RESEARCH OF COMPOSITE LAMINATES WITH EPOXIED MATRIX REINFORCED WITH GLASS FIBERS AND METALLIC POWDERS

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Abstract

The aim of the study is to determine the effect of metallic nano- and microparticles entered into laminates with the epoxy resin matrix reinforced with fiberglass.

The reference analysis showed that research in the field of composites focus on improving strength properties, including fatigue, resistance to impact, thermal and electrical conductivity and combustibility.

Most of the tests are carried out in standard laboratory conditions, whereas in reality these materials often work in the most adverse external conditions. The paper presents the results of epoxy resin laminates fatigue studies. The laminates were reinforced by fiberglass, modified with metallic powders of different granulation including nanopowders.

Particular attention was paid to the study of fatigue strength at low temperature and to compare it with the results of standard tests. The tests were performed on a specially designed bench with a mechanical forcing variable load on samples in the form of sidely fixed bar. The bench was equipped with a thermal chamber that allows for the implementation of research at temperatures from - 40 ° C to + 60 ° C.

Based on these results, the guideline was developed for the planning of more advanced experiments, the results of which will be the basis for the design of laminates operating at extremely low or elevated temperatures.

Keywords: Composites, metallic and ceramic powders, fatigue, low temperatures

1. INTRODUCTION

In the past few years, composite materials have been used in more and more applications [1]. Composite materials based on epoxy resins are used in the aerospace industry for the production of compressor blades, in the automotive for bearing [2-4]. Development of new composite materials or modification of existing one is the real challenge for most of the materials engineers [5]. The key problem in the composites engineering is to study their resistance to cyclic fatigue. They have significant advantages over metals, not only because of its high rigidity and strength, but also the fatigue resistance [2]. Light resin transfer molding (LRTM) has been developed as a cheap alternative to current dry resin infusion. Light RTM is a process in which the laminates are produced by using a closed mold system. Closed form consists of a rigid base and semi-rigid, translucent cover, which when applied to the base is sealed by vacuum [6].

The aim of tests was to investigate the degradation of the structure in composite materials with the addition of metallic powders during cyclic loading at various temperatures. The size being determined in tests was the number of cycles (N) at which the strength drops below a predetermined value.

2. EXPERIMENTAL

Laminate for tests were produced by LIGHT RTM method on special designed bench (**Figure 1**). The composite was made of epoxy resin Polimal AWTP 1094, Metox-50 was used as hardener. The reinforcement consisted of six layers of fiberglass mat STR 026-450-125. Into the matrix were entered 5 % by weight powders of Al_2O_3 with gradation of 63 um, $CoAL_2O_4$ with gradation of 63 um and nanopowder of Al with gradation of 63 nm. Preparation of laminates with nanopowders Al was necessary to made in protective atmosphere of argon, to avoid the immediate oxidation, therefore whole operation was performed on glovebox. Samples for fatigue tests were cut out by waterjet. Their dimensions were 125 x 20 x 3 mm.

Figure 1 Bench for manufacturning laminates by LRTM method

Fatigue tests were carried out at various temperatures in an isothermal chamber using a heating-cooling module. The chamber was made as a cast of polyurethane foam. The module a module consisted of a fan that circulated air in the chamber, two cascaded Peltier cells powered by separate power supplies and copper water block for heat removal. That kit allows maintain a constant limit temperature of -40 °C in the chamber. 3D model of the chamber is shown in **Figure 2**.

