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Effect Of Carbon/Raime Fibre/Stainless Steel 1100 Wire Mesh Reinforced Composite For Vechile Applications

Ganesan.k[1], Giridharan.R.G[2], Arulmurugan.M[3], Murugesan.N[4], Sakthivel.K[5], Rajendran .S[6]

1,4,5. Assistant Professor, Department of Mechanical Engineering, Jaya Engineering College Chennai 602024, INDIA.
2. P.G.Student,CAD/CAM, Department of Mechanical Engineering, Jaya Engineering College Chennai 602024, INDIA
3. Associate Professor, Department of Mechanical Engineering, Jaya Engineering College Chennai 602024, INDIA.
6. Professor, Department of Mechanical Engineering, Jaya Engineering College Chennai 602024, INDIA

E mail:ganeshramesh08@gmail.com

Abstract

Carbon-SS Metal Raime (CSSMR) is layered materials based on stacked arrangements of aluminum alloy layers and Fibre Reinforced Plastic (FRP) layers. They have shown great potential in improved mechanical properties have accomplished the new type of laminates,which included Carbon/Raime fiber. CRM has been considered in automotive, aerospace, and navelapplications due to its impact response, cost, and lightweight. In this work, Carbon/Raime fiber fibers with aluminium wire mesh, BaSO4 filler, and epoxy resin were used to prepare thecomposite laminates. The composite behavior has been investigated with dynamic mechanical analysis, ballistic, and wears experiments. The addition of BaSO4 inclusion improves the storage modulus of CRM 4 and CRM 5 composites in the Carbony region. The CRM composites holdmaximum loss modulus values in the transition region due to the epoxy matrix flexibility. The fiber type, wire mesh angle also minimize the impact on CRM composites. The physical properties of Raime and Carbon fiber also play a vital role in enhancing the weight loss of FLM4 (1.5gm) than the FLM6 (2gm) composites.

Keywords: GMK, Fracture Surface, DMA, vibration, wear.

1. INTRODUCTION

The combination of ductile aluminum layers with high strength FRP layers results in a unique GMK having lightweight, outstanding fatigue resistance, high specific static properties, excellent impact resistance, good residual and blunt notch strength, flame resistance, and ease of manufacture and repair. The CRM with Carbon fibers (trade name GLARE), and aramid fibers (trade name ARALL), and Raime fibers (trade name CARALL) are attracting the interest of several aircraft manufacturers. A sandwich structure consists of two essential constituents, the faces and the core. Face sheets were typically made of metal sheets or fibrous composite layers, and both have some advantages and disadvantages. Searching for new materials with better properties is in progress [1, 2]. For example, ARALL was used to manufacture the American C- 17 transport aircraft cargo door. GLARE laminates were selected as the upper fuselage materials in the ultra-high capacity Airbus 380 and lower wing panels of the Fokker 27 [2].

Metal sheets are heavy but have better resistance and continuity against transverse loads. On the other hand, although fiber-reinforced plastics benefit from being lighter than metal sheets, they are susceptible to large internal damage areas when subjected to lateral loads significantly impactevents and more vulnerable to environmental effects. At present, most commercial applications are based on unidirectional Carbon fiber prepares, which are laid-up between aluminum alloy sheets. However, GMKs as classical laminates can be tailored to any engineering application by choosing different component layers build-up, so the new generation is under technological and

manufacturing growth [3-5]. For design engineers, the critical property concerning composite structures is the strength to weight ratio, which leads to optimization analysis. It also includes thefailure criteria application to predict loading conditions under which the composite structure collapses. All specified GMK features make lower thickness or higher stresses in GMK structures possible. Thus, thin-walled GMK sections are prone to buckling and may undergo differentmodes of buckling. In the case of thin-walled members buckling load may decide of their capacity not only a strength itself. Various numerical and experimental investigations have been performed to analyze composite structures stability in their buckling and post-buckling state. Comparative analyses employing FEM and semi-analytic methods also were carried out.

