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## Testing of Mechanical Properties of Carbon Fibre Reinforced Hybrid Composite

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**ABSTRACT:** The present work aims to investigate the mechanical properties and fracture toughness of woven fabric Glass /Kevlar based hybrid composite tailored using modified epoxy with micro and rubber silica. The principal aim of this work is to clarify the importance of hybrid fiber/filler addition and stacking sequence of be reinforcement in epoxy matrix. The epoxy was modified with addition of 9% micro and 11% of rubber silica by weight fraction. Both glass and Kevlar woven mats were made by hand weaving and the composites were prepared during hand lay-up method. The fracture toughness results revealed that the exclusive addition of particles in epoxy reduces the strength and modulus but improved fracture toughness. Further tailoring the hybrid composite by adding rubber silica of 11 wt. % increased tensile and flexural modulus. The highest tensile and flexural strength of 275 and 162 MPa was observed for composite, which contains rubber silica as reinforcement at accumulated layer stacking sequence. The fractograph results revealed the dispersion of rubber additions and fracture characteristics of hybrid composites. These mechanically toughened epoxy composites could be used in high damping mechanical applications.

### I. INTRODUCTION

Glass fibers exhibit better tensile and compressive strength, and offers great resistance to chemical, heat, moisture, and fatigue properties. Glass fibers are also an excellent and economical. However, glass fibers have low impact strength, low strength to weight ratio and high density compared to other synthetic fibers. Therefore glass fibers are often combined with Kevlar fiber or carbon fiber. The favorable properties of Kevlar fibers are low weight, excellent strength to weight ratio, high impact resistance and great flexibility. Nevertheless, it has poor compressive strength, sensitive to moisture and relatively expensive. Hybridizing both

Glass and Kevlar fibers would produce a material, which has resistance and tolerance, high strength and light-weight but decreases its compressive strength. Since the compressive strength of polymer composites depends on the properties of the resin system, in the present research, a stiffer and tougher resin system was developed by incorporating fillers to provide better lateral support to the fibers and enhance the resistance to crack initiation and propagation. Arunprakash et al. [1] studied and concluded the effect of filler addition into glass-epoxy composite. They reported that the addition of iron(III) oxide particles along with E-glass fiber increased the tensile, flexural, impact laminar shear strength. Guru Raja et al. [2] investigates the performance of Glass fiber/Aramid fiber/Epoxy sandwich edge handle covers with different fiber introductions to portray the malleable properties. They confirmed that the ductile properties for 0°/ 90° orientation were more than ±45° & 60°/30° oriented composite. Thus, the 0°/90° orientation could be suitable in the field of Automobile, Marine, and Aerospace because of the conveying limit. Manjuna et al. [3] observed the table exhaustion properties of a glass fiber supported polymer (GFRP) with elastic molecule changed epoxy framework

They affirmed that the expansion of 9% weight of elastic miniaturized scale molecule in the epoxy network enhanced the weakness life of a glass fiber strength plastic composites by 3 times. The addition of 10% wt. of silica rubber particles in

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the epoxy grid of GFRP polymer demonstrates a relative impact in the wear properties. The break increased to a great extent in FRP polymer composites with crossbreed epoxy network, i.e. micro particles and silica rubber particles. Park et al. [4] fabricated a phosphoric acid solution treated Kevlar/epoxy laminated composites and determined mechanical, fracture, and impact energy properties. They are the chemical treatment significantly improved the degree of adhesion a faces between fibers and resin matrix, resulting in improve mechanical and interfacial strength with high fracture energy. Valencaet al. [5] evaluated the mechanical behavior of epoxy composite reinforced with Kevlar plain fabric and glass/Kevlar hybrid fabric. There from the mechanical tests showed that the structures developed with the hybrid material of Kevlar and glass fibers possess highest values of mechanical strength and specific stiffness. Liang et al. [6] found that the incorporation of rubber-fillers into polymer resin system and FRP composites improved the compressive behaviors of composite systems. Although in certain conditions, the compressive strength decreased with the increase of filler content, nevertheless the strength values were still higher compared to pure epoxies. Arunprakashetal. [7] indicated that addition of SS-304 and AL-6061 metal wire mesh into glass-fiber epoxy composite improve mechanical and drop act behavior of composite material. The inclusion of metal wire mesh along with glass fiber in epoxy matrix observed sudden impact energy under sudden load, which increased its stability. These literatures strongly indicated a better load bearing property of the rubber composites. The present research develop a new hybrid resin system which could be based on silica rubber particles, and micro for the fabrication of hand weaved hybrid Kevlar/glass fiber composites. The silica rubber particles could be used as filler, since it possesses high hardness, very high melting and boiling points and also high crystal line structure This silica could act as load observe ring polymer composites under external conditions. More over the cost and production of silica rubber particles are comparatively cheaper and easier than other types of particles. Similarly the micro filler material could be selected as The proposed fibre arrangements could be symmetric layering [GG/KK/KK/GG], alternate layering [GG/KK/GG/KK] and accumulate layering dispersant, since very lower density, high a brasion resistance, high ductility and cheaper in cost. The matrix could be modified by blending pure epoxy resin (E100) with micro and rubber silica (E80-S11R9) based on rule of mixture. The lamina of 3 layers could be arranged in a systematic manner as three stacking sequences. The laminate stacking sequences be designed based on the strength requirements. Since fibers play crucial role in load transfer, their system of arrangement needs to be analyzed well in manner.