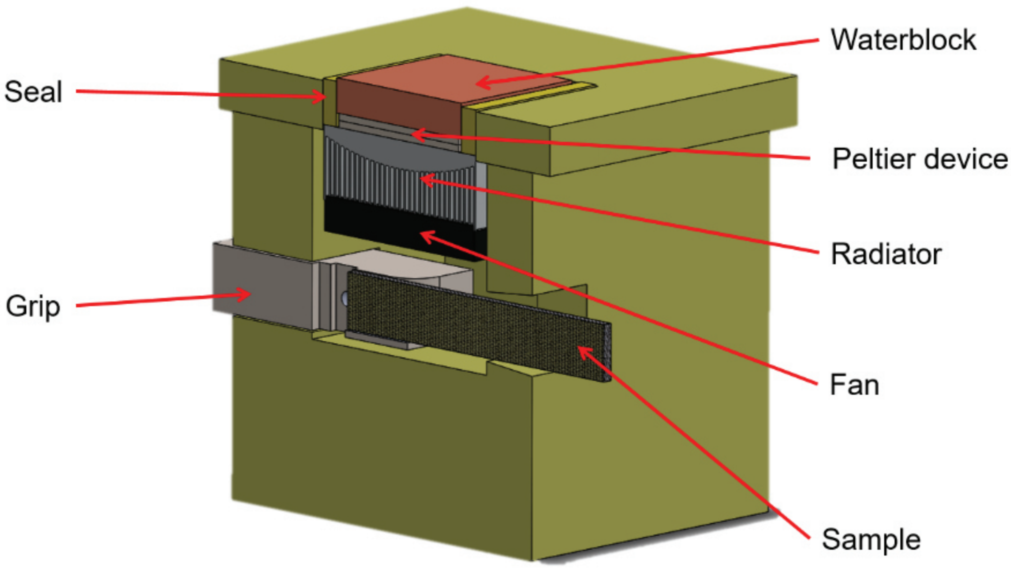

Figure 2 3D model of isothermal chamber that was used to perform the cast

The tests were performed on a specially designed bench presented on **Figure 3** with a mechanical forcing variable load on samples (c) in the form of sidely fixed bar, which included a strain gauge (f) equipped with grip (g) holding steady one end of the sample, the electric engine moving the rolls (d) holding the other end of the sample on the rail, control panel, measuring amplifier, a computer and a temperature gauge. Samples were tested with a constant frequency of 5 Hz and the amplitude of 4 cm. In order to register the slope of the load displacement, and the number of cycles was used measuring amplifier SPIDER 8, which read the voltage directly from the strain gauge. The measurement was performed with a frequency of 200 Hz.

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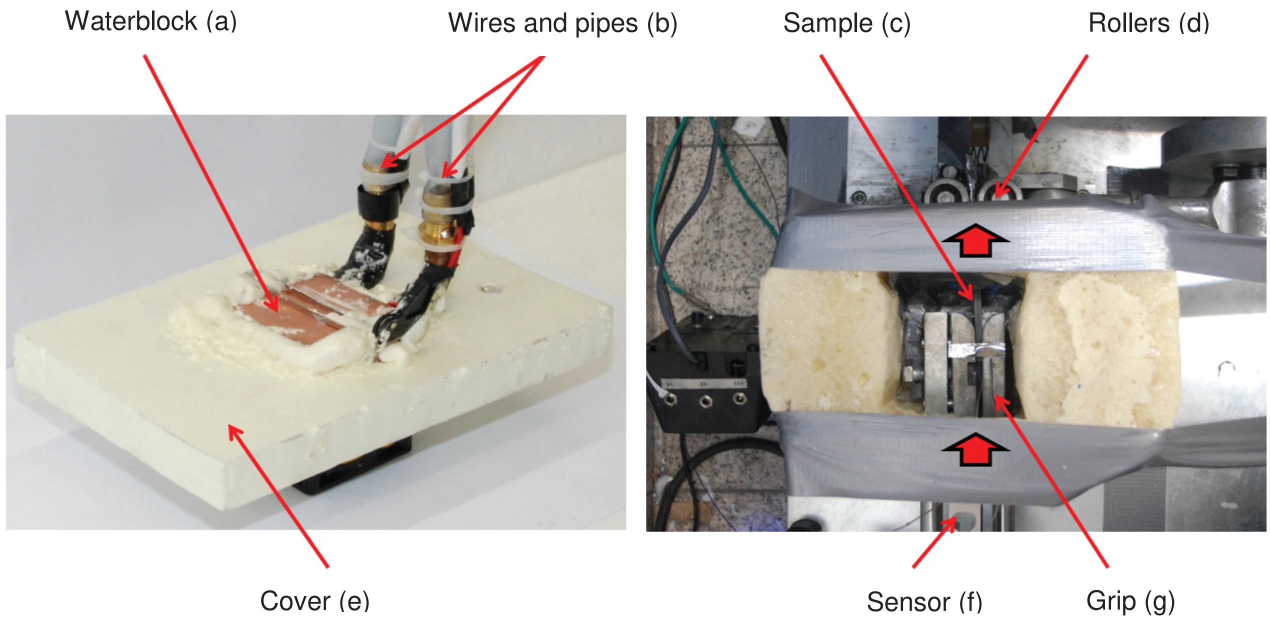

