53rd Conference on Experimental Stress Analysis
Český Krumlov, Czech Republic, June 1–4, 2015

Experimental Determination of Mechanical Properties of Prepreg Carbon Composites Designed for Bicycle Rims

S. Rusnáková [1,*], M. Žaludek [1], L. Fojtl [1], A. Čapka [1], V. Rusnák [2]

[1] *Department of Production Engineering, FT TBU in Zlín, 760 05 Zlín, Czech Republic*
[2] *Faculty of Metallurgy and Materials Engineering, VŠB-Technical University of Ostrava, 708 33 Ostrava-Poruba, Czech Republic*
[*] *rusnakova@ft.utb.cz*

Abstract: This paper presents an experimental investigation of mechanical and impact properties of carbon and Kevlar-carbon composites prepared from pre-impregnated materials. Namely, flexural performance in three-point bending at different temperatures is evaluated. Moreover, low-velocity impact test is also conducted for classification of impact properties and character of rupture. These all properties are important for material design of sport bike rims.

Keywords: Composite; Rim; Prepreg; Flexural Properties; Low-Velocity Impact.

1 Introduction

Carbon composites are widespread especially in the automotive and aerospace industries, but we can find them even in sport equipment and supplies, such as tennis rackets, racing and mountain bikes frames and rims [1, 2]. These composites are used for its lightness and strength, which can be compared to aluminum alloys (Duralumin) but carbon composites are lighter and more flexible [3, 4].

Composite parts with carbon reinforcement are used in cycling for a long time, especially for a production of bicycle frames, or smaller parts of the bicycle, such as the handlebars and pedal cranks. Pre-impregnated fabrics (prepregs) are mostly used for these applications due to precise portion of resin and fabric variability [5]. Requirements on rims for bicycle wheels differ according to their classification. Road rims have to satisfy demands on minimal weight and a high level of aerodynamics for maximum inertia. On the other hand, rims for mountain bikes have to be rigid and durable. Among the most stressed part of the rims belong spoke nipple location and breaking surface. This surface is an area of about 1 - 1.5 cm thick strip around the circumference, and is the most thermally stressed part of the rim during braking.

Impact tests are used to determine the impact strength of material against i.e. ability of material to absorb impact energy. Devices with rotating hammer have in their use some limitations and drawbacks, especially with regard to choice of energy and speed. These drawbacks are eliminated by devices called drop testers. They are based on the principle of free falling stamper with optionally chosen kinetic energy. Size of the kinetic energy depends on the stamper mass and starting altitude.

The aim of presented paper is to characterized mechanical and impact properties of carbon and Kevlar-carbon composites designed for bicycle rims. The influence of temperature on decline of mechanical performance is also assessed.

2 Experimental

The composition of prepared composite samples corresponded by thickness (number of prepreg layers) to dimensional requirements on individual parts of tubular wheel rim. Totally, two types of prepreg materials with similar area weight were used. Both of these prepregs were impregnated by epoxy resin. Prepared samples were tested in three-point bending at room (23 °C) and elevated temperature (60 °C). Impact tests were conducted at room temperature by impactor of approximately 20 kg weight. All tests were performed according to appropriate international standards [6–8].

Results from bending tests showed that epoxy matrix is more flexible at elevated temperature causing an increased deformation of both prepared composite types. Following figure (Fig. 1) shows values of flexural strength measured for carbon composites. Flexural strength of 555 N was measured for four layers of prepreg, where the greatest increase of this parameter (by more than 40 %) was noted for six prepreg layers. Further increase was not so major. Decrease of flexural strength of approximately 20 - 30 % for carbon composites was measured during tests at elevated temperature.

