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Original article

Influence of the polymer matrix type on cavitation resistance of composites

*M. Dojčinović[a], M. Pavlović[b], S. Jezdimirović[a], B. Purić[a], A. Cvetković[c]

[a]*University of Belgrade, Faculty of Technology and Metallurgy, Karnegijeva 4, Belgrade, Serbia, rina@tmf.bg.ac.rs*
[b] *Kontrol Inspekt, D.O.O., Mladena Mitrića 12, Belgrade, Serbia,*
[c] *University of Belgrade, Faculty of Civil Engineering, Bulevar Kralja Aleksandra 73, Belgrade, Serbia*

ABSTRACT

Cavitation resistance of polymer matrix / basalt powder composites was determined in this work. Two types of composites were tested: epoxy resin / basalt powder composite and polyester resin / basalt powder composite. In both cases, a basalt powder was used as reinforcement in the resin (grain size 20μm, in the amount of 15 wt%). An ultrasonic vibration method with a stationary sample was used to test the cavitation resistance of composites in laboratory conditions. The change in sample mass with test time was monitored to define cavitation rate. Scanning electron microscopy was used to monitor the morphology of composites surface damage.

Key words: *cavitation, composite, cavitation damage;*

1. INTRODUCTION

Composites are modern engineering materials of specific properties: low density and mass, good mechanical properties, corrosion resistance, wear resistance. Compared to other engineering materials (metal materials, polymers, ceramics) they are characterized by a range of positive application properties in different fields of technique. Significant application of composite materials is in the areas of production and application of high-temperature materials. Most composite materials have two components: matrix and reinforcement. Composite properties depend on the properties of both constituents such as size, distribution, form, nature and the strength of connections between constituents [1, 2].

Ultrasonic vibration method with stationary sample according to ASTM G32 was applied for cavitation testing of two types of composite : epoxy resin/basalt powder composite and polyester resin/ basalt powder composite.

Epoxy resins are used to make coatings, adhesives and composite materials with carbon and glass fibers. Epoxy resins are mainly known for excellent adhesion, chemical and thermal resistance, excellent mechanical properties and very good electrical insulation properties. Polyester resins are often used due to the possibility of their application at temperatures up to 100°C.

The ultrasonic vibration method, applied to examine the properties of the obtained composites, is based on the creation and implosion of cavitating bubbles on the sample surface. Monitoring the formation and development of surface damage, and measuring the loss of sample mass during the time of exposure to the effects of cavitation enable assessment of applying the obtained composites for the production of parts of equipment that are exposed to the conditions of wear, corrosion, cavitation was evaluated [3-6].

2. EXPERIMENT

Synthesis and characterization of polymer matrix / basalt powder composites was done in this experimental research. Two types of composites were tested: composite epoxy resin/basalt powder (samples A) and composite recycled polyester resin/basalt powder (samples B). In

**Corresponding author's.e-mail: rina@tmf.bg.ac.rs*

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both cases, a 20 µm basalt powder-sized reinforcement was applied, amounting to 15 wt% [7].

Basalt rocks from the "Vrelo"-Kopaonik deposit were used as a starting material for the production of reinforcements for composites. The basalt rocks were crushed and ground to a grain size of 20 µm in a vibrating mill with agate balls. The chemical composition of pyroxene-olivine basalt was: 56.21% SiO_2; 18.61% Al_2O_3; 1.15% Fe_2O_3; 2.97% FeO; 3.40% MgO; 7.78% CaO; 4.73% Na_2O; 3.37% K_2O; 1.10% TiO [8].

Fig.1 shows the SEM microphotograph of basalt powder used as a resin reinforcement for both series of composite samples (samples A and samples B).