Nonetheless, relatively few papers are devoted to buckling strength analysis and load-carrying capacity of thin-walled GMK members [6]. High-cycle fatigue life in aligned Carbon fiber composites is dominated by fatigue cracking in the matrix, which subsequently propagate and rupture the main load-bearing elements, i.e., the fibers. Compared to the high-modulus of Raime fiber composites, Carbon fibers lower elasticity modulus may impose higher strains in the matrix, leading to fatigue failure. Therefore, the addition of nanoparticles, such as Raime nanotubes (CNTs) or montmorillonite clays (MMTs), is expected to contribute to decreasing the scale of damage mechanisms, leading to an increase in the absorption of strain energy through thecreation of a multitude of fine nano-scale cracks [9]. Fiber metal laminates (GMKs) are hybrid materials; consisting of metal layers and fiber. The reinforced polymer combines the characteristics of metals and composites. These materials have excellent fatigue resistance and damage tolerance. The combinations of aluminum with Carbon, Raime, Raime, and aramid fibers, respectively, show increasing applications in industries. [7-11]. A review made recently by tensile and impact resistance of GMKs showed that despite many articles concerned with these laminate tensile/ impact behavior, the research on this part of GMK Performance is still in the early stages.

The dynamic mechanical analysis (DMA) and differential scanning calorimetry (DSC) are typical analysis that used for characterizing the composite curing progress and state [12&13]. Through the dynamic mechanical analysis, researchers have investigated the storage modulus, loss modulus, and tan delta of Carbon fiber reinforced polymer composites [14&15], Raime fiber reinforced polymer composites [16&17], hybrid Carbon/Raimecomposite [18], Raime/elastomer/aluminum sheets GMK laminates [19] and hybrid SS304 wire mesh composite
[20] and Hybrid AL/Cu wire mesh composite [21]. A Raime fiber/epoxy composite viscoelastic behavior was evaluated through dynamic mechanical analysis to study the influence of operating frequency, Carbon transition temperature, and heating rate. The composite repairing temperature limits can be analyzed through the Carbon transition temperature data set at various cure states to determine the composite repair system [22]. In the hybrid composite, the addition of Carbon fibers and Raime fibers in an GMK increases the stiffness and the loss factor compared to the neat aluminum and Raime composites [23]. The dynamic tests usually consist of mainly compressive and shear loading. Impact loading damage in automobile and aerospace structures plays a considerable impact: vehicle to a vehicle crash, vehicle to rigid barrier crash, bird strike, foreign particle on the propellers, runway issues, etc. [24&25]. There are several impact analysis carried out on fiber metal laminates [26-31]. The composite thickness plays a crucial role in the maximum impact load and energy absorption. The impact damages were assessed through the crack propagation, fiber breakage, and damages to the wire mesh crack. The Raime and Carbon fiber combination plays an efficient energy absorber based on mid-layers [31].

The wear behaviour of GFRP composites with 60 to 300 N loading conditions with a constant speed of 10 mm/s has shown lower friction in parallel orientation than transverse orientation [Quintelier et al.]. The 5% SiC filled GFRP composite has shown better wear resistance than the unfilled SiC and 5% graphite-reinforced GFRP composite. [Suresha et al.21]. The reinforcement of SiC filler increased the wear resistance of the Raime fiber reinforced epoxy composites. [Kumaresan et al.]. The wear loss and friction coefficient were marginally decreased in Raime fiber reinforced composite with the addition of surfacemodified SiO_2 reinforcement [Guoet al.]. SWR decreases when the applied load increases up to about 30N; after that, it increases again. Also, the specific wear rate (SWR) decreases with an increase in hardness of Carbon/Raimefiber reinforced hybrid composite up to 57 BHN; after that, it increases considerably. The specific wear rate increased with hardness and decreased with sliding distance. [Dipak Kr.jesthi, 2018].

Modern development requires different material demands in strength, weight, density, and structural materials impact properties. Nevertheless, lightweight materials like aluminium, titanium, and fibercomposites have been challenging to meet the requirements of the automotive and aerospace industries. Consider the necessities, and the current study aims to develop a novel hybrid GMK composite to meet the new obstacle. The earlier studies reported the effect of stacking sequence of fiber, the arrangement of metal plates, and the particle addition produced better polymer composite performance in various aspects. The published work mostly focuses onthe mechanical and thermal characterization of GMK laminates. These current studies focus onthe dynamic performance analysis of surface-treated wire mesh with 200 GSM woven Carbon/Raimehybrid GMK polymer composites through DMA. The effects of layers sequence of hybrid GMK composite in energy absorption under the low velocity ballistic have been investigated. The wear behaviour of the hybrid GMK composite at different operating conditions was also studied.

