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Studies On Wear and hardness Properties of Kevlar/E-Glass/Epoxy with SiC Reinforced Polymer Matrix Composites

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Abstract: Over the last twenty to thirty years' composites materials has been used in engineering field. Composite materials possess high strength and high strength to weight ratio, and due to these facts composite materials are becoming popular among researchers and scientists. Wear test is one of the prime characteristic investigation test for determining the tribological behaviour of material under surface sliding and erosion. In the test sliding wear mechanism is adopted to study the material degradation under slides or contact surface using Pin-on-disc apparatus, in which materials are tested under dry sliding non-abrasion condition. Tribological characteristics of hybridized polymer matrix nano composites is determined by subjecting the composite specimens to sliding wear on Pin-on-disc sliding wear testing facility, the wear rate and co-efficient of friction were determined on ASTM G-99 Hardened steel disc, placing the fiber orientation of the composite specimen in parallel and normal to the sliding direction. The test was conducted on three samples of each composite specimen with different percentage integration of SiC viz, 0% 0.5%, 1.0% and 1.5% volume fraction of SiC reinforcement in composites under different loads.

Keywords: Kevlar, SiC, Eglass, Wear and Hardness..

I. Introduction

The composite material is a 'material system' composed of a combination of two or more micro or macro constituents that differ in form, chemical composition and which are essentially insoluble in each other. Composites are one of the most applicable and adoptable engineering materials. Progress in the field of the materials science and technology has given the birth to these fascinating and wonderful materials. A composite material is a superior mechanical and physical property, the reason behind this, it combines the most desirable properties of its constituents and suppressing their least desirable properties. At present composite material play a key role in automobile industry, aerospace industry, marine industries and other engineering applications as they exhibit outstanding mechanical properties like, strength to weight and modulus to weight ratio.

In present days' fibre-reinforced composite (FRC's) materials are widely used in various engineering applications including aviation, automotive and engineering structures due to their high stiffness, strength, lightweight and damping properties. But, in an impact event, several damage types occur in composite materials such as matrix cracking, delamination and fibre breakage.

Consequently, the mechanical behavior of the laminated composite materials is an important phenomenon to be studied. The brittle nature of most fibre-reinforced polymer (FRP) composites accompanying other forms of energy absorption mechanisms such as matrix cracking, fibre breakage, debonding at the fibre–matrix interface and especially plies delamination, play important roles on progressive failure mode and energy absorption capability of composite structures. The greatest advantage of composite materials is strength and stiffness combined with lightness. By choosing an appropriate combination of reinforcement and matrix material, manufacturers can produce properties that exactly fit the requirements for a particular structure for a particular purpose.

Currently, composites are used extensively in consumer products and building materials (in addition to the traditional industries) as a light weight, cost efficient alternative to metals. Parts as large as passenger aircraft fuselages are being constructed as a single unit from composite materials. A composite material is a combination of two materials with different physical and chemical properties. When they are combined, they create a material which is specialized to do a certain job, for instance to become stronger, lighter or resistant to electricity. They can also improve strength and stiffness, composites provide corrosion resistance, they're often used in chemical manufacturing plants, for example, as glass-fibre reinforced polymer ductwork. You'll also find composites in air-pollution control, mineral processing, mining, oil and gas, solid waste landfill and water treatment industries.

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Fibre reinforced composites are being new generation composites. Because the composites have light weight and eco-friendly nature, natural and synthetic fiber are the another type of composites and these composites are the center of attraction for industries over traditional composites, but the reinforcing fibers are being resulted in high cost of composites, therefore to counter the issue researchers have initiated the idea of hybridizing the composites with different reinforcing elements such as high modulus and low modulus fibers used together in required orientation to meet the strength requirements of material.

The polymers are classified into two categories; natural and synthetic (glass fiber, carbon, and aramid) fibers. These natural polymer composites are not used as component of automobiles, ships, and structural applications, but they do provide desirable properties such as high-strength to weight ratio, ease of fabrication, complex shapes, low cost, and good resistance to corrosion and marine industry. The lightweight composites can enable energy savings in applications where large amounts of energy use and carbon emissions occur in the use phase, such as fuel savings in lighter-weight vehicles.

