PROPERTIES AND APPLICATION OF MOLDING CLAYS

[1]Toymas Madatov., [1]Mahmudova Feruza., [1]Muftullayeva Marziya., [2]Sarvar Parmonov., [2]Asadjon Kambarov.

[1]Academy of Sciences of the Republic of Uzbekistan.
[2]Almalyk branch of Tashkent State Technical University named after I.A. Karimov.

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Abstract. *The maximum property enhancement in nano clays reinforced polymers is obtained when high levels of intercalation, exfoliation and dispersion of the nano clay in the polymer matrix is achieved. Processing of polymer nanocomposites by melt blending techniques requires sufficient stress levels and time for a maximum exfoliation/intercalation of the nano clays (with minimum polymer degradation), which both are very limited in conventional polymer processing techniques. Shear Controlled Orientation in Injection Moulding, SCORIM, is a non-conventional injection moulding technique based on the concept of in-mould shear manipulation of the melt during the polymer solidification phase. This technique is able of applying high shearing levels to the polymer, leading to high levels of molecular orientation. SCORIM of nano clay-based polymer nanocomposites may be therefore beneficial for achieving high levels of nano clay intercalation/exfoliation and orientation, thus imparting improved mechanical properties. In this work, a nano clay based masterbatch was mixed with polypropylene and direct injection moulded by conventional and SCORIM techniques. In SCORIM, two extreme shear levels were applied by changing processing conditions (melt temperature and shear time). We assess therefore the effect of high shear conditions in the levels of intercalation/exfoliation and orientation of the nano clay in the polymer matrix and in the mechanical properties of the nanocomposite. The levels of clay intercalation/exfoliation were evaluated by Wide-Angle X-ray Scattering.*

Keywords: *molding, moldability, mixture, absorption coefficient, SCORIM.*

Introduction. The water contained in clays is divided into those included in the minerals (chemically bound) and those not included in them (adsorbed and capillary). The moisture content of molding clays is determined according to [12]. A sample of clay weighing 20 g is dried in a drying cabinet at a temperature of 105–110 °C to constant weight, then cooled in a desiccator and weighed. The mass fraction of moisture x in percent is calculated using the formula

$$X=(m-m_1)/m*100$$

where m and m1 are the mass of a sample of clay before drying and after drying, g. The grain composition of clays characterizes their degree of dispersion and the presence of coarse inclusions in them. The dispersion of clay has a significant impact on their strength properties.[1] The granulometric composition of clays is determined according to [9]. The degree of dispersion is judged by the content of the clay component, i.e. particles less than 0.02 mm in size. For most clays, the clay component content is in the range of 75–99%. *Bonding capacity* – the most important property characterizing the quality of clays. As it increases, the amount of clay introduced into the molding mixture decreases, the gas permeability and fire resistance of the mixture increase, and in most cases the humidity decreases, which reduces the adhesion of the mixture and improves its moldability.[5] However, when making molds when wet, the clay must have moderate strength in the dry state, since otherwise it will be difficult to knock out and prepare the waste mixture. The binding capacity is determined by the tensile strength of the samples in the wet and dried state. Drying of samples is carried out at t = 150–180 °C for 1.5 hours. *Wet strength most* significantly depends on the mineralogical composition of clays, the dispersion of clay particles, the capacity and composition of the exchange complex. There are free water molecules in raw molding sands. The more layers of these molecules, the less connection between the constituent components and the less strength of the mixture when wet. In this regard, when preparing mixtures for raw forms, the optimal ratio between clay and water is important, which is different for clays of different mineralogical nature and granulometric composition.[2] This ratio for each new batch of clay is determined experimentally. The compressive strength in a wet state is determined on standard samples with a height of 50 and a diameter of 50 mm in accordance with [13].