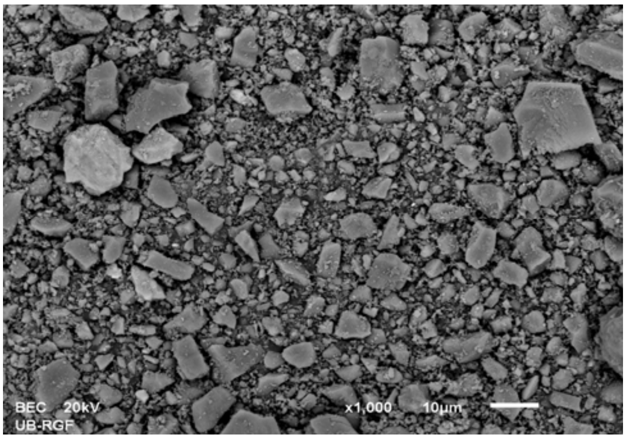

Fig. 1 SEM microphotography of basalt powder samples

Mixtures of resin and basalt powder for each composite were put in a blender and mixed for 1 to 2 min. During the mixing, a magnet was placed in the pan to prevent the mixture from sticking to the walls of the dish. After that, the mixture was placed on the ultrasound bathroom for 5 min to remove the bubbles from the mixture. For composite B, 2% of initiator (methyl-ethyl ketone peroxide, 0.15 ml) was added to the mixture. The mixture was stirred in an ultrasonic bath for 15 s, and then poured into teflon molds to obtain test samples. Samples B were left in the mold for 30-45 min at room temperature to harden, then dried into a laboratory dryer at 70°C / 2h. After that, the molds were removed from the dryer, left for 48h at room temperature, and then samples were removed from the mold. Composite based on epoxy resin (samples A) was polymerized faster. The basalt powder was involved in the composite matrix and mixed for 1 to 2 min, the mixture was poured into teflon moulds and polymerization was performed at room temperature

The mechanical properties were tested on the obtained samples of composites: tensile strength and hardness according to the Shore method. An ultrasonic vibration method (with a stationary sample) according to the ASTM G32 standard was used to test cavitation resistance of composites [3]. To assess cavitation resistance, the change in sample mass as a function of cavitation testing time was monitored. The sample exposure interval and the total testing time were adjusted to the behavior of the samples during the experiments (min): 15; 30; 45; 60.

After each test interval, the samples were dried at 110°C for 1h and then the mass of the samples was measured using an analytical balance with an accuracy of ± 0.1 mg. Measurements were performed individually for each sample after all cavitation test intervals, for a total test time of 60 min. Obtained results calculated for the coordinate system: mass loss (ordinate) and exposure time (abscissa). The diagram shows relation between mass loss and testing time, where the lines were drawn by least-square method and data can be expressed by a straight line. The slope of the straight line represents the cavitation rate. The change in the surface morphology of the samples with the testing time was monitored using scanning electron microscopy ("JEOL" model JSM 6610 LV).

3. RESULTS AND DISCUSSION

The test results of the obtained A composite showed that in the case of B composite, grouping and uneven distribution of reinforcements in the composite appear in some places. The examination revealed weak points in the structure of individual samples where cracks appear during deformation (Fig.2.b), which also affected the lower values of mechanical properties of B composite. The testing results of the mechanical properties of A composite A and B composite are shown in Table 1.

Table 1. Mechanical properties of composite samples

Samples	Tensile strength (MPa)	Hardness Shore
A	19,97	96
B	18,61	95

Composites with epoxy resin matrix and unsaturated polyester resin and reinforcements based on basalt powder with a particle size of 20 µm (designations of composite series: A, B) were subjected to cavitation resistance testing using ultrasonic vibration method with a stationary sample according to ASTM G32.

Fig. 2 shows the samples of A composite and B composite at the end of the cavitation testing for 60 min. During the cavitation resistance test, the change in the mass of the composite as a function of the exposure time was monitored, Fig.3. Based on the results of mass loss measurements during the test, cavitation rates were calculated as an indicator of the resistance of the samples to the action of cavitation. Cavitation rates were calculated as the total mass loss at the time of cavitation testing. Composite samples tested for cavitation showed the following cavitation rates: V_A=0.73 mg/min and V_B=0.91 mg/min.

a. A b. B

Fig. 2 Samples of A composite and B composite at the end of the testing time (60 min)

The results show that A composite has a significantly lower value of cavitation rate compared to B composite, which shows that this composite with epoxy resin matrix has higher resistance to cavitation compared to composite with polyester resin as matrix. It has been shown that the presence of larger grains of the reinforcments leads to its uneven distribution in the polymer matrix as well as the accumulation of grains in certain places in the matrix. These are potentially weak points, which reduce the resistance of composites to the action of cavitation. Formation and development of damage to the surface of samples under the action of cavitation are manifested in the form of shallow and deeper pits, located most often in places where the accumulations of reinforcements are located and where there is an unbalanced place in the composite, Fig.2. Larger reinforcment grains prevent a higher proportion of reinforcements in the composite. It is considerably more favorable in case of smaller dimensions of grain. Then there may be higher proportions of reinforcements in the composite, which would contribute to obtaining composites with better characteristics.