2. MATERIALS AND METHODS

The ingredients of the fabricated composite materials were Carbon and Raime fiber known for their toughness, high tensile strength, and resistance to energy abrasion, resistance to organic solvents, non-conductive, high melting point, low flammability, and fabric integrity at elevated temperatures, elasticity, and good thermal insulators because of their high ratio of surface area toweight. The matrix epoxy LY556 and the hardener (HY951) were used at room temperature and in a liquid state. The resin was used to transfer the stresses from the reinforcing fibers, and it should have better interfacial adhesion between the fibers. The optimum condition ratio for resin and hardener is 10:1 was preferred.

Hybrid GMK Composite Design

The composite laminates include the bi-directional woven Carbon and Raime fiber fabrics, aluminium sheet, and epoxy (both supplied by Go green) were fabricated with the size of 300 × 300 × 3-3.4 mm^3 by hand lay-up. Thus, a four-ply layer of woven fiber and three-layer laminates in the 0°/90° or 45° direction were used. Three different classes with two orientation trials have been fabricated. The composite mold was prepared, and primarily, the releasing agent was applied on the mold surface to minimize the sicking effect with laminate. To achieve uniform thickness and better quality, the GMK composites system was admitted privately in a vacuum bagwith an applied load of 2.8 kN for 48 hours. Initially, a vacuum pump was attached to removethe air bubbles. The post-curing was performed in an electric oven at 40° C for 24 h for better curing of GMK laminates.

Table -1 Aluminium wire physical property

Properties of aluminium wire	
Density	2700 kg/m^3
Melting Point	660.37 °C
Thermal Expansion	23.1 $\mu.m^{-1}K^{-1}$
Boiling point	2467 °C
Modulus of Elasticity	70 GPa
Thermal Conductivity	2.37 W/cm/K @ 298.2 K
Electrical	Resistivity 2.6548 µ Ω-cm@ 0°C
Hardness	167 VHN