Composites Technology is an immersive, nationally accredited program that teaches students to design and build with advanced materials like carbon fiber and fiberglass, preparing them for careers in exciting industries from maritime to automotive to sporting goods to wind energy and beyond.

Kevlar fibers have very good impact resistance characteristics

Both Kevlar fibers and E-Glass fibers have very good energy absorption capacity.

Hybridizing or integrating both Kevlar and E-glass fiber laminates tends to reduce damage area.

The Nano filler SiC/AlO2/MWCNT particulates improves the physical and mechanical properties.

II. EXPERIMENTATION

2.1 Material selection

Fabric Determination may be a pivotal assignment to plan and create the novel competitive composites, possessing the best-in-class properties and highlights. Within the investigate work, most extreme care has been taken in selecting the proper materials in arrange to meet the targets of the inquire about project.

In depth study in crucial areas of technology and hi-tech applications, high performance composites are desirable to meet the functional requirements. Therefore, synthetic fibrous reinforcement was marked with high-quality epoxy resin to meet the requirements. Also, for further strengthening of composites filler material Silicon Carbide (SiC) particulates was used.

Characteristic details of elements of hybrid composites are as follows:

1. Kevlar Fiber(200GSM) in fabric form.
2. E-Glass Fiber (190GSM) in fabric form.
3. Epoxy Resin LY 556 and Hardener HY 951.
4. Silicon Carbide in Powder form.

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2.2 Fabrication Technique

Composites laminates were manufactured by hand layup process and Vacuum bag molding technique. The prime objective of using these techniques is, the hand layup process is only process where high reinforcement to matrix ratio can be obtained under fully controlled conditions, because of the direct human interference in the fabrication process, also in this process, there are significantly less chances of resin starvation or interlaminar debonding, as the optimum/ required wetting or resin can be applied on the reinforcement fibers resulting in high strength to density ratio. As matrix material is basically performing the task binding the reinforcement elements and uniformly distributes the loads acting on the composite structure, so composites designer always tends to minimize the matrix material and use more reinforcement material to obtain the high strength for the unit volume/ weight of the composite.

2.3 Wear Test

Wear test is one of the prime characteristic investigation tests for determining the tribological behavior of material under surface sliding and erosion. In the test sliding wear mechanism is adopted to study the material degradation under slides or contact surface using Pin-on-disc apparatus, in which materials are tested under dry sliding non-abrasion condition.

In the test the tribological parameters such as coefficient of friction, wear rate and temperature were studied under the influence of sliding wear.

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In recent years for a decade or two, polymeric materials are widely being used in various friction units due to their excellent properties such as, low density, good mechanical properties, high resistance to wear, high irradiation resistance, chemical inertness, self-lubricating properties and easy manufacturability etc. In order to enhance the tribological and mechanical properties, reinforcement is done is systematic and controlled conditions by regular orientation in case of continuous fibrous reinforcement and particulate reinforcement by uniform dispersion.

Various high-performance fibers have been used as primary reinforcement in FRP composites, and inorganic carbon fibers (CF) and organic aramid fibers (AF) that own excellent mechanical properties and favorable dispersion in polymers are the main candidates. Polymers, e.g., epoxy, polyamide, polyacrylate and polyetheretherketone (PEEK), are increasingly used for developing anti-wear composites and coatings, owing to their lightweight, flexibility, excellent corrosion resistance, good process ability and low cost, compared to metals and ceramics.