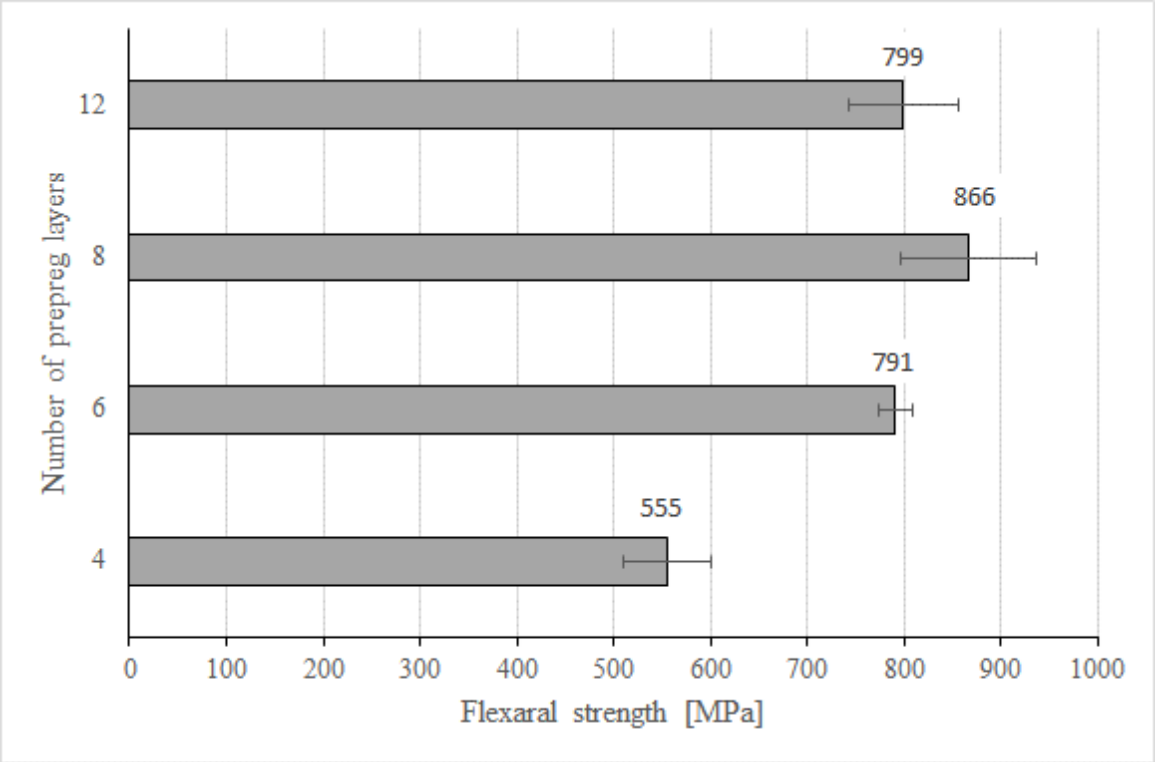


Fig. 1: Data of impact force for different number of carbon prepreg layers.

Values of impact force are depicted in Fig. 1. As can be seen, data have growing trend with an increase of carbon prepreg layers. Addition of one layer increases evaluated parameter by about than 20 %. Furthermore, four layers of carbon prepreg with total thickness of 0.8 mm showed necessary impact force equal to 1571 N. Maximal impact force of 6613 N was measured for twelve layers of nominal thickness of 2.4 mm.

The figure below (Fig. 2) shows the selected samples after low-velocity impact test. Penetration area of carbon composite is greater (more affected) and fracture is more brittle (Fig. 2a). On the other hand, same area in case of hybrid aramid/carbon laminate is smaller, compared to previous case, because aramid fibers are capable to absorb more of this impact energy.

3 Conclusion

Experimental measurements of mechanical and impact properties of carbon fiber composites designed for sport bike rims were conducted. It was found that flexural performance is dependent on number of prepreg layers and quality of production. The effect of temperature on decrease of mechanical properties was also proved. Impact properties showed difference between hybrid and pure carbon prepreg materials. All obtained results are import for further material design for composite bike rims.

Contribution of composite materials in the sports industry is significant and their application is becoming increasingly popular. In many ways they are superior to the previously used materials and are often used as a full replacement for the original materials.