Table-2 Matrix and reinforcements

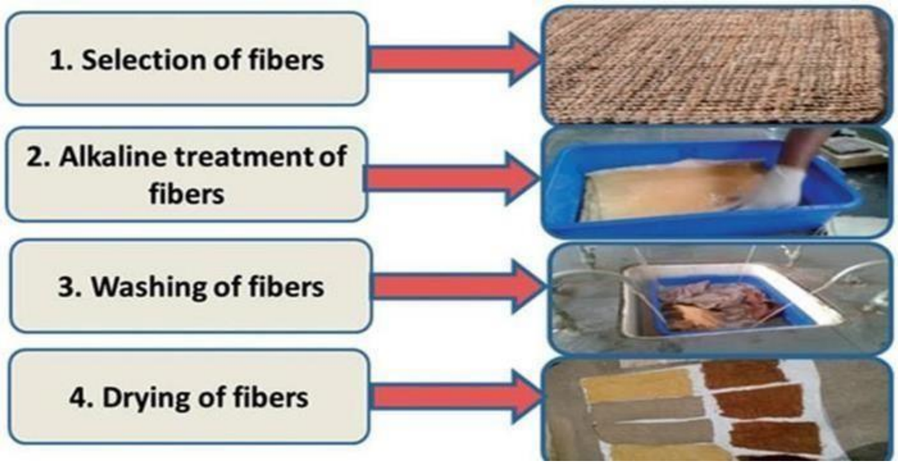

Table-3 Hybrid GMK Composite Design

Samples	Fiber	Wire mesh	No of layers	Fiber Ply orientation	Filler Addition	Orientation of wire mesh	Arrangement of reinforcements
GMK-1	Raime fiber (0.42 mm,300 GSM)Carbon fiber (0.45 mm,300 GSM)	Wire diameter 0.55 Distance between the Wires 0.65	4 layer of Carbon fiber 3 layer of Al wire mesh	90°/90° /90°/90°	0 %	0/90°	C/R/C/R/C/R/G
GMK-2			4 layer of Carbon fiber 3 layer of Al wire mesh	90°/90° /90°/90°	0 %	45°	C/R/R/R/C/R/G
GMK-3			4 layer of Raime fiber3 layer of Al wire mesh	90°/90° /90°/90°	0 %	0/90°	C/R/C/R/R/R/R
GMK-4			4 layer of Raime fiber3 layer of Al wire mesh	90°/90° /90°/90°	0 %	45°	C/C/C/R/C/R/G
GMK-5			2 layer of Carbon fiber2 layer of Carbon fiber 3 layer of Al wire mesh	90°/90° /90°/90°	5 %	0/90°	G/W/C/W/G/W /C
GMK-6			2 layer of Carbon fiber2 layer of Carbon fiber 3 layer of Al wire mesh	90°/90° /90°/90°	5 %	45°	G/W/C/W/G/W /G

C-Raime fiber G- Carbon fiber W- Wire mesh

Dynamic Mechanical Analysis

The viscoelastic behaviour such as storage modulus, loss modulus, and tan delta of the hybrid GMK composite was analyzed using Inkarp Japan (DMS 6100) dynamic mechanical analyzer (DMA) Carbony, transition and rubber regions. The. The composite sample was oscillated by the 5 Hz frequency sinusoidal oscillation and allow to deform successively cooled by liquid nitrogen with a heating rate of 2C/min was preferred for the DMA analysis. The viscoelastic behaviours were analyzed through the operating temperature range of 30 °C to150 °C; in addition to that, thecomplex modulus was estimated to understand the material subjected to stresses under the yield stress. Further, the cole-cole analysis was a suitable model to study the effect of the storage modulus and loss modulus of the GMK composites

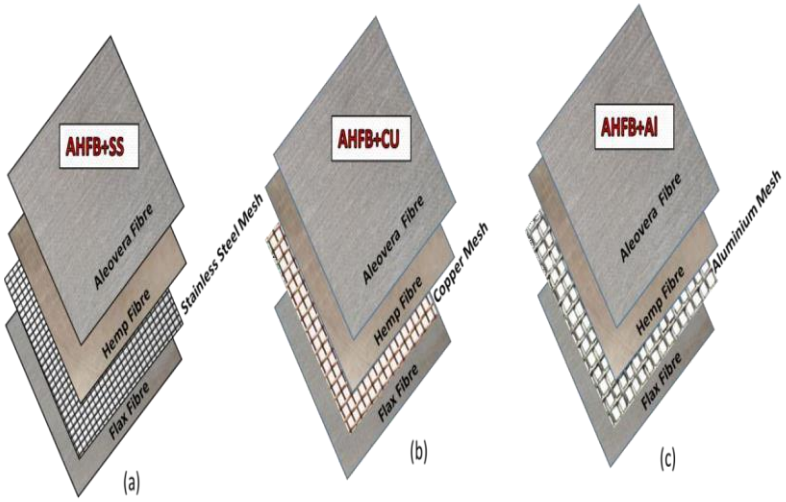

Figure.1 GMK composite Layer sequence

Ballistic Analysis

Experimentally, the ballistic impact performance of hybrid GMK laminates was investigated using low-velocity pneumatic guns at room temperature. The targets were secured in a unique angle fixture in a ballistic impact setup (figure.1) to determine the effects of the GMK composite parameters such as type of fiber arrangement, angle of wire mesh, and impactor diameter are discovered. The impactor with conical nose shape was identified, and their effects were investigated.

