A STUDY ON THE TECHNOLOGICAL PARAMETERS’ INFLUENCE ON THE PROPERTIES, POLISHING AND MICROSTRUCTURE OF CORUNDUM CERAMIC DISCS FOR WATER TAPS

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ABSTRACT

Some of corundum ceramics properties like high chemical resistance, hardness and mechanical strength make it an extremely suitable material for water tap gaskets and regulators. Solid fragments that normally get into the water, like sand, rust and limestone, cannot damage corundum ceramics. The latter stability allows these products to remain perfectly smooth even when exposed to varying levels of pressure and extreme water temperature fluctuations. The corundum ceramics properties depend mainly on the purity of the starting powder, the production method and the microstructure. This work investigates how the pressure applied during the semidry pressing, the firing temperature and the source materials composition (percentage of \( \text{Al}_2\text{O}_3 \)) affect the apparent density, the coefficient of abrasion, the polished surface (the degree of polishing) and the microstructure of corundum ceramic water taps discs. Four types of a corundum powder were used as a source material for the process of semidry pressing. Five different pressures (100 MPa, 150 MPa, 200 MPa, 250 MPa, 350 MPa) and three firing temperature values (1600°C, 1650°C, 1680°C) were applied in addition to the subsequent procedures of lapping and polishing in the course of production of corundum ceramic water taps discs. The fired corundum samples underwent characterization aimed to determine the apparent density (using the method of Archimedes), the coefficient of abrasion (determined by the loss of mass in percentage points), as well as the degree of surface polishing. Using SEM and optical microscopy we proved that the technological parameters determine to a large extent the appearance of a microstructure which in turn affects the properties and the degree of polishing of corundum ceramics. Water taps of a homogeneous structure having the highest density, the smallest pores, the lowest coefficient of abrasion and the highest degree of polishing were made from a starting powder containing 98 % of \( \text{Al}_2\text{O}_3 \) and a glass phase containing \( \text{CaO}, \text{MgO} \) and \( \text{SiO}_2 \). A firing temperature of 1650°C and pressing pressure 350 MPa were applied.

Keywords: corundum ceramic, technological parameters, structure, properties.
processing of the starting ceramic powders allow well controlled microstructure and properties. The latter are also greatly influenced by the presence of admixtures and additives in the source material and hence they can be controlled by selecting the right additives. The glass phase of corundum ceramics, when present in small quantities, decreases the grains size and hence increases its strength [8 - 17].

This work aims to study how the pressure applied during the semidry pressing, the firing temperature and the source materials affect the properties, the polishing and the microstructure of corundum ceramic discs to be used for water taps.

**EXPERIMENTAL**

*Source materials*

There are four types of starting powders of varying corundum content which are used in semidry pressing to produce corundum ceramic discs for water taps:

A. $\text{Al}_2\text{O}_3$ (Nabaltec, Granalox NM 9212, $D_{50} = 180 \text{ μm - 230 μm}$, purity of 92 %)

B. $\text{Al}_2\text{O}_3$ (Nabaltec, Granalox NM 9620, $D_{50} = 80 \text{ μm - 120 μm}$, purity of 96 %)

C. $\text{Al}_2\text{O}_3$ (Nabaltec, Granalox NM 9816, $D_{50} = 180 \text{ μm - 230 μm}$, purity of 98 %)

D. $\text{Al}_2\text{O}_3$ (Martinswerk, MZS-3, $D_{50} = 5 \text{ μm}$, purity of 96 %) modified with addition of $\text{TiO}_2$ (rutile, Kronos International INC, $D_{50} = 0.43 \text{ μm}$, purity of 99.00 %) and $\text{MnO}_2$ (pyrolusite, Teokom OOD, $D_{50} = 10 \text{ μm}$, purity of 90.00 %).

*Production technology of corundum ceramic discs for water taps*

We applied five different levels of pressure in the course of semidry pressing (100 MPa, 150 MPa, 200 MPa, 250 MPa, 350 MPa) and three firing temperature values (1600°C, 1650°C, 1680°C) with an arrest for 1 hour at the maximum temperature aiming to produce corundum ceramic discs for water taps of a varying microstructure. The technological scheme consisted of the following stages: resource materials preparation, semidry pressing with the application of a hydraulic press at a pressure of 100 MPa to 350 MPa, firing the ceramic items in an electric furnace at different temperatures of 1600°C, 1650°C and 1680°C and, finally, machining – lapping and polishing in particular. The corundum samples were pressed using a powder compacting press model EPM C160 R. We made series of corundum ceramic discs for water taps (300 in every series) for each of the four types of starting press-powders applying different levels of pressure (100-350 MPa).

