https://dx.doi.org/10.24001/ijcmes.3.1.9 ISSN: 2455-5304

Mechanical Behavior of Polymer Matrix Composite Materials Reinforced With Ceramic Fibers

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Abstract— *In the present work, the mechanical properties of PMC specimens with various types of ceramic reinforcements were investigated. The PMC specimens were reinforced with glass, carbon fibers and Kevlar. The effect of the % content of the reinforcement material in the matrix and the effect of the applied strain velocity (2,4,6 mm/min) were found to affect the mechanical properties of the specimens.*
Keywords*— *PMC, mechanical properties, carbon fibers, glass fibers, Kevlar, strain velocity.

I. INTRODUCTION

Fiber reinforced composites were widely used in the automotive and aerospace industry. The main advantage that these materials offer, is the very high mechanical properties the show while their weight is very low combining them with the metallic alloys. Many researchers have investigated the mechanical properties of these reinforced fibers, such as fracture toughness of Carbon NanoTubes (CNT) [1-13].

In addition to that, the geometrical parameters of the reinforced material, such as their diameter were found to affect the mechanical properties of the reinforced composites. Fibers with diameters as thin as some nanometers were widely used in order to improve electrical and thermal properties of these composites, apart from the mechanical properties [14-17]. Nan Zheng et. al. [18] used a vacuum filtration method to fabricate sandwiched carbon nanotubes/polysulfone nanofiber (CNTs/PSF) paper as an interleaf to improve the interlaminar fracture toughness of CF/EP composite laminates. Lippo Lassila et. al. [19] have investigated the reinforcing effect of discontinuous glass fiber fillers with different length scales on fracture toughness and flexural properties of dental composite. These investigators found that the use of different length scales of discontinues fiber fillers (hybrid) with Polymer matrix yielded improved mechanical performance compared to commercial FRCand conventional posterior composites.

II. EXPERIMENTAL METHOD

Composite specimens with glass, carbon and Kevlar fibers with epoxy ritine, were made using the techniques of autoclave and infusion. 5 categories of specimens were prepared in order to investigate the effect on the mechanical behavior of specimens with one dimension or two dimension reinforced fibers. At the first three categories, the epoxy/ reinforced specimens were consisted of 10 layers of carbon Prepeg, 10 layers of S Glass Prepeg and 7 Carbon layers and 3 S Glass layers in one dimension, respectively. The other two categories of specimens were with 3carbon/7 S Glass layers and 5 Carbon/5 S Glass layers respectively. In tables 1-3 the deposition of each layer are given for the above specimens.

Table.1: Layer distribution of the Carbon fibers and the Glass fibers in the Carbon 70% - Glass 30% specimens

Layer	Fibre material
1	Carbon
2	Carbon
3	Glass
4	Carbon
5	Carbon
6	Glass
7	Carbon
8	Glass
9	Carbon
10	Carbon

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Table.2: Layer distribution of the Carbon fibers and the Glass fibers in the Carbon 50% - Glass 50% specimens.

Layer	Fibre material
1	Carbon
2	Glass
3	Carbon
4	Glass
5	Carbon
6	Glass
7	Carbon
8	Glass
9	Carbon
10	Glass

Table.3: Layer distribution of the Carbon fibers and the Glass fibers in the Carbon 30% - Glass 70% specimens.

Layer	Fibre material
1	Glass
2	Glass
3	Carbon
4	Glass
5	Glass
6	Carbon
7	Glass
8	Carbon
9	Glass
10	Glass

The strain velocity was 2mm/min and it was constant for all the experiments. In figure 1, the sketch of the specimen is shown. The total length of the specimen was 250cm and the gauge length was 150cm.

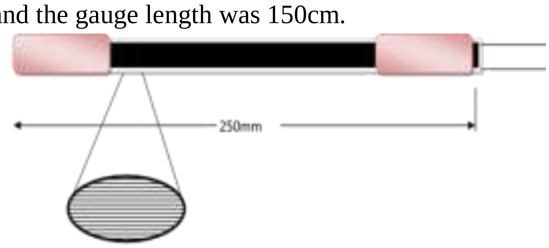

Fig.1: Sketch of a reinforced composite specimen.

In order to investigate the effect of strain velocity on the mechanical properties of the reinforced composite specimens, 4 types of specimens were made, with biaxial reinforcement. All specimens were consisted by 4 laminates. The first type of specimen was reinforced with Woven Prepreg Carbon, the second one with Prepreg Kevlar and the last two, were reinforced with carbon and glass fibers using the infusion technique. As it was mentioned, all these specimens were reinforced in two dimensions and they were tested in monoaxial tensile tests with various strain velocities (2-4-6mm/min), using an Instron 4483 equipment. All reinforced composites were examined with the aid of an optical microscope Nikon E200 Eclipse, after their fracture.

III. RESULTS AND DISCUSSION

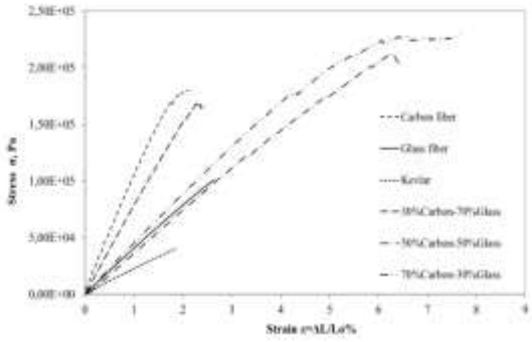

Fig.2: Stress- strain curves for the specimens reinforced in the same direction with the applied tensile load.

