Influence of Quartz-Containing Filler on the Impact Viscosity of ED-20 Epoxy Resin

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Abstract. This article discusses the effect of quartz-containing dispersed filler on the toughness of ED-20 epoxy. The optimum content of this filler was established, at which the impact strength of epoxy composite samples increases by 73%. When the test temperature decreases, the reinforcing effect of the filler disappears at temperatures below 0 °C.

1. Introduction

Epoxy polymers, due to the modification possibility, caused by presence of reactive hydroxyl and epoxy groups, with obtaining materials with high physical and mechanical properties, are still the most promising among other organic high-molecular substances [1-5]. Composite materials based on epoxy oligomers are widely used in practice due to high adhesion, high heat resistance, low brittleness, low shrinkage during curing, stability of technological properties and several other properties. Due to such properties, materials based on epoxy resins are widely used in various industries: as film-forming substances in the refining industry, shipbuilding, construction, etc. [6-9]. However, the characteristics of these materials do not always meet the requirements of modern technology, therefore, obtaining materials with improved performance is of great scientific and technical importance. In practice, in order to expand the areas of application, epoxy resins often undergo modifications. Obtaining polymer composite materials with the required performance characteristics can be achieved by modifying the original epoxy polymer, during which purposeful regulation of the structure occurs [10-13]. Production of epoxy polymer composites for construction purposes with predetermined properties is usually associated with the use of physicochemical modification methods: the introduction of solid insoluble fillers and aggregates, surfactants, inert plasticizers and diluents.

The strength of epoxy composites is significantly affected by the dispersion and shape of the filler grains. The introduction of angular-shaped cullet improves the strength of the composite due to the better adhesive and cohesive bond between the filler grains and the binder. It has also been established that the strength decreases with commensurate particle sizes of the filler and matrix crystals. That is, the high dispersion of the filler is undesirable [14-18]. It contributes to the filler aggregation before the interaction with the matrix and causes a decrease in mechanical strength due to “dry” encapsulation. The strength of epoxy composites decreases when the filler is introduced above its optimal flow rate.
2. Research objects and methods
To obtain the initial composite, ED-20 (GOST 10587) was mixed with a TETA (TU 6-02-1099-83) hardener in a ratio of 16:1. The resulting solution was placed in a vacuum chamber to remove air bubbles.

Ground cullet with a particle size of less than 0.05 mm was selected as the filler for the epoxy resin. The specific surface of the filler was in the range from 2300 to 2500 cm$^2$/g. A filler was added to the TETA hardener to obtain a modified composite. The resulting solution was mixed with ED-20 resin.

The check tests of the samples were performed according to GOST4647-2015 “Plastics. Charpy impact strength testing”. The sample is a rectangular cross-section 80 mm long, 10 mm wide, 4 mm thick, and with no incision. It is subjected to impact in the center, while seated on the support legs unfixed. The distance between the supports is 64 mm, and the pendulum is 0.5 J.

3. Discussion of research results
According to the results of the impact strength tests of samples of an epoxy composite based on ED-20 and a quartz-containing dispersed filler with a particle size of fewer than 50 microns in the range from 0 to 2 wt.%, the optimal filler content is 0.5% (Fig. 1). When the content of the quartz-containing dispersed filler is 0.5 wt.%, the impact strength of the epoxy composite samples increases by 73%.

![Figure 1](image_url)

**Figure 1.** Dependence of the impact strength of the epoxy composite on the concentration of the quartz-containing dispersed filler in the content.

The extreme change in the impact strength of an epoxy composite due to the concentration of the quartz-containing dispersed filler (Fig. 1) is explained by the following factors:

Firstly, the portion of the external load is received by the filler particles, which have a higher modulus of elasticity than the polymer matrix;

Secondly, in an epoxy composite, the matrix in the boundary layer near the surface of dispersed filler particles turns to a structurally ordered state, in which the elasticity and hardness are higher than that of the bulk matrix;

Thirdly, the filler promotes the formation of a three-dimensional structure in the epoxy composite, which more effectively transfers external forces to all particles of the filler. The decrease in the impact
strength in the range of 0.5 ÷ 2% is due to the lack of a polymer binder that wets particles of reinforcing filler.

The impact strength deteriorates with decreasing test temperature (Fig. 2) due to the difference in the coefficients of linear thermal expansion of the filler and the polymer matrix of the composite material. Therefore, stress arises in the structurally ordered layer, which leads to a decrease in the impact strength of the epoxy composite.

![Figure 2. Dependence of the impact strength of the epoxy composite with 0.5 wt.% of the quartz-containing dispersed filler on test temperature.](image)

4. Conclusion
The results of the impact strength tests of samples of an epoxy composite based on ED-20 and a quartz-containing dispersed filler with a particle size of fewer than 50 microns, in the range from 0 to 2 wt.% have revealed that the optimal filler content, in which the impact strength of the samples of the epoxy composite increased by 73%, is 0.5 wt.%.

When the impact tests temperature is reduced to minus 60°C, the reinforcing effect of the filler disappears at temperatures below 0 °C.

5. References
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Acknowledgments
The research was carried out within the state assignment of FASO of Russia (project No. 0377-2018-0001).