Dry compressive strength is the main characteristic of sand-clay mixtures used for the manufacture of dry molds. To obtain maximum strength of mixtures in the dry state, a higher water content is required than in the wet state.[3] This is due to the need for a more uniform distribution of the clay shell over the surface of the filler grains. During the drying process, capillary water is first removed, and then adsorbed water. When drying forms, the mixture shrinks, which can lead to the formation of macro- and microcracks and a decrease in the strength of the mixture in the dried state. In this regard, in order to obtain maximum strength of dry forms, it is necessary to correctly set the drying modes for each mixture, taking into account the dimensions of the flasks and rods.[4] The ultimate compressive strength in a dry state is determined on standard samples with a height of 50 and a diameter of 50 mm according to [10].

To assess the binding ability of bentonite clays, the tensile strength in the moisture condensation zone is determined according to [14]. The method is based on determining the tensile strength of a sample under one-sided surface heating. *Colloidality* characterizes clays from the point of view of the formation of a stable water-clay suspension, affects the distribution of the clay component in the molding sand and thereby the strength and ductility of molding sands.[6] Colloidality as a percentage is determined according to GOST 3594.10–93 by the ratio of the volume of sediment to the total volume of the water-clay suspension (%) after settling for 24 hours. For testing, 0.5 g of air-dried and ground clay is poured into a test tube about 150 mm high and 15 ml of distilled water is added. After this, the contents are thoroughly shaken and 0.1 g of MgO is added, shaken again for 1 minute and left alone for 24 hours, after which the volume of the formed precipitate is measured. The composition of exchangeable cations is determined according to [13], using special methods of chemical analysis and is expressed in mg·eq. per 100 g clay. Exchangeable cations include K^+, Na^+, Mg^{++}, Ca^{++}. The higher the sum of exchangeable cations in clay, the higher its quality. When one cations are exchanged for others, the properties of the clay change. For example, when calcium bentonite is treated with soda, Ca^{++} cations are replaced by Na^+ cations and the bentonite changes from calcium to sodium. *Water absorption of bentonites* characterizes the ability of clay to absorb moisture, depends on the structure of the clay crystal lattice and the amount of impurities. Based on water absorption, you can roughly determine the type of clay. Water absorption has some influence on the change in the size of the imprint of molds made dry and on the characteristics of water-clay suspensions. The water absorption coefficient is determined according to [14].

The method is based on determining the moisture capacity of clay, corresponding to the transition of the clay-water system from a paste state to a suspension state. A sample of clay weighing 5 g is placed in a glass, 5 cm^3 of distilled water is added and the clay mass is thoroughly mixed using a glass rod until smooth. Add distilled water until the meniscus becomes mobile. Water is added in portions of 0.5 to 2.5 cm^3. Portions are reduced as water is added.

Water absorption coefficient (k) is calculated using the formula

$$k=m_1/m,$$

where m1 is the mass of distilled water required for the transition of the clay-water system to the state of suspension, g; m – mass of clay sample, g.

The concentration of hydrogen ions (pH) affects the strength properties of molding materials. It is observed that with increasing pH, the hot strength of the molding sand increases. The simplest analysis to determine pH allows you to very quickly find out from which mining site a given batch of clay was obtained; pH is determined using a device in accordance with [11]. A sample of clay weighing 8–10 g is placed in a glass and 80–100 ml of distilled water is added. After shaking for 10 minutes, the electrodes of the device are lowered into the glass with the solution and the pH is determined on a scale.[7] The thermal stability of bentonite clays is based on determining the wet compressive strength after heating the clay and holding it for 1 hour at a temperature of 550 °C. After cooling the clay in a desiccator, mixtures are prepared from the original and calcined clay. Then the compressive strength is determined for the original and calcined clay.[8]

Thermal stability is determined by the formula

$$T=\sigma_1/\sigma_2,$$

where σ1 is the compressive strength in a wet state according to the results of testing calcined clay, Pa (kgc/cm^2); σ2 – ultimate compressive strength in a wet state according to the test results of the original clay, Pa (kgf/cm^2).