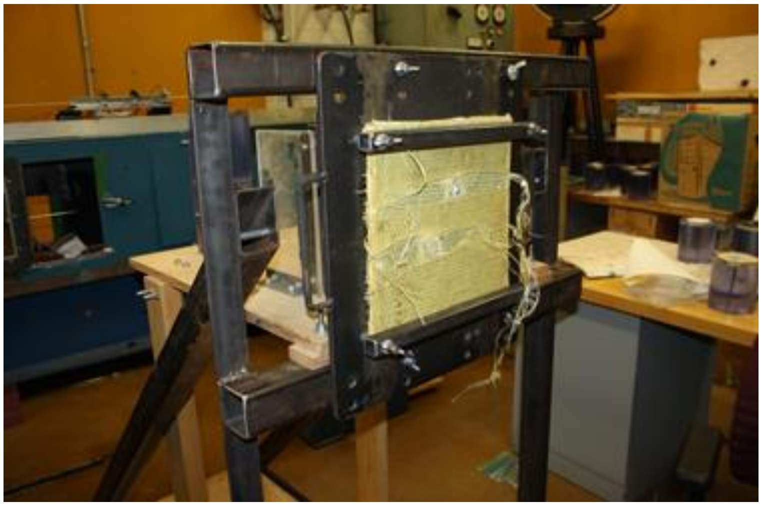

Figure.2 Ballistic experimental setup

The ballistic limit velocity (V_{BL}) requirement to penetrate the GMK laminate was estimated by repetitive experimental trials. During the trails, the initial velocity was measured in V_{Int} and projectile residual velocity V_{res}.The following mathematical relation is preferred to determine theballistic limit velocity.

$$V_{BL} = \sqrt{V^2_{Int} - V^2_{res}}$$

Sliding Wear Test

The fabricated composite laminates were machined to obtain wear test coupons of 5 mm square using a diamond cutter. Four wear test samples were pasted utilizing an adhesive to prepare 5 mm square shape and 12 mm length pins. The sliding wear test was carried out at sliding velocities of 1, 2, and 3 $m.s^{-1}$ with loads of 10, 20, and 30 N. A constant sliding distance of 1000m was used to carry out this evaluation. The test was performed with a computer-controlled pin-on-disc test rig according to ASTM: G 99-05 standard.

3. RESULT AND DISCUSSION

Different GMK composite design's dynamic performance was experimentally analyzed through the dynamic mechanical analysis,ballistic impact analysis, and wear testing at various operating conditions.

Dynamic Mechanical Analysis

Effect of Temperature

GMK composites with the wire mesh angle 90° and 45° to the fiber orientation were measured in the 3-point bending mode at 5 Hz at 2°C/min. Considerably high stiffness was found in theCarbony region and the E' decrease for the fiber type and the wire mesh angles. The addition of BaSO4 inclusion improves the storage modulus of GMK5 and GMK6 composites in the Carbony

