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O.S. Khomenko

CHOICE OF CERAMIC MASSES FOR THE MANUFACTURE OF ELECTRICAL CERAMICS

Ukrainian State University of Chemical Technology, Dnipro

This paper gives the results of comparative study of molding and thermal properties of ceramic masses for the production of electrical porcelains manufactured by «Pershotravensky Electrotechnical Porcelain Plant» (mass no. 1) and «Ceramic Masses of Donbas Plant» (mass no. 2). It has been found that the ceramic mass no. 2 is more preferable to press the products of a simple configuration because it has an enhanced binding capacity due to the presence of the hydromica component in the mineralogical composition. The ceramic mass no. 1 is advantageously to use for the manufacture of products of a more complex profile, since it contains quartz sand and have a less shrink. It has also been established that the water absorption of calcined specimens of less than 0.5% is achieved at the temperature of 1280^{0}C for the samples from the mass no. 1 and at the temperature of 1250^{0}C for those from the mass no. 2. This should be taken into account when choosing the temperature regime for the firing of products.

Keywords: electrical porcelain, plasticity, shrinkage, water absorption, density, strength, sintering, burning.

Introduction

High-quality ceramic products may be fabricated from electrical porcelain that combines high electrical insulating properties, strength, chemical resistance and durability [1,2]. Despite the relatively complex and costly production technology [3], definite classes of products (ceramic cartridges, fuses, lamps etc.) are mainly made of low-voltage porcelain, because plastic products are unstable towards thermal shock and glass products have increased fragility.

The right selection of ceramic masses, with due regard for the characteristics of the raw materials and the characteristics of each stage of the process, directly affect the quality of the finished products [4]. There are studies on the properties of electrical porcelain based on traditional clay and field-spat raw materials in the scientific literature of recent years [5–7]. However, the information about the research of electrical porcelain fabricated on the basis of raw materials of Ukraine is limited; therefore, the study and development of such ceramic masses represent both scientific and practical interest.

Experimental

In this work we present the comparative study of ceramic masses for the production of electrical porcelain used by two following domestic manufacturers: «Pershotravensky Electrotechnical Porcelain Plant» (mass no. 1), which produces a wide range of electrical products, and «Ceramic Masses of Donbas Plant» (mass no. 2), which offers ceramic masses for the porcelain industry.

The determination of chemical composition of ceramic masses was performed by means of common chemical analysis. The X-ray analysis was carried out using X-ray analyzer DRON-3 with Cu-K$_\alpha$ radiation. The differential thermal analysis was conducted using thermal analyzer STA 449 F1 Jupiter [8]. The fineness of milling was determined by the sieve method, and plasticity was evaluated by the difference of moisture upper limit and lower limit of the yield stress cracking. The water absorption was determined by the mass change of vacuum saturated samples, the shrinkage was assessed by the change of linear dimensions [9]. The samples were compressed using the hydraulic press PSU-10 with a power force of 7 MPa, burned in a laboratory furnace at 1250^{0}C and 1280^{0}C with the exposure for 1 hour at maximum temperature.

Results and discussion

The chemical compositions of masses are given in Table 1. These data show that the chemical compositions of two identical masses have only minor difference in the content of the heat-resistant

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Table 1

The chemical compositions of ceramic bodies, wt.%

Number of mass	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	Calcination loss
1	67.73	21.31	0.63	0.53	0.59	0.54	2.76	1.26	4.63
2	67.50	20.70	0.55	0.55	0.40	0.25	2.40	1.40	5.80

aluminum oxide, the mass no. 2 contains smaller amount of Al_2O_3. Under conditions being equal, an increase in the content of Na_2O promotes inclination to deformation. Analyzing the calcinations loss data, we noticed that this factor is lager for mass no. 2, hence, it contains more clay materials, and, thus, has a higher binding capacity, but the sensitivity of such masses to drying is higher [9,10].

The mineralogical composition of the ceramic powders was studied using X-ray diffraction analysis (Fig. 1). This figure shows that the main part of minerals are kaolinite $Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O$, quartz β-$SiO_2$, microcline $K_2O{\cdot}Al_2O_3{\cdot}6SiO_2$, albite $Na_2O{\cdot}Al_2O_3{\cdot}6SiO_2$; the illite mineral $(Al(OH)_2((Si, Al)_2O_5)){\cdot}K(H_2O)$ [11] is identified in the mass no. 2 too.

