Technology and technological scheme of a workshop for the production of beehives made of amorphous quartz ceramics

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Abstract: *The development refers to an innovative technology and technological scheme of a workshop for the production of beehives made of amorphous quartz ceramics. The conditions for obtaining stable suspensions from quartz glass are emphasized and investigated. The time for the treatment of the glass in the grinding device, the amount of water, the influence of the modifiers in stabilizing the suspension by adjusting the pH level, as well as the most suitable sedimentary composition of the glass particles are established. The factors determining the speed and degree of sintering of the ceramics are investigated and established. They include the density of the raw products, the dispersion of the quartz glass particles and its purity, as well as the environment in the furnace and the sintering mode.*

Keywords: *BEEHIVE, AMORPHOUS CERAMICS, SUSPENSION, SEDIMENT COMPOSITION*

1. Introduction

Quartz ceramics is a sintered material made of ground quartz glass, which is molded using the known ceramic technologies. The resulting products are opaque and white in color. Quartz ceramic is the only ceramic material made not of crystals but of a vitreous phase. There is no material better suited for building beehives than quartz ceramics, as it is an extremely pure material which, as opposed to marl clays on their own or mixed with kaolin, does not contain any other mineral phases apart from amorphous silica.

Quartz ceramic is applied in many areas where ordinary quartz glass is also used. This is due to its high thermal stability, the stability of its thermophysical properties and its high thermal insulation properties. It is extremely suitable for the production of structural elements with a high level of cavities, such as those used for the construction of beehives, since it is not only thermally and acoustically insulating but is also atmospherically and chemically resistant to acid rain, etc. At the same time, quartz ceramic products are highly resistant against mites and rodents [1].

2. Choice of Forming method on structural parts with a high level of cavities designed for beehives

The most suitable method in this case is slip casting of aqueous suspensions. It is important to note that it is mandatory to ensure that the starting material maintains its high purity during all technological operations [2].

It is known that practically all impurities activate the crystallization of quartz glass. Therefore, the correct selection of both the material of the lining of the grinding unit and the grinding bodies is of great importance. The lining and the grinding bodies are best made of quartz glass, but due to its high wear (up to 10%), it is permissible to use high alumina ceramics with a density above 3.65-3.75 g/cm^2. This leads to a significant reduction of the grinding time (4-5 times), and the observed wear is below 1%, which is essential for the quality of the final product. The use of devices with metal working parts is undesirable.

The slip casting of quartz ceramic parts with cavities results in products with the highest density. This helps to reduce not only the time of the sintering but also its temperature.

An important stage in the technology is the preparation of a suspension of finely ground quartz glass. This is done by coarse and fine wet grinding of the glass in the same grinding unit. Thus, a slip with a minimum amount of water (16÷20%) is obtained [3]. The effectiveness of wet grinding is explained primarily by the fact that water is one of the best surfactants in relation to SiO_2. The adsorptive decrease of strength, the saturation of the unsaturated bonds of the material, the disaggregating action of water, the high specific impact energy of the milling bodies and the reduced soothing action of the suspension are also essential. The wet grinding process is exothermic and the total amount of bound water decreases sharply with the increasing of the temperature. As the temperature increases, the strength of the aqueous layers decreases due to the greater mobility of the ions. Thus the amount of bound water decreases and the free water in the suspension increases.

To create a suspension with low humidity, we use the method of maximum saturation. Its essence is that during wet grinding, the unit is stopped two or three times and ground glass with a sediment composition of 50÷100 microns is added to the suspension in a ratio of about 1/10 of the amount of glass in the suspension. Equilibrium viscosity is reached after 2-3 hours of additional grinding. In this way, the water content of the maximally saturated suspension is reduced by about 4 times. The suspension is quickly sintered, which reduces the shrinkage during drying of the obtained products. The suspension is quickly absorbed on the walls of the mold, as a result of which the shrinkage of the obtained product during drying is minimal. The thickness of the absorbed layer depends on the running time of the process.

The quartz glass particles in the suspension are considered chemical compounds of SiO_2 with ionized silicic acid, continuously dissociating according to equations:

$$[H_4SiO_3] \rightleftarrows SiO_4^{4-} + 4H^+ \quad (1)$$

$$[H_2SiO_3] \rightleftarrows SiO_3^{2-} + 2H^+ \quad (2)$$

It is assumed that the hydration of SiO_2 is limited by the specific surface area of the particles in the suspension as a result of the building of surface tetrahedra.