Molding clays are selected for preparing the mixture depending on the molding method, the type of alloy being poured, and the formation of the least burn on the castings. The higher the pouring temperature, wall thickness and mass of the casting, the more refractory and high-strength clay must be used. Thus, for dry molding of steel and cast iron castings, clays of the 1st and 2nd dry strength groups, groups T1–T3, are used; when molding wet - groups T1 and T2, and for thick-walled castings (>70 mm) - clay of group T1. In mass production for green molding, bentonite clays are used more often than other types of clays. In this case, the best results are achieved when using bentonite clays activated with soda. For cast iron casting, it is advisable to use calcium montmorillonite clays, and for steel casting, sodium clays. Recommendations for the use of clays are presented in table. 1.

Conclusion

The performed study of the sintering process of high-siliceous clay enables us to provide recommendations on the implementation of the energy-saving technology for producing building ceramics using the method of plastic molding of blanks, namely:

* it is necessary to introduce a small amount of montmorillonite/ bentonite into clay to provide plastic molding of blanks;

* for binary and ternary mixtures of clay, sand, and glass, it is necessary to choose thoroughly the solid-to-liquid (water) ratio, in order to avoid the appearance of suspensions during plastic molding of blanks;

* to realize the low-temperature sintering of high-siliceous clays, it is necessary to add low-melting glass to them for the formation of low-temperature eutectics;

* subject to the above conditions of blanks preparation, the sintered at 800 °C during 8 h materials are glass ceramics with high strength properties.

Table 1
Application of molding clays

Filling material	Characteristics of the casting according to the prevailing wall thickness, mm	Forming method	Recommended brand of clay
Cast iron Same Steel Same –>>– Steel Cast iron	10–15 More 50 8–20 20–70 More 70 80	Raw Same –>>– –>>– –>>– Dry	(P, S, M) (1–3) T_1 (P, S) (1–3) (T_1–T_3) (P, S, M) (1–3) T_1 (P, S) (1–3) (T_1–T_3) P (1–3) T_1 (P, S, M) (1–3)T_1

REFERENCES

1. Borovskiy Yu. F. Molding and core mixtures / Yu. F. Borovskikh, M. I. Shatskikh. - L.: Mechanical engineering. Leningr. department, 1980. - 86 p. 2
2. Vasiliev V. A. Physico-chemical foundations of foundry production: Textbook for universities. - M.: Intermet Engineering, 2001. - 336 p.
3. Gulyaev B. B. Molding processes / B. B. Gulyaev, O. A. Kornyushkin, A. V. Kuzin. – L.: Mechanical engineering. Leningr. department, 1987. - 264 p.
4. Molding materials and mixtures / S. P. Doroshenko, V. P. Avdokushin, K. Rusin, I. Matsashek. - Kyiv: Higher school; Prague: SNTL, technical publishing house. lit., 1990. - 415 p.
5. Molding materials and casting mold technology: Handbook / S. S. Zhukovsky, G. A. Anisovich, N. I. Davydov, N. N. Kuzmin, E. L. Atroshchenko, I. P. Renzhin, B. L Suvorov, S. D. Teplyakov, A. A. Shpector; Under general ed. S. S. Zhukovsky. – M.: Mechanical Engineering, 1993. - 432 p.
6. Illarionov I. E. Molding materials and mixtures: Monograph / I. E. Illarionov, Yu. P. Vasin. - Cheboksary: Chuvash Publishing House. University, 1992. - Part 1. - 223 p.
7. Svarika A. A. Coatings of foundry molds. - M.: Mechanical Engineering, 1977. - 216 p.
8. Stepanov Yu. A. Molding materials / Yu. A. Stepanov, V. I. Semenov. - M.: Mechanical Engineering, 1969. - 157 p.
9. GOST 2138-91. Molding sands. General technical conditions.
10. GOST 29234.0-91 – GOST 29234.13-91. General requirements for testing methods for molding sands.
11. GOST 3594.0 -77 – GOST 3594.12-77. Molding clays. Test methods.
12. GOST 3594.0-93 – GOST 3594.15-93. Fire-resistant molding clays. Test methods.
13. GOST 3226-93. Fire-resistant molding clays. General technical conditions.
14. GOST 28177-89. Bentonite molding clays. General technical conditions.