Figure 3 Isothermal chamber for casting of polyurethane foam

3. RESULTS

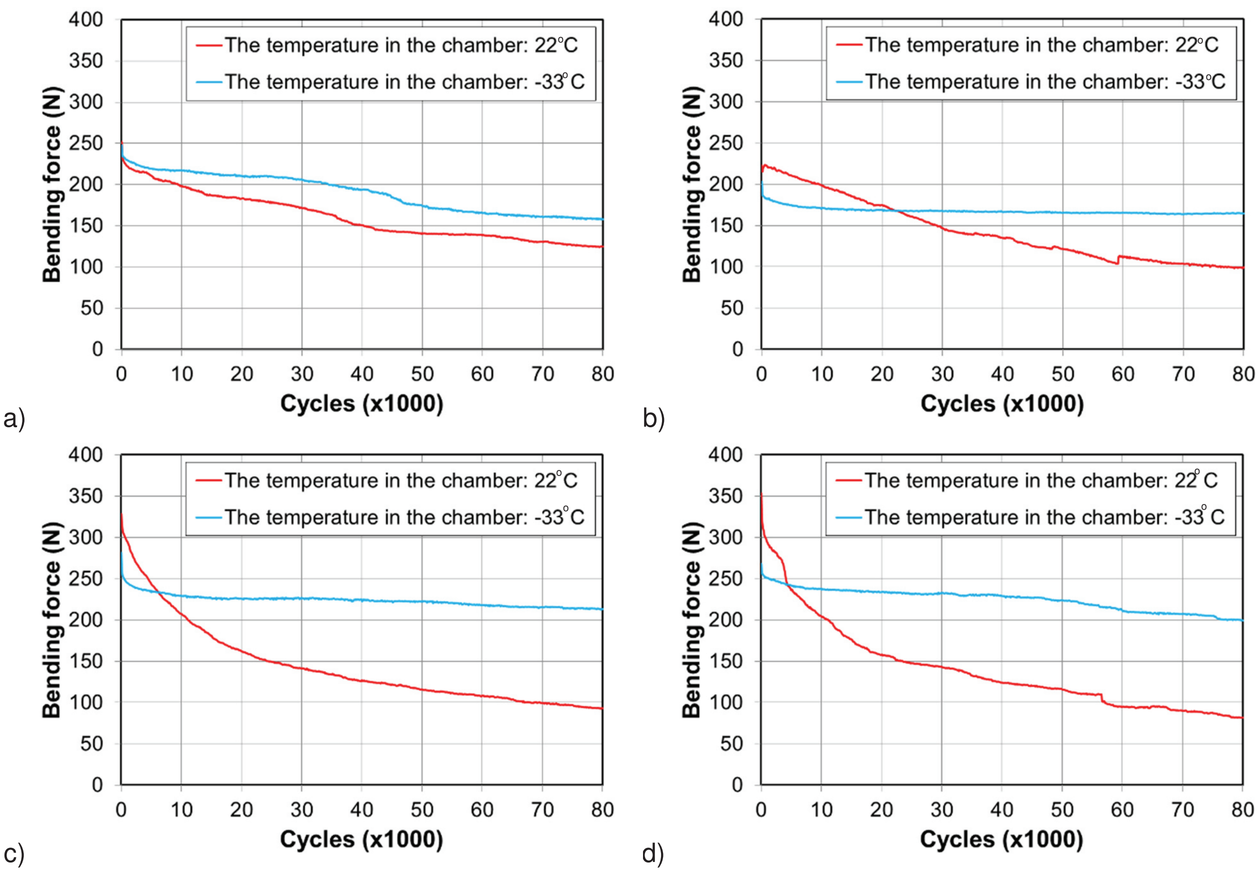

Figure 4 Fatigue curves, lamina: a) without powder, b) Al nanopowder, c) Al_2O_3 powder, d) $CoAl_2O_4$ powder

On the **Figure 4** results of fatigue tests are presented. The figures are shown intentionally only with one curve - more of the curves was unnecessary due to the repeatability of results. The blue curve corresponds to the test carried out in a low temperature, the red curve corresponds to the test performed at room temperature. The aim of the research was to prove the general trend observed during the tests, not to designate specific values.

Analyzing the figures two relationships can be seen. The first is that the addition of powders to lamina slightly deteriorates fatigue strength, when tests are carried out at room temperature. Laminas become stiffer. In the initial test phase observed force is higher, but during the test, force decreases rapidly. As expected a greater effect in this case has a granularity of the powder than the type.

The second is that the powders significantly change the fatigue strength of the laminate in the case of the tests carried out at low temperatures. Clearly we observed it in the case of a laminate containing Nano aluminum powder. The observed strength decreases only in the first few cycles, and does not change till the end of the test. In the case of powders with μm grain size, fatigue strength is higher than the laminates without the addition of powder. The addition of powder stabilizes the strength of the laminate when it is deformed at low temperature.

Tests were also conducted at high temperature (~70 °C). As expected in the high temperature resin is softening very fast and it causing delamination of samples after few cycles.

4. CONCLUSION

The main conclusion is that addition of powder to lamina, changes it fatigue strength. When lamina is tested in the room temperature, fatigue strength is slightly decreased. Situation is rapidly changed when test are performed in low temperature. Fatigue strength rises significantly, especially for samples with addition of powders. Best results are obtained with Nano Aluminum powder. The fatigue strength of those samples wasn't change - samples are more elastic. The mechanism of this behavior is so far unknown.

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