In general, the phase compositions of mineral powders are identical; the differences are only in the fact that the mass no. 2 includes a large quantity of illite which is presented in the form of hydromica clays. The illite usually provides the flexibility of masses [12] but also it increases their susceptibility to shrinkage and deformation during drying (because of removing a lot of water from the mean-package space of hydromica). In addition, the mass no. 2 shows a larger quantity of albite, which is consistent with the data of chemical analysis. Albite is feldspar mineral with the melting temperature of 1117⁰C, so its presence in such mass reduces the temperature of its sintering.

The forming properties of ceramic masses are depending on the fineness of its constituent components [3]. For comparison purposes, the grinding residues of the researched masses for the sieve No. 0063 were determined (Table 2).

Table 2

Technical indicators of experimental masses

Number of mass	Residue on sieve No. 0063, %	Plasticity index
1	1.48	6.9
2	1.33	7.4

It can be seen from these data that despite the fact that these masses were prepared by different manufactures and under different conditions, the residues on the test sieve for every of them are practically indistinguishable. In the case of a long grinding, the mass will be more inclined to deformation and cracking, not only during shaping and drying but also during the burning-out. The coarser dispersed particles of skinning component should act as a «frame»; the voids between them would be filled with fine clay particles which would link the mass together and increase the density and strength of semi-finished products. If the particles are very fine, the structure of the skinning component is broken and it does not perform its function of a frame, but simply reduces the connectivity of mass and increases its shrinkage.

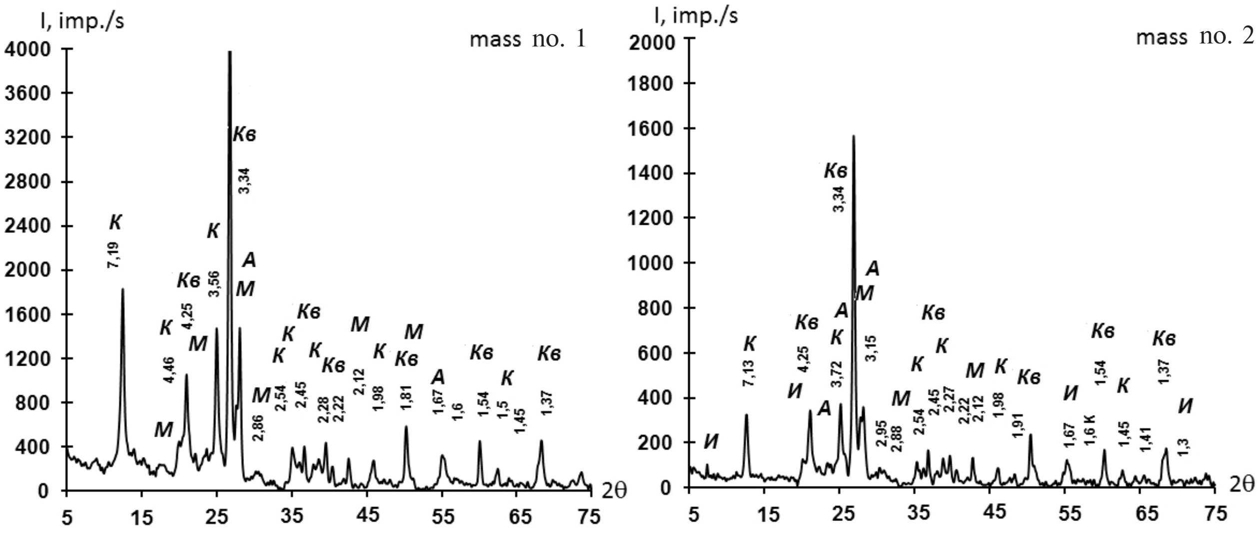

Fig. 1. X-ray diffraction pattern of ceramic masses no. 1 and no. 2: K – kaolinite, Кв – b-quartz, M – microcline, A – albite, И – illite

The plasticity index defines the molding properties of ceramic masses [3]. The both masses are of a moderate plasticity. Slightly more weight plasticity of mass no. 2 is caused by the high content of clay minerals which is consistent with the results of X-ray analysis.