## 1. Fabrication of Hybrid Laminates

The woven fabric form of E-glass (MIL-Y-1140H) and Kevlar 49 were prepared using handloom weaving method. In this both the yarns of specific quantities were taken for weaving with average roving diameter as 0.32mm. In glass fibre woven fabric weaving, both we and warp consist of similar glass fibre yarns and they were weaved by average speed of 1 square meter for every 8 h. Similar weaving trend was kevlar also but the time taken for weaving 1 square meter was near 9h. This incremental in time taken was because of high stretchability of Kevlar than glass fibre. The optical micro- scope image of warp and weft formation of glass and Kevlar fibre made by handloom weaving method

## 2. Preparation of Hybrid Epoxy Composites

The epoxy hybrid rubber composites were prepared using hand lay-up method in the size of 300mm×300mm, which contain eight layers of fiber layup. Nine sets of hybrid E-glass/ Kevlar weave fiber were made with virgin epoxy, epoxy blended micro (9 wt.%) and rubber silica (11 wt.%) and epoxy with micro (9wt%) to form the hybrid resin  
Experimental Work

## 3. Materials

The epoxy matrix used in this research was a liquid DGEBA (LY556, Huntsman India Ltd) with average molecular weight of 190 g/mol. Triethylenetetramine (TETA, HY951, Huntsman India Ltd.), a low viscosity amine with viscosity of 20 cps and density of 0.98g/cm<sup>3</sup> was used as curing agent. The Glass fibre (MIL-Y-1140H) of 344 GSM

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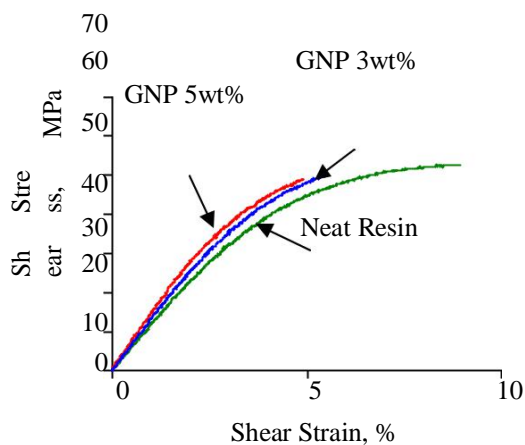
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and Kevlar (49) of 244 GSM were purchased from Fiber India Pvt. Ltd. Chennai, India. Rubber silica and micro of dimensions .

### Preparation of Modified Epoxy with Micro and rubber silica

Thermo mechanical blending method. In this the resin was pre-heated to the temperature of 80 °C and maintained at the temperature. The nano-silica of 11 wt.% was then dispersed into pre-heated epoxy resin and stirred thoroughly using a mechanical stirrer. The resulted colloidal suspension was then mixed with micro-rubber (CTBN) of 9 wt.% followed by gentle stirring for about 30 min. The particle's dispersion morphology in matrix medium was analyzed using a HR-TEM (FFT Tecnai 20, USA) at an accelerated voltage of 200 kV. The colloidal suspension was dissolved in Ethyl-acetate then a drop of sample was kept on the holy copper grid (200 mesh) and transmission images of particle dispersions were captured. The additional attachment for analyzing the elemental presentation (EDAX) also used for confirming the elements presents. Figure 1 shows the TEM image of micro rubber dispersed epoxy resin at 10 μm



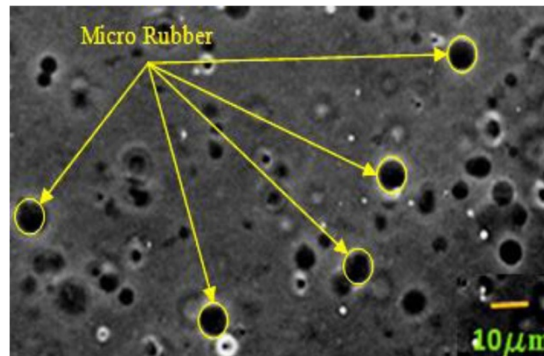
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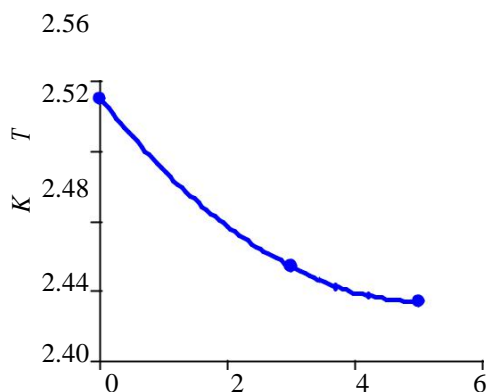
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## Tensile Properties

