Modification of water glass with colloidal slurries of metal oxides

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Abstract

There were taken attempts to modify the properties of water glass with suspensions of zinc oxide (ZnO) nanoparticles and boehmite AlOH(O) nanoparticles dissolved in various solvents. It has been shown that the wetting properties of quartz (SiO₂) can be effected by:

• the amount of modifier,
• the type of solvent,
• nanoparticles size.

The best wetting properties of water glass has been achieved with the modification of ZnO nanoparticles suspended in propanol and butyl acetate ester.

Keywords: Nanoparticles, Water glass, Modification, Binder, Moulding sand

1. Introduction

Water glass is an alternative binder for moulding and core sands with organic binders. It is inexpensive, easily available and non-toxic. Besides the advantages of the sands combined with this binder, there are also some negative characteristics, such as: brittleness, a worse knock-out property and a more difficult recovery. On the other hand, it is known that the abilities of water glass as a binder of moulding and core sands are not fully utilized. This leads to the necessity of a deeper understanding of its physico-chemical properties, such as: wettability, viscosity, as well as cohesive and adhesive strength, which enable a modification of the binder in the aspect of the improvement of the utilitarian parameters of the sand. The analysis of the technological properties of the sands with water glass shows that it is advisable to improve the strength properties of the sands by improving the cohesive and adhesive characteristics of the binder.

In the last years, we can see an interest in the ceramic nanomaterials (SiO₂, Al₂O₃, CaSiO₃, MgO, ZnO [1-5]) and their application, among others, in the modification of moulding sands. These nanoparticles introduced into the systems of a multiparticle matrix (binder) can change their properties by way of a physico-chemical or chemical reaction [6, 7]. The subject of the paper is the modification of water glass by a colloidal slurries of ZnO and boehmite AlOH(O) nanoparticles, in alcohol or butyl acetate ester.

2. Materials and measurement methodology

For the measurement of wettability, the following materials were applied:
• water glass R „145”; M = 2.5; d \(_{20}\) = 1470 kg/m\(^3\) and modifying colloidal solutions of oxide nanoparticles (0.3 M) of the sizes of 10 – 100 nm,
• modifier I – suspension of ZnO nanoparticles in propanol,
• modifier II – suspension of ZnO nanoparticles in butyl acetate ester,
• modifier III – suspension of AlOH(O) (boehmite) in butyl acetate ester,
• optically pure quartz.

The evaluation of the wettability of quartz by the binder was performed by way of measuring the change of the value of the contact angle in time, in the system: quartz–binder, on the samples thermostated at 20 °C. In the measurement, a prototype device for measuring wettability was applied [8]. For the measurement of wettability, 4x8 mm quartz plates were used, whose surfaces were prepared in an identical way. This aimed at ensuring a constant free surface energy value (FSE) and the arising repeatability of the results. Each of the quartz samples was used once. The modification of water glass was performed by means of adding and homogenizing 3% or 5% mass of modifiers.

3. Test results and discussion

Figures 1 - 4 illustrate the changes of the contact angle value in time \(\Theta = f(\tau)\), for the system: quartz–binder, at 20°C. Figure 1 refers to the non-modified water glass, and Figures 2–4 to the water glass modified by the suspension of ZnO nanoparticles in propanol (Fig. 2) or butyl acetate ester (Fig. 3). Figure 4 presents the changes of the contact angle value \(\Theta\) in time, for the water glass modified with the suspension of AlOH(O) (boehmite) in butyl acetate ester.

Figure 3 illustrates the effect of the addition of modifier II in the form of a suspension of ZnO nanoparticles in butyl acetate ester. Similarly to the case of modifier I, better wettability results are obtained with the application of the addition of 5% mass of modifier II. The latter influences both the value of the initial \(\Theta_0\), the balance contact angle \(\Theta_r\) and time \(\tau_r\). The values of the mentioned parameters with the addition of 5% mass of modifier II equal, respectively, 46 deg and 27 deg, with the time of 11 min.

Figure 4 shows the changes of the wetting angle value of quartz by water glass modified by 3 and 5% mass of the suspension of boehmite nanoparticles in butyl acetate ester (modifier III). From the comparison of the courses \(\Theta = f(\tau)\) for the binder modified by different amounts of modifier III, it can be inferred that this modifier has a minor effect on the values of \(\Theta_0\), \(\Theta_r\) and \(\tau_r\).
4. Conclusions

The performed tests of the effect of the modification of water glass showed that:

- the additive modifier has a positive influence the wettability of quartz by the binder,
- the wettability of quartz depends on the type of the nanoparticle and the, solvent, as well as on the mass fraction (in reference to the binder) of the applied modifier.

The best wettability of quartz by the binder was achieved with the application of 5% mass of the suspension of ZnO in propanol (36 degrees).

The verification of the effect of the modifier $R_{m}^{w}$ of loose masses (Fig. 5) after 24 h of hardening showed a similar influence of the tested modifiers on the mass strength.
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