The nature of the thermal transformations of the mineral powders was studied using the differential thermal analysis (Fig. 2). The obtained thermograms show that the thermal conversion of both powders is identical during the heating. The weak endothermic effect at 100^0C is associated with the removal of residual moisture from the materials; the well expressed endothermic effects with a maximum at 560^0C for mass no. 2 and at 550^0C for mass no. 1 indicate the removal of chemically bound water from clay minerals (mainly from kaolinite); the exothermic effects at 1000^0C and 970^0C indicate the formation of primary mullite in masses [5,7].

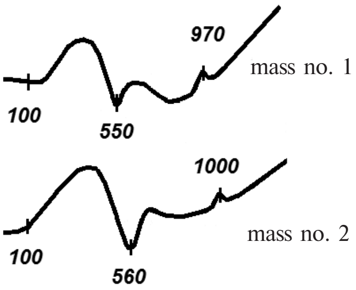

Fig. 2. DTA curves of mineral powders under consideration

For further studies, the press molding powders of both masses were prepared with the same amount of organic connections and water; the obtained masses were subjected to press-sampling, the sample cylinders were gained and then they were burned at temperatures of 1250^0C and 1280^0C.

Table 3

Evaluation of sintering of ceramic masses

Number of mass	Water absorption of samples, %		Total shrinkage of samples, %	
	1250^0C	1280^0C	1250^0C	1280^0C
1	0.91	0.43	10.8	11.0
2	0.25	0.14	12.3	12.5

Table 3 shows that the samples of the mass no. 2 can be sintered at 1250^0C to achieve the required degree of water absorption of less than 0.5%, while the mass no. 1 forms a pot with a less dense structure at this temperature. However, the mass no. 2 suffers from its increased complete shrinkage (12.5%), which is undesirable in the manufacture of products with fixed geometrical dimensions [3]. At the same time, the samples from the mass no. 1 are characterized by a required water absorption after burning at the temperature of 1280^0C, they have the lowest shrinkage (11.0%).

Conclusions

The comparison of the properties and behavior of masses no. 1 and 2 allows one to conclude that they are similar in their basic technological properties, thus the both masses can be used in the manufacture of electrical porcelain. However, the differences is a higher content of clay minerals in the mass no. 2, explaining its higher flexibility (connectivity), which contribute increasing the strength of intermediate product during molding and drying. The sintering of products based on the mass no. 2 can be carried out at the temperature of 1250^0C. On the other hand, the higher flexibility, sensitivity and increased drying shrinkage during burning hamper the application of mass no. 2 in production of especially important details of precise dimensions. Therefore, the mass no. 1 is recommended for molding of goods with complex configuration since it is characterized by lower shrinkage processes (the ability to deform). However the sintering temperature of such products cannot be less than 1280^0C.

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ВИБІР КЕРАМІЧНИХ МАС ДЛЯ ВИГОТОВЛЕННЯ ЕЛЕКТРОТЕХНІЧНОЇ КЕРАМІКИ

О.С. Хоменко

В даній роботі надані порівняльні дослідження формувальних і термічних властивостей керамічних мас для виготовлення електротехнічного фарфору ПАТ «Першотравенський завод електротехнічного фарфору» (маса № 1) та ЗАТ «Керамічні маси Донбасу» (маса № 2). Встановлено, що для пресування виробів нескладної конфігурації більш переважною є керамічна маса № 2, оскільки має підвищену зв'язуючу здатність за рахунок наявності гідрослюдистої складової у мінералогічному складі. Керамічну масу № 1 слід використовувати для виготовлення виробів більш складного профілю, оскільки вона більш опіснена кварцовим піском і має меншу усадку. Також встановлено, що водопоглинання випалених зразків електрофарфору менше, ніж 0,5%, відбувається при температурі 1280^{0}С для зразків з маси № 1 та при температурі 1250^{0}С для зразків з маси № 2. Це слід враховувати при виборі температурного режиму випалу виробів.

Ключові слова: електротехнічний фарфор; пластичність; усадка; водопоглинання; щільність; міцність; спікання; випал.

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