

# Development of high performance fiber reinforced polymer composite with toughened matrix

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## STATEMENT OF PURPOSE

The purpose of this research was to develop a relatively tough high performance fiber reinforced material for engineering applications.

## INTRODUCTION

In the field of fiber reinforced high performance polymer composites still new types of raw materials and more perfect technologies are available to produce materials with better and better mechanical properties. Therefore they are able to follow the increasing demands of industry. The application field of the composites is still widening because of their relatively good performance-mass ratio. For instance a few years ago in the aircraft industry appeared airplanes, in which more than half of the structural components are made from polymer matrix composites [1, 2].

From a mechanical point of view the high performance thermoset composite materials can bear similar loads as steel or other metallic structural material, but they are more rigid and brittle. They can not absorb energy of dynamic loads like vibrations or impact loads as effectively as metals. For this reason one of the main objectives of the development of high performance composites is to produce more tough materials [2, 3, 4].

There are different techniques to increase the toughness of a polymer. One of the opportunities is to create nano-scaled structure in the material. This method can be achieved by incorporation of nanoparticles into the material as additives; the result is classical nanocomposite. Another method is when immiscible polymers are used (two phases are present).

Preferably, high energy absorbent thermoset blend can be prepared if the resins are miscible but the prepared polymers not, and the phase separation is hampered. In this case a special construction awakes where between the phases an interphase is present in which the properties change gradually. From the molecular structure point of view it means that molecular entanglements is created. Because of the entanglements the polymer chains become more flexible and during the deformations the mechanical energy is absorbed. By this way the toughness of the matrix material can be improved significantly [3, 4 5, 6].

Delamination is one of the most common failure mode in case of fiber reinforced laminates. The nanostructured matrix polymer composite can have better interlaminar properties. The entanglements between the phases leads to better phase interactions therefore the load-transfer

between laminate layers is better. Overall this can manifest in higher bending properties and improved resistance against fatigue loads [1, 2, 3, 7].

## APPROACH

In this study a hybrid thermoset resin matrix composite was produced and tested. As matrix material bisphenol A diglycidyl ether epoxy (EP) resin (IpoX ER 1010, IpoX Chemicals, Hungary) with isophorone diamine (IpoX EH 2293, IpoX Chemicals, Hungary) and modified, 35% styrene contained vinylester (VE) resin (AME 6000 T 35, Ashland Italia S.p.A., Italy) with in diisobutyl dissolved methyl-ethyl ketone peroxide accelerator (MEKP-LA-3, Peroxide Chemicals, South Africa) were used. Unidirectional carbon fabric was applied (Panex 35 FB UD 300, Zoltek Zrt., Hungary) as reinforcement.

In the first step of the matrix preparation 1:1 (wt./wt.) rate EP/VE resin mixture was stirred for ten minutes. Then the amine of EP was added in and stirred for two minutes again. Finally the catalyst of VE was added and stirred also for two minutes. Composites were made by simple hand lay-up method using 6 carbon fabric layers, where beside the EP/VE matrix, EP and VE matrix reference composites were also prepared. The nomination of these composites is EP/VE/CF; EP/CF and VE/CF. After 24 hours all of laminated composites were cured at 80°C for 4 hours.

The bending properties were characterized according to ISO 14125:1999. The bending tests were carried out on a Zwick Z020 (Germany) universal testing machine. The test speed was 2 mm/min, the gauge length was 80 mm. The fatigue properties of the composites were measured with an Instron 8872 fatigue testing machine in bending mode, according to the ISO 13003. The test was carried out in force controlled mode, the load factor (the ratio of the applied load and the tensile strength, LF) was 0.85 and 0.95, the stress ratio (R) was 0.1 and the frequency of the loading method in all of cases was 5 Hz.

## RESULT AND DISCUSSION

The most common load in a fiber reinforced polymer composite is the bending load. Therefore firstly the bending strengths of the prepared composites were characterized. The results showed that the material with mixed resin (EP/VE/CF) has the highest bending strength among the composites (Fig. 1). The higher performance can be explained by the entanglements between the polymers phases can hamper the crack-propagation

therefore the matrix material can have greater role in the load distribution that leads to higher strength.

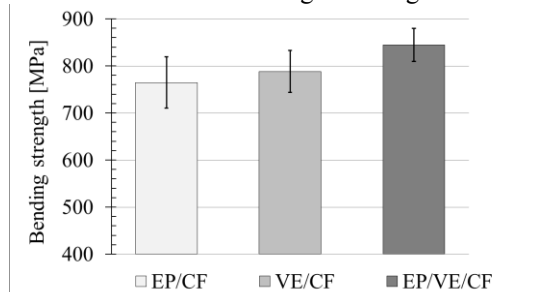


Figure 1: The bending strength of the investigated composite materials

The fatigue test has a great potential in the investigation of composites under endurance loads. This test can model the load-conditions that awake at a real engineering application. The fatigue tests were carried out under two different load levels. The results of the bending fatigue tests showed that the abided cycle numbers of the mixed resin composites (EP/VE/CF) were higher compared to the other investigated composites at both load levels (Fig. 2 and 3). In case of the lower load level (LF=0.85) the hybrid composites did not break until 50000 cycles.

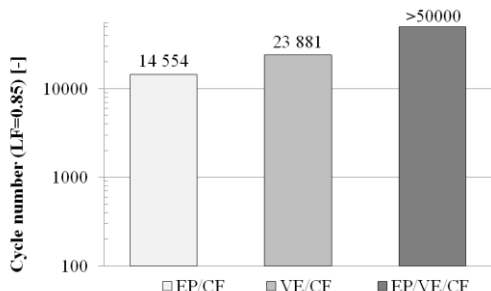


Figure 2: Abided cycle numbers of composites at bending fatigue load, in case of 0.85 load factor

At higher load level (LF=0.95) in case of the hybrid system the abided cycle number is higher not just compared to the reference composites at the same load rate, but also compared to the measured values at lower loading rate for the EP or VE composites.

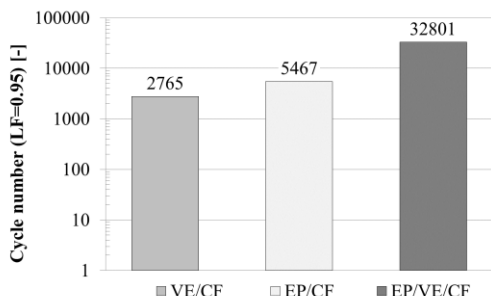


Figure 3: Abided cycle numbers of composites at bending fatigue load, in case of 0.95 load factor

## CONCLUSIONS

The real positive effects in the mechanical properties of carbon fiber reinforced hybrid resin composite were demonstrated. In case of the EP/VE/CF composites the interlaminar properties were much better, therefore increased bending properties were exhibited. The improved load distributing ability of the matrix was manifested in the fatigue properties, too.

## FUTURE WORK

The effects of the hybridization has to be proved for other thermoset polymer blends and in case of different reinforcing materials.

## KEYWORDS

Carbon fiber, polymer composite, epoxy, vinylester, fatigue.

## ACKNOWLEDGMENTS

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