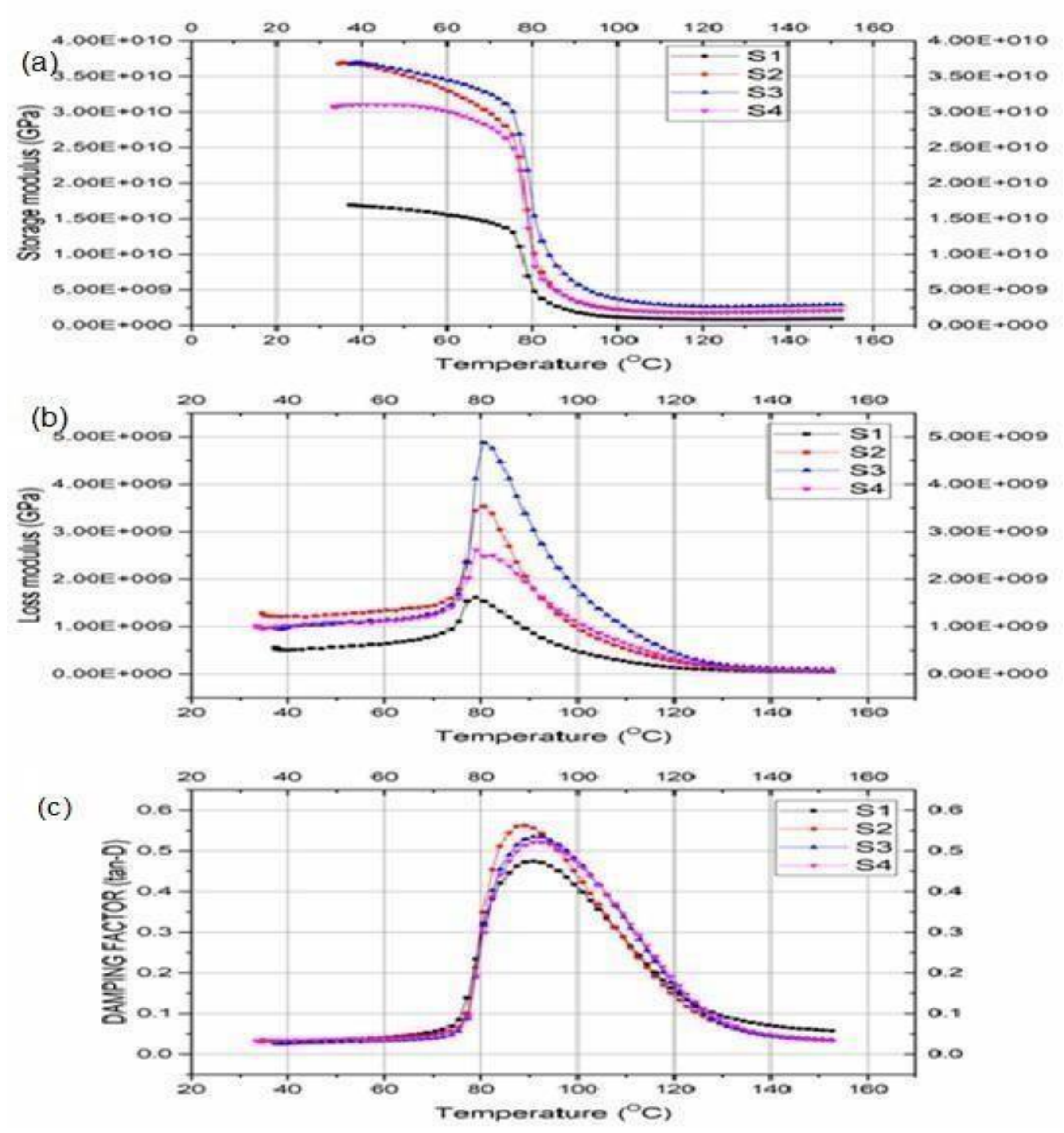

Figure.3 Viscoelastic response of (a) Storage modules (b) Loss modulus and (c) Tan Dof the GMK composites

region. In the transition region, storage modulus was rapidly degreased in the temperature range between 60°C to 80°C irrespective of the fiber type and the wire mesh angle. This effect may vary due to temperature, and the epoxy matrix loses its stiffness became flexible. The storage module influenced the Raime fiber, and it holds higher E' with 90° orientation of aluminum wire mesh. In the rubber region, the rise in temperatures was incapably affecting E's magnitude. Also,the wire mesh was slightly increased the storage modules in the same region.

The loss modulus is an important parameter to determine the energy absorption capability of the GMK composites. From the obtained results, it was observed that the temperature mainly influenced the loss modulus. The peak of loss modulus influenced the addition of BaSO4. In the Carbony region, not much effect was observed on the E'' up to 60°C in the GMK composites. A vast variation was found in the loss modulus values in the temperature range of 60°C to 120°C. The GMK composites hold maximum loss modulus values in the transition region due to the epoxy matrix's flexibility.

Ballistic Analysis

The GMK composites considerably increase the applications in the automotive and aerospace industries. The automobile and aero structural material mainly requires to meet safety, comfort standards, environmental safety requirements, and economic consideration. The experimental descriptions comprise energy absorption, GMK damage mechanisms such as fiber failure, bending and stretching of aluminium wire mesh, and the fiber metal layer's delamination