The particles of the unstabilized slips are whole aggregates (floccules) with water-filled voids which are preserved during molding. Therefore, a traditional method for stabilizing such slips is gravity stirring. The electric double layer formed by reactions (1) and (2) is insignificant due to the small amount of silicic acid (up to 0.01%) and its low degree of dissociation. The stability of the slip is achieved through a uniform distribution of water dipoles around the ionized solid SiO_2 particles, which is achieved by prolonged stirring (for about 70-80 hours).

The rate of absorption of the suspension on the walls of the mold and the casting density depend significantly on the pH of the suspension. Its optimal value lies in the range from 4.5 to 6. At a pH value of 5 ± 0.3, the silicic acid is most stable, while in a neutral environment it polymerizes intensively, releasing water and reducing the concentration of H^+ ion. HCl is used to lower the pH of the suspension, and NH_4OH to increase it [4].

3. *Molding hollow structural details for beehives from amorphous ceramics*

After preparing a stable suspension of amorphous quartz glass powder, the next stage in the technology involves casting test bodies, carrying out drying and high temperature sintering, and establishing the shrinkage coefficient of the samples. Following this is the making of models and mold outfits for each of the hollow structural details of the ceramic beehive. The residence time of the slip in the mold is determined experimentally and the uncollected slip is drained from the molds.

The time between the filling of the mold with slip and its draining is 12 minutes. The thickness of the cavity wall is 3 cm, and the width of the cavity is 18 mm.

A technological diagram of a workshop for the production of beehives is shown in Fig. 1.

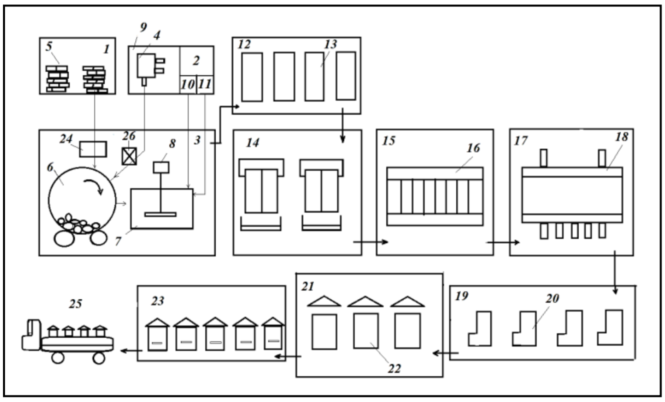


Fig. 1. *Technological diagram of a workshop for the production of beehives*

1. Quartz glass warehouse;
2. Modifier sector;
3. Sector for the preparation of quartz glass suspension with particle size below 100μm;
4. Distiller;
5. Quartz glass with particle size below 100μm;
6. Grinding device;
7. Container for ready-mixed suspension;
8. Stirrer;
9. Distilled water and modifiers sector;
10. Tank for HCl;
11. Tank for NH_4OH;
12. Molding equipment sector;
13. Mold outfits;
14. Molding sector;
15. Sector for drying structural ceramic parts with cavities;
16. Drying sector;
17. Furnace sector;
18. Furnace;
19. Warehouse for finished structural ceramic parts;
20. Sintered structural details for beehives;
21. Ceramic beehive assembly sector;
22. A beehive made of amorphous quartz ceramics
23. Warehouse for finished products;
24. Scales;
25. Dispatch vehicle;
26. Container measuring the volume of the drained fluid (distilled water).