The stress strain plots for various composition and stacking sequences of prepared FRP laminates were shown in Fig. 6. The response curves reveal that there is difference in characteristic behavior among the samples for different loading conditions. It is observed that the additions of hybrid fibre and hybrid particles into epoxy resin increased the tensile strength and modulus. The tensile strength of virgin epoxy composite measures 165 MPa whereas additions of glass/kevlar hybrid fibre into epoxy resin increased its tensile and modulus along with nano silica. It is noted that the addition of micro rubber alone into epoxy resin decreased the tensile strength and modulus. This decrement in tensile stress and modulus is because of clustering effect of micro rubber, which could agglomerate and increase the stress concentration [10]. But addition of nano silica in epoxy composites gives very highest tensile strength of 275 MPa this is 40% of improvement. Similar improvements also were noted for various composites, which contain nano silica and micro rubber. The presence of nano silica acts as bridging element, which could transfer the load



Initial fiber misalignment was measured graphically at different sites of the specimens in the compression tests, and an effective fiber misalignment of  $4.0L (\pm 0.2L)$  was determined by averaging the measurements. It must be mentioned here that, since unidirectional composites are considered as transversely isotropic materials, throughout the thickness, fiber misalignment can be treated like in-plane misalignment using in-plane shear properties in the analysis. Thus, in this study, the effective misalignment angle determined was used in Eq. (3) and subsequently the  $s_{12}$  and  $c_{12}$  values satisfying Eq. (4) were obtained from the experimentally measured in-plane shear stress–strain curves in Figure 5. It is seen in Figure 6 that the calculated compressive strengths from this model compare fairly well with experimental results. Also, as shown in Figure 6, it is seen that, in order to improve the compressive strength further, the fiber misalignment must be reduced

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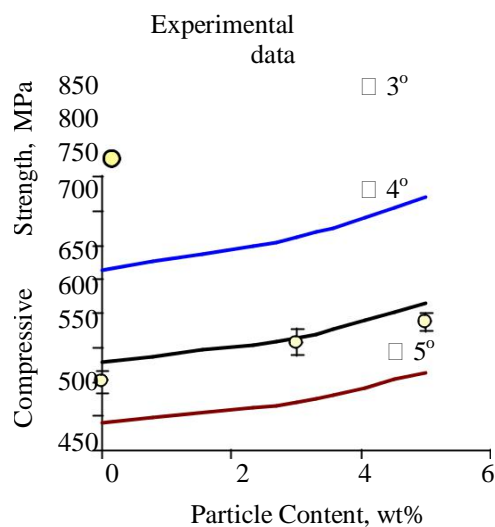
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## III. RESULTS AND DISCUSSIONS

Modulus of the Nano composite matrix and the resulting decrease in the shear stress concentration factor. It was also shown using a model that the compressive strength improvement results from the enhanced in-plane shear properties by the nanoparticles, and that this strength can be further improved by reducing the initial fiber misalignment.



The shore-D hardness graph of various composite tested. It is observed that sample A<sub>1</sub> measures hardness of 58.6 whereas A<sub>2</sub> and A<sub>3</sub> composite designations give higher average hardness value of 61.2 and 65.2. This is the improvement of 4.2% and 10% for composite designation A<sub>2</sub> and A<sub>3</sub> respectively. This is because additions of hard silica rubber particles, which gives high fracture modulus on composite surface. The improved hardness also attributes the cross linking effect of epoxy resin after addition of silica rubber particles. Since additions of oxide.

## IV. CONCLUSION

Hybrid Kevlar/glass fiber composites for high load withstanding application. The stacking sequence and orientation of fiber influences the mechanical behavior of E-glass/Kevlar hybrids at axial and bend loading conditions. The mechanical properties of hybrid E-Glass/Kevlar composite with Nano silica and micro rubber found to be higher than composites contain only fiber reinforcement. The fracture toughness results explicated that the combination of E Glass/Kevlar composite with micro rubber epoxy is of higher value than plain epoxy and hybrid Nano silica/micro rubber epoxy. The stacking sequence of [(0°, 90°)/(0°, 90°)]<sub>4</sub>S GG/GG/KK/KK was found to be giving good mechanical properties than other stacking sequences. The SEM fractograph revealed interfacial cracking phenomenon in various composites. The composite, which contain hybrid glass/kevlar fiber and Nano silica of 11 wt.% possesses greater interfacial bonding than other composites. These fracture toughness and mechanical strength improved epoxy hybrid composites are highly preferred in automobile body manufacturing, machinery lateral body manufacturing, aircraft vehicle manufacturing industries, structural, electronic components (computer bodies) and domestic sectors. As a future research, surface modification of various reinforcements using Sic coupling agent could be performed for knowing the effect of interfacial bonding behavior between matrix and fiber and their importance in mechanical properties. Also the sudden impact failures in laminates and wear resistance of epoxy composite could be analyzed with

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inclusion of metal wire-meshes of various ductile materials such as stainless steel, aluminum and copper in surface-modified condition

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