Figure 2 shows the stress-strain curves of the reinforced composite specimens under a constant strain velocity of 2mm/min. As it can be mentioned, all specimens seemed to follow a linear function of stress and strain, which may be attributed to the fact that all reinforcements were brittle. The specimens that were consisted from laminates reinforced with only one type of reinforcement didn't have the similar mechanical behavior as these that were consisted of both types of reinforcement in various contents. The increase of the % content of the carbon fibers in the reinforced specimens was found to increase both, the UTS and the strain of the specimens.

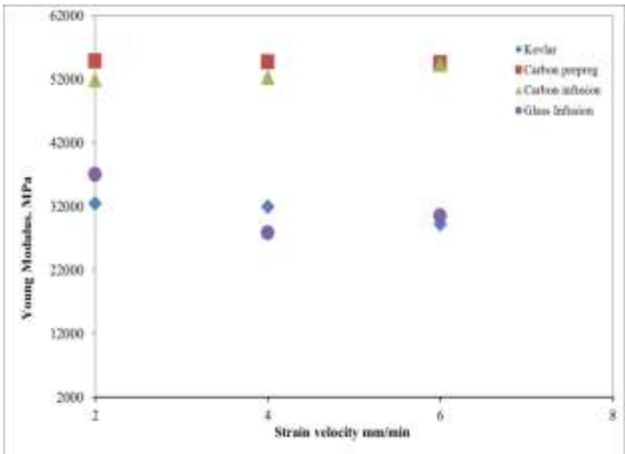

Fig.3: Young Modulus (MPa) vs strain velocity (mm/min).

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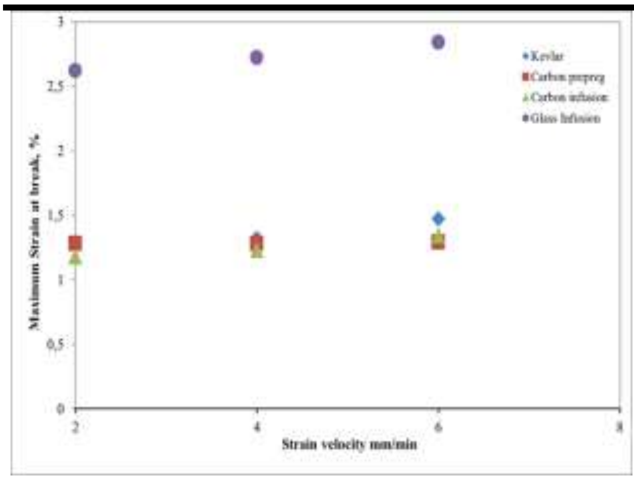

Fig.4: Strain at fracture % vs strain velocity (mm/min)

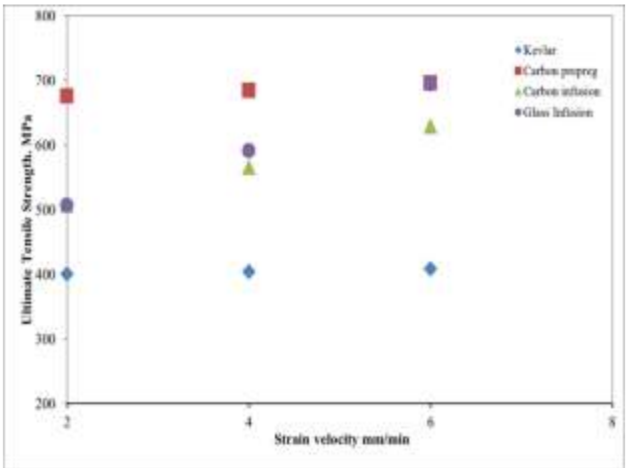

Fig.5: Ultimate Tensile Stress, (Pa) vs strain velocity (mm/min).

In figures 3-5 the Young modulus, the uts and the strain at breaks are depicted as a function of the strain velocity, for fiber reinforced laminate composite specimens.

The stiffness of the specimens was found to be constant while the strain velocity increases (fig 3). In addition to that, the reinforced composites with carbon fibers found to have greater stiffness than the glass and Kevlar reinforced composites. The strain at break of all reinforced specimens was found to be unaffected by the increase of strain velocity (fig 4). On the other hand, as it can be seen in figure 5, the maximum stress at break (UTS) was found to increase while the strain velocity increases, for the glass and carbon reinforced composite specimens. The Kevlar reinforced composite specimens shown a stable mechanical behavior with the increase of strain velocity.

Fig.4: Photographs of fractured fibers from optical microscope, (a) carbon woven made with the autoclave technique, (b) glass fibers made with the infusion technique, (c) Kevlar woven made with the autoclave technique, (d) carbon woven made with the infusion technique.

The fracture surfaces of the fibers from specimens made with woven carbon, glass and Kevlar woven are depicted in figure 4 (a-d). In photos (fig4), the brittle fracture of the fibers is shown. The reinforced composite layers seem to fail due to the delamination of the fibers under the transverse loading. The fracture of the fiber reinforced laminates can be occurred either by fracture of the fibers, or by delamination and matrix cracks joining up to produce a fracture surface without the need to break fibers. [20] In all photos, it is obvious that brittle tensile failure in fibers of the woven laminate was occurred.

IV. CONCLUSION

In the present work, the mechanical properties of laminated, fiber reinforced composite materials were investigated. The effect of the % content of the fibers and the strain velocity increase were found to affect the mechanical properties. The main conclusions of the above research can be summarized as:

1. The increase of the % content of carbon fibers found to increase the UTS of the laminate composite specimens.
2. The increase of the strain velocity was found to increase the stiffness and the UTS of the woven reinforced laminates.
3. The main fracture mechanism was found to be the brittle fracture of the fibers, without any delamination phenomena appeared between the laminates.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Hellenic Aerospace Industry for their contribution to the above research.

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