4. *Sintering of amorphous quartz ceramics*

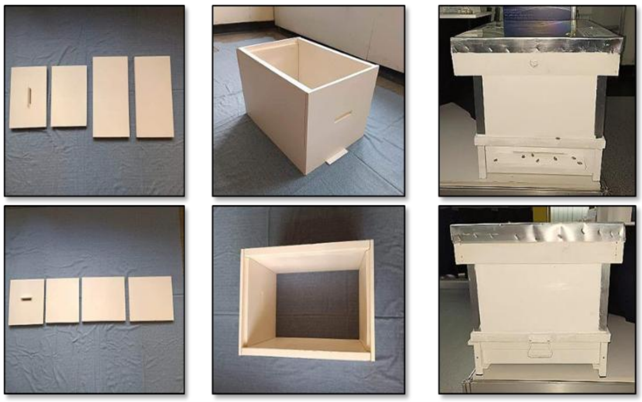
The main factors determining the sintering mode include: the purity of the quartz glass, the density of the cast details, the sedimentary composition of the ground quartz glass and the crystallization tendency.

The quality of the final product is significantly dependent on the heating rate in the temperature range from 1000 ^{0}C to a final temperature of 1200-1300 ^{0}C (in this case 1250 ^{0}C). At slow increase in the temperature (50 - 100 K/h), the crystallization ability also rises, leading to phase formation of high temperature cristobalite, which is a contributing factor to the reduction of the strength of the products. The established optimal heating rate, at which the formation of crystallization centres is avoided, is 400 K/h [5].

The chosen method of obtaining articles from slip ensures a sufficiently high density of the final product. Nevertheless, sintering should not necessarily aim for high density, which is achieved with longer heating and higher temperature, as this leads to an increase in crystallization and sharply reduced strength.

In our case, since the products are not used at high temperatures, a sintering intensifier – 1.2% $B2O_3$ – was added to prevent crystallization.

Fig. 2 shows ceramic structural details with cavities - an intermediate stage of assembling the ceramic beehive, and a completely finished, ready-to-use hive.



a) b) c)

Fig. 2. a) *hollow ceramic structural details;* ***b)*** *intermediate stage of assembling a ceramic beehive;* ***c)*** *ceramic hive ready for the settlement of a bee family*

5. *Properties useful for the amorphous quartz ceramics and supporting its use, such as ceramic structural details with high level of cavities designed for beehives*

The mechanical properties are determined by the grain structure and porosity of the suspension absorbed on the walls of the mold. Amorphous quartz ceramic samples with a porosity of 3% had a hardness of about 5.5 Mohs. As the porosity increases to 20%, the hardness drops sharply to about 2 Mohs.

The flexural strength ranges from 3 to 80 MPa. It should be noted that the relationship between porosity and strength typical of other ceramics is not observed in quartz ceramics.

The compressive strength ranges from 50 to 600 MPa depending on the technological parameters, the porosity and the environment in the furnace. It reaches 500 MPa in an air environment and 600 MPa in a vacuum.

It is interesting to note that the value of tensile strength is 75% - 85% of that of flexural strength. This is a very high value, unusual for a ceramic material.

An important indicator for beehives is thermal conductivity. In the case under consideration, it depends both on the structure and the porosity of the material and on the presence of impurities. For opaque materials and for materials with an amorphous structure, such as quartz ceramics, the heat transfer process is determined by the so-called phonon conductive thermal conductivity.

6. *Conclusions:*

1. A technology and a scheme of a workshop for the production of structural details from amorphous quartz ceramics and their assembly into whole beehives have been developed.
2. The factors for obtaining stabilized suspensions of amorphous quartz particles, as well as the conditions for proper high temperature sintering, have been established.

3. A prototype of a beehive has been created, built from structural ceramic details made of amorphous quartz ceramics with a high level of cavities.

7. References

[1] Luben Lakov, Bojidar Jivov, Todorka Lepkova, Krasimira Toncheva, Stancho Yordanov, "Comparison of innovative collapsible ceramic hive and traditional non-separable hives made on the basis of natural plastic raw materials", Machines. Technologies. Materials. Vol. 16, (2022), Issue 10, pg(s) 340-343.
[2] E. Gerasimov and others. under the editorship of Prof. Dr. Eng. S. Bachvarov, "Technology of ceramic products and materials", IC "Sarasfati", Sofia, (2003)
[3] Yu. E. Pivinsky, F. T. Gorobets, "Ogneopory", No. 8, (1968)
[4] G. Solovushkova, Yu. Polonsky, etc., "Ognepory", No. 7, 5÷6, (1980)
[5] Yu. E. Pivinsky, A. G. Romashkin, "Quartz ceramics", Moscow, ed. Literate. in construction, (1972)