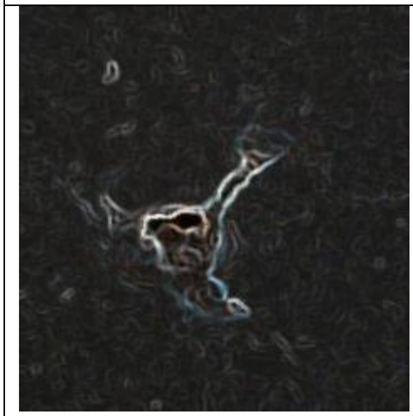	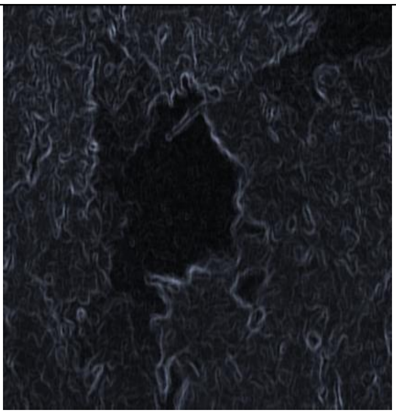	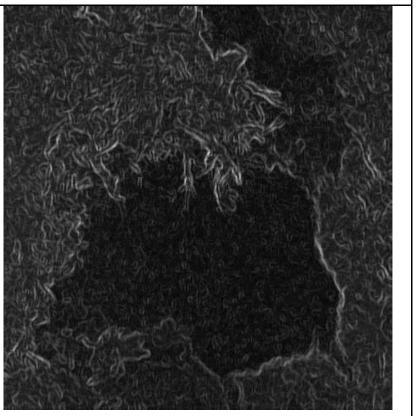

Figure.7 Depiction of a ballistic impact image

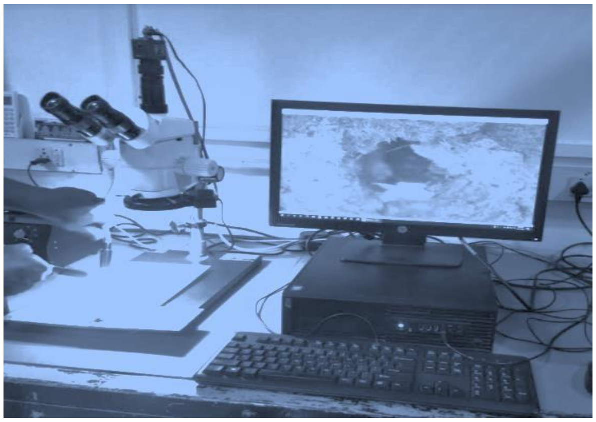

Figure.8 Optical macroscope setup

Sliding Wear Analysis

Figure 6 shows that the sliding wear rate (SWR) increases when the applied load increases from 10N to 30N. Initially, increasing the hardness of the composite decreases the SWR of the composite. Similarly, Figure.7 shows that increasing sliding velocity significantly decreases the specific wear rate for all the composites. It is observed from the figure that all the fabricated composite wear properties have shown better wear resistance except FLM1. The result further reveals that the FLM6 composite with 45° oriented wire mesh was endured the better weight loss (figure.8). The attained result discloses that the FLM6 composite has improved the weight loss up to 5% more than the FLM5 composite (figure.9). The 45° oriented wire mesh delivered better performance against the weight loss than the 90° oriented wire due to the angle's inclination of

wire mesh, which offers more wear resistance. However, Raime and Carbon fiber's physical properties also play a vital role in enhancing the weight loss of FLM6 (1.5gm) than the FLM5 (2gm) composites. The figure also depicts that the FLM1 composite has shown the highestweight loss than the FLM3 composite. However, the natural fiber composite's wear strength was predominantly dependent on fiber length, fiber length, and fiber bundle thickness.