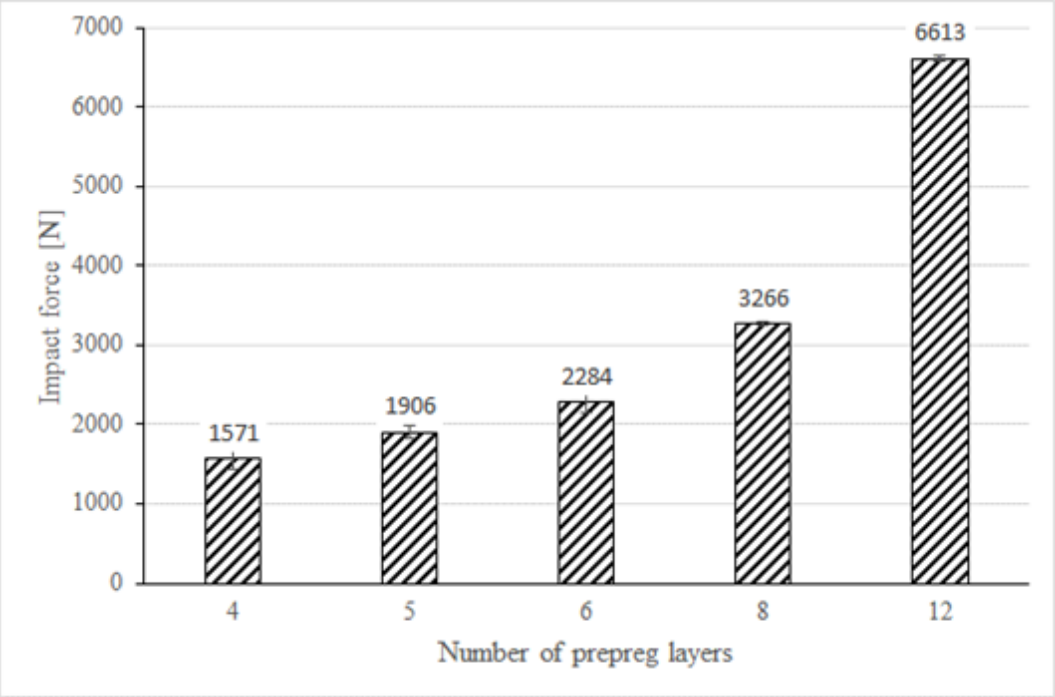
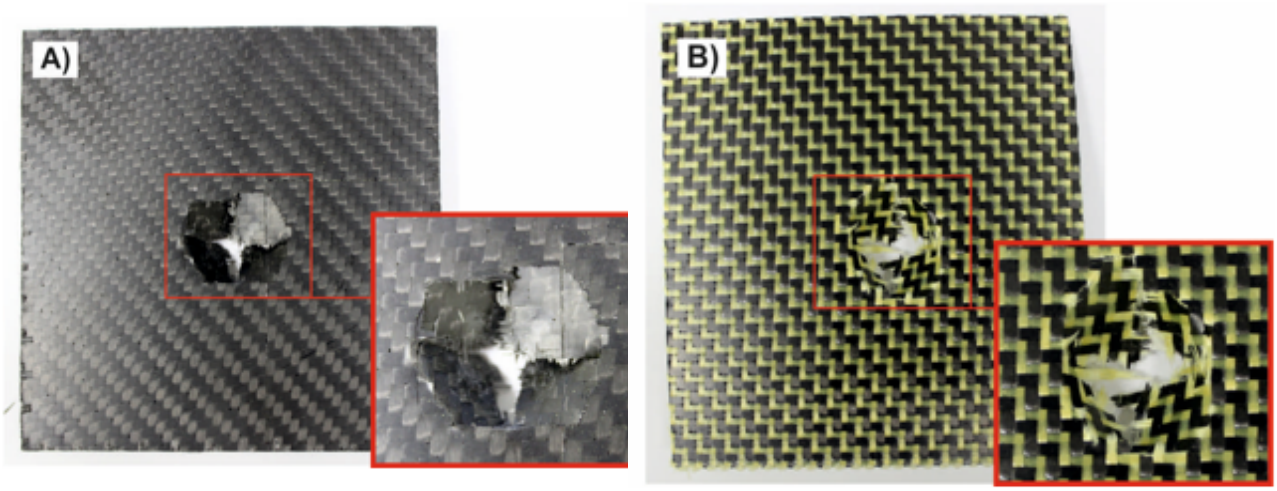


Fig. 2: Data of impact force for different number of carbon prepreg layers.



(a) carbon fabric composite

(b) kevlar-carbon fabric composite

Fig. 3: Composite samples after impact with detail of penetration area.

Acknowledgement

This study was supported by the internal grant of TBU in Zlín No. IGA/FT/2015/001 funded from the resources of specific university research.

References

[1] F. Campbell, Structural Composite Materials. ASM International, Ohio, 2010.

[2] H. Zabala, et al., Impact velocity effect on the delamination of woven carbon–epoxy plates subjected to low-velocity equienergetic impact loads, Composites Science and Technology 94 (2014) 48-53, doi: 10.1016/j.compscitech.2014.01.016.

[3] I. Taraghi, A. Fereidoon, F. Taheri-Behrooz, Low-velocity impact response of woven Kevlar/epoxy laminated composites reinforced with multi-walled carbon nanotubes at ambient and low temperatures, Materials & Design 53 (2014) 152-158, doi: 10.1016/j.matdes.2013.06.051.

[4] N. Baral, et al., Delamination behaviour of very high modulus carbon/epoxy marine composites, Composites Science and Technology 68 (2008) 995-1007, doi: 10.1016/j.compscitech.2007.07.022.

[5] Retrieved from: www.hexcel.com/resources/technology-manuals/HexPly® Prepreg Technology.

[6] ČSN EN ISO 14125 Fibre-reinforced plastic composites-determination of flexural properties.

[7] EN ISO 179-2. Plastics – Determination of Charpy impact properties – Part 2: Instrumented impact test. CEN, 1999-05-06.

[8] EN ISO 6603-2. Plastics – Determination of puncture impact behaviour of rigid plastics – Part 2: Instrumented impact testing. CEN, 2001.