The corundum ceramic discs were then fired in a laboratory chamber furnace Naberterm HT at three different temperatures (1600°C, 1650°C, 1680°C) with one-hour arrest at the maximum temperature. Then they underwent lapping to reduce their thickness and prepare the working surface for polishing. The lapping was performed on a burnishing machine using diamond suspension of grains of a 28/20 size. The processing time was 6 min. The goal in this phase was to polish the surface to a certain degree. The degree of polishing required for ceramic discs is in the 58 % - 75 % range. Values below that threshold result in poor adhesion between components, while values above the 75 % mark make sliding difficult. The polishing was performed with a burnishing machine with diamond suspension of a 7/5 grain size. The processing time was 9 min. Then the polished ceramic discs were thoroughly washed in an ultrasound tub and dried. All discs prepared underwent strict screening for visible defects, surface evenness and thickness. They are shown in Fig. 1.

*Samples’ properties determination*

The fired samples were characterized on the basis of the following physico-mechanical properties: apparent density (determined using the method of Archimedes), a coefficient of abrasion (determined by the loss of mass in percentages) and a degree of surface polishing.
Methods of corundum samples analysis

Optic microscopy was performed using a Shanghai Changtang Optical Instrument Co. Ltd. and a Reflected Metallurgical Microscope CMM 30E. The main requirement referred to a preliminary thermal exposure which provided clearer, distinct and well visible surface in case of using a moderate magnification. This was achieved through heating at a temperature value of 200°C - 300°C lower than that applied for materials firing.

SEM was performed by a scanning electron microscope SEM 525 M, Phillips with an energy-dispersive spectrometer EDS – EDAX 9900.

RESULTS AND DISCUSSION

Figs. 2 - 4 show the results referring to the apparent density, the coefficient of abrasion and the degree of surface polishing. The corundum samples made from press-powder type A and fired at 1680°C got stuck to the fireproofing, i.e. there was no data for their behavior at that temperature. The pressure increase results in increase of the corundum discs density. The temperature increase influences also the consolidation in a positive way. The increased percentage of corundum in the starting powder results in increased density of the product. At 1600°C - 1650°C and high pressure during pressing, the degree of surface polishing increases. Higher density and temperature lead to a lower coefficient of abrasion. The pressing at a lower pressure results in a lower degree of surface polishing, while the increase of the corundum content of the starting powder increases it. No correlation with the temperature variation is established. The coefficient of abrasion shows a tendency of decrease after polishing at higher temperature and pressure levels. There is no correlation between the corundum content of the starting powder and the change of the product’s size after lapping and polishing. The optical microscopy results after the thermal exposure of the polished corundum samples are shown in Fig. 5. The microscopic analyses shows that corundum ceramic discs for water taps made from starting powders A, B and C have a finer-grained structure compared to that of discs made from powder D. It is found that the temperature increase results in increase of the grains size. As far as the influence of pressure is concerned, no change is observed. SEM is used to analyze discs from powder B subjected to pressure of 100 MPa and 350 MPa during the pressing stage and firing temperature of 1600°C and 1650°C as well as discs from powder C treated at pressure of 350 Mpa at a firing temperature of 1600°C and 1650°C. The microscopic images are shown in Fig. 6. It is seen that the pressure applied during pressing and the firing temperature affect the ceramics microstructure after polishing, and more specifically, the pores quantity, size and...
The SEM analysis also shows that compositions containing 96% of $\text{Al}_2\text{O}_3$ (B) have larger pores compared to those of 98% content of $\text{Al}_2\text{O}_3$ (C) at 1600°C and 1650°C and an equal level of applied pressure during pressing. Fig. 7 shows the SEM image of the corundum ceramics structure viewed from the inside of a pore of ca 50 microns. It is seen that the ceramic sample is very dense, fine-grained, with round grains of a size less than 10 microns. The grains roundedness is an indication of the presence of a glass phase around the edges of the grains. Its composition is determined by an EDS analysis and is as follows: < 1% CaO, < 1% MgO, < 1% $\text{SiO}_2$.

**CONCLUSIONS**

This work reports data from an investigation on the effect of the pressure in the course of semidy pressing, the firing temperature and the initial composition (percentage of $\text{Al}_2\text{O}_3$) on the apparent density, the coefficient
of abrasion, the degree of surface polishing and the microstructure of corundum ceramic discs to be used for water taps. It is found that the pressure increase during semidry pressing results in an increased apparent density and a higher degree of surface polishing - a trend that corresponds to a decreased coefficient of abrasion of the samples. Also, the coefficient of abrasion decreases, the
apparent density increases, while the polished surface improves with increase of the firing temperature. The increase of Al$_2$O$_3$ content of the resource material leads to increase of the apparent density, to increase of the degree of surface polishing and decrease of the coefficient of abrasion. Using SEM and optical microscopy we find that the size of the crystals grows, the size and the quantity of the closed pores decreases, while the density of the ceramic materials increases with the increase of the pressure in the course of semidry pressing, with the increase of the firing temperature and the increase of Al$_2$O$_3$ percentage. Corundum ceramic discs for water taps of a homogeneous structure having the highest density, the smallest pores, the lowest coefficient of abrasion and the highest degree of polishing are made from a starting powder containing 98 % of Al$_2$O$_3$ and a glass phase containing CaO, MgO and SiO$_2$. A firing temperature of 1650°C and pressure of 350 MPa have to be applied.

REFERENCES