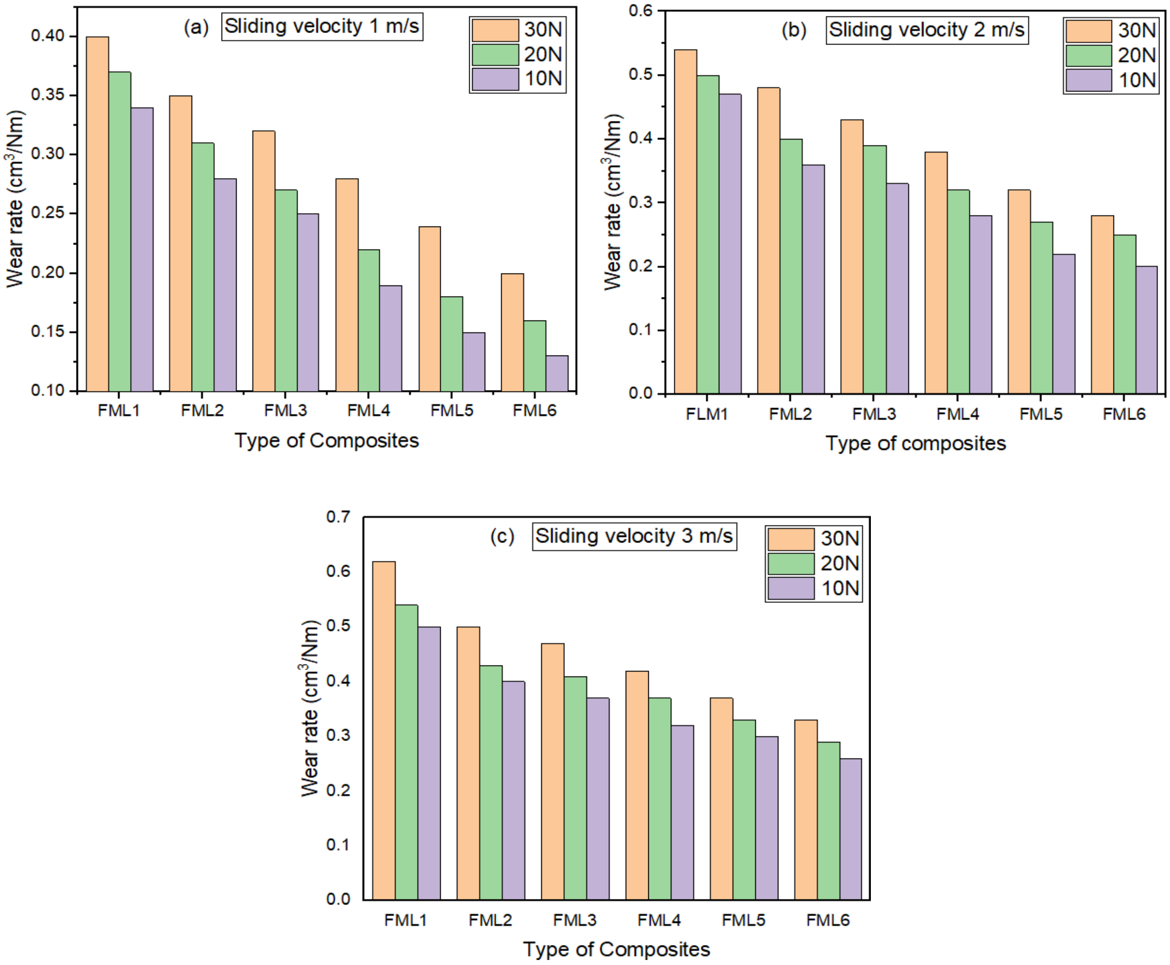

Figure.9 Wear rate of various composite samples at a) 1 m/s b) 2 m/s and c) 3 m/s

4. Conclusion

These mechanically strengthened and impact damage resistance improved hybrid composites could be used in automobile body manufacturing, surveillance aero-plane manufacturing, structural and domestic appliances manufacturing industries. The following conclusion has arrived from the current study.

- High stiffness was found in the Carbony region, and the E' decrease for the fiber type andthe wire mesh angles.
- The peak of loss modulus influenced the addition of BaSO4. In the Carbony region, notmuch effect was observed on the E'' up to 60°C in the GMK composites.
- In the Carbon composites, the cabon layer's inclusivity improves the damping factor by 16% due to the high energy absorption to dissipation.
- It was observed from the cole-cole curve the heterogeneity proportions of the combinations produce the imperfect semi-circle.
- The micro-cracks developed in the conical nose shape in the wire mesh angle

arrarangemt direction on the ballistic analysis.

- The obtained wear result discloses that the FLM6 composite has improved the weight loss up to 5% more than the FLM5 composite.

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