the mold may be dried both by the heated air stream and without heating it. In the first case the heat carrier washes uniformly over the inner surface of the whole mold, not leading to overheating of the inner flange and thereby not creating additional stresses in the gypsum. Drying in intensified and the mold is entirely dried to the required moisture level. In the second case mold drying is accomplished without use of a heated air stream. This leads to a small (by 4 – 5 h) increase in mold drying time, although here in the gypsum there is breakdown of bonds in $CaSO_4 \cdot 0.5H_2O$ crystals that provides an increase in mold service life.

The method proposed was verified in standard molding units. Currently in two molds up to eight preforms have been prepared, and both molds are in operation. Analysis of data for preform quality, performed in molds dried by the proposed version and by a normal scheme, did not reveal any markedly different indices, that points to the efficiency of the proposed method.

In view of the promising nature of drying molds with a heating fan it is necessary to continue work in this direction:

– to develop and manufacture a single universal device fro drying several molds simultaneously;

– to develop a control and measurement system (CMS), delivering information continuously to a personal computer; in the computer all of the information will be processed, recorded and stored on weight – time axes.

Development of the CMS will make it possible to prepare a monitoring method for the moisture of the working surface of gypsum, since it is well known if a mold has residual moisture of –5%, then the process of preform preparation within it occurs more rapidly. Here at the mold surface in the initial instant there will be formation of a dense layer, slowing down assembly of the preform wall thickness and promoting creation of additional shrinkage stresses at the surface of a preform during drying and heat treatment.

As a result of this work it was established that the problem posed for increasing the service life of the forming surface of molding units may be resolved within the complex: gypsum quality – mold preparation – mold design – mold drying. For this it is necessary to accomplish:

– to carry out monitoring of the treated gypsum up to limiting the technology to use of low quality grades (here introduction of an addition citric acid may considerably improve mold quality);

– to monitor parameters of the gypsum mold manufacturing process: water-gypsum ratio, gypsum paste mechanical mixing conditions, use of industrial vibration tables;

– to avoid the design disadvantages of a mold revealed;

– to dry a mold by means of a device providing supply of heat carrier within the mold.

Overcoming these disadvantages will increase the life of gypsum molds to 50 or more moldings.