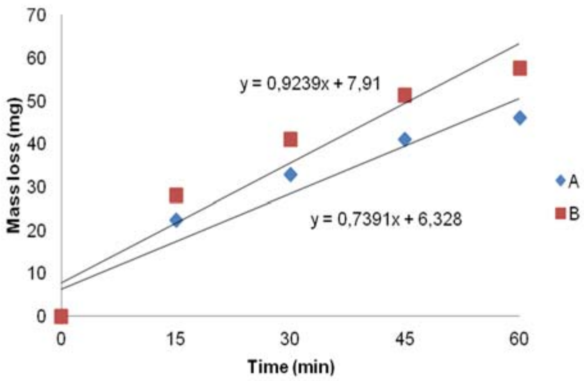

Fig. 3 Cavitation rate diagram of composite A and composite B

Fig.4 and Fig.5 show SEM micrographs of the surfaces of the samples of A composite and B composite before the test (0 min) and at the end of the test (60 min) under the action of cavitation (magnification 500x).

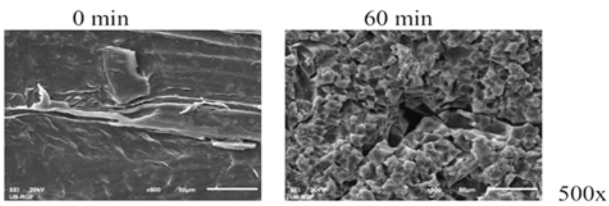

Fig. 4 SEM microphotographs of the A composite sample surface before (0 min) and after cavitation testing (60 min)

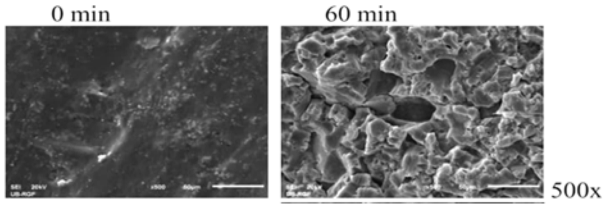

Fig. 5 SEM microphotographs of the B composite sample surfaces before (0 min) and after cavitation testing (60 min)

Composite A, epoxy resin/basalt powder show lower cavitation rate (VA = 0.73 mg/min) compared to composite B, polyester resin/basalt powder where the cavitation rate was higher (VB = 0.91 mg/min), shown in Figure 3. Also, samples A showed higher values of tensile strenght and hardness than samples B with a polyester resin matrix, Table 1. This suggests that A composite have better cavitation resistance than B composite.

Both types of composites can be applied in conditions of lower cavity loads.

Analysis of SEM micrographs of composite samples shows that after 60 min of cavitation, the surface changes and pits are formed. In the case of A composite, shallower pits are formed, which indicates a lower level of damage to the surface of the samples after cavitation for 60 min, Fig.2a and Fig.4. In the case of B composite, larger and deeper pits are created, which join and thus increase the level of damage to the sample surface, Fig. 2.b and Fig.5.

4. CONCLUSION

Based on the results of determining the cavitation resistance of two types of polymer matrix / basalt powder composites, it can be concluded that satisfactory properties of the resistance of composites to the action of cavitation have been obtained. Tests have shown that the properties of the obtained composites are greatly influenced by the matrix of the composite. In A composite the matrix was epoxy resin, while in B composite the matrix of the composite was recycled polyester resin. It has been shown that the matrix of epoxy resin affects the production of composites with better properties, both mechanical properties and properties of resistance to cavitation. Epoxy resin polymerized faster compared to polyester resin, which had an influence on the composite synthesis process.

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NOTE

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