2.3.1 Specimen preparation and mounting for Sliding Wear Test:

To evaluate the performance of these composites under dry sliding condition, wear tests are carried out in a pin-on-disc type friction and wear monitoring test rig (supplied by DUCOM) as per ASTM G 99. The experimental set up is shown in Figure 1. The counter body is a disc made of hardened ground steel (EN-32, hardness 72 HRC, surface roughness 0.6 Ra). The specimen is held stationary and the disc is rotated while a normal force is applied through a lever mechanism. A series of test are conducted with constant sliding velocity 1m/sec under three different sliding distance of 500m,1000m and 1500m under constant load of 20N.

According to the ASTM standard ASTM G-99 for pin on disc sliding wear test, fiber reinforced composites specimen architecture is as shown below.

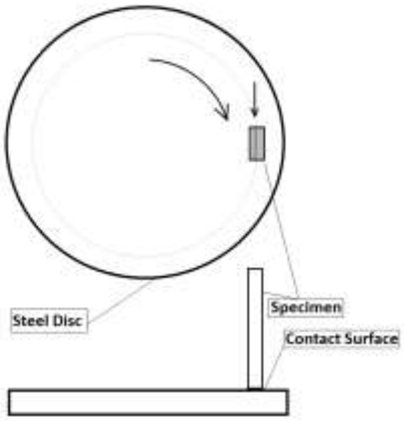

Fig 1: Sliding wear surface contact mechanism

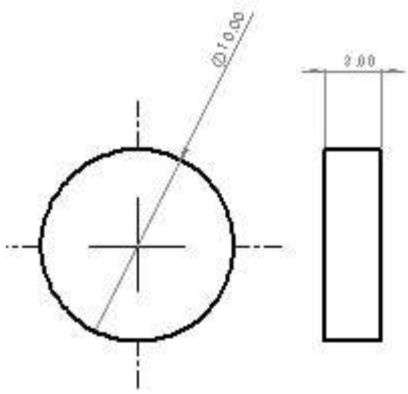

Fig 2: Specimen geometry for wear test.

Fig 3: Experimental Setup of Pin and Disc

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2. 4 Hardness Test

The hardness of a material is defined as its ability to withstand localized permanent deformation, typically by indentation. Hardness may also be used to describe a material's resistance to deformation due to other actions, such as:

- Cutting
- Abrasion
- Penetration
- Scratching

The type of deformation under consideration when measuring hardness is plastic deformation. In other words, the object or material will not return to its original shape after being deformed, unlike elastic deformation.

Hardness is used in numerous engineering design applications. This property is essential as it directly correlates to the material's performance and suitability. For example, a component's resistance to wear generally increases with increasing hardness. This is especially important for mechanical equipment with moving parts, like flooring material, elevator shafts.

2.4.1 Shore D Hardness Test as per ASTM D2240 Standard

Needle-like indenter of the spring load. Shore scales ordinarily measure the hardness of polymers (rubbers, plastics). For estimating delicate elastomers (rubbers) and other delicate polymers, the Shore A scale is utilized. The durability is determined by the Shore D size of hard elastomers and most other polymer materials (thermoplastics, thermosets). Ocean hardness is estimated with the Durometer instrument. An indenter stacked by an aligned spring is utilized by Durometer. The hardness estimated is characterized by the profundity of entrance of the indenter underneath the heap. For two Shore scales (A and D), two unmistakable indenter shapes (see the picture beneath) and two particular spring loads are utilized. Shore A stacking power: 822 g (1,812 lb), Shore D: 4536 g (10 lb). The estimation of shore hardness can fluctuate in the 0 to 100 territories. For each size, the general entrance is 2.5-2.54 mm (0.097-0.1 inch).

Fig 4: shore D Durometer

III. RESULTS

3.1 Wear Test of Kevlar E-glass and epoxy SiC Reinforced Polymer Matrix Composites.

Tribological characteristics of hybridized polymer matrix nano composites is determined by subjecting the composite specimens to sliding wear on Pin-on-disc sliding wear testing facility, the wear rate and co-efficient of friction were determined on ASTM G-99 Hardened steel disc, placing the fiber orientation of the composite specimen in parallel and normal to the sliding direction. The test was conducted on three samples of each composite specimen with different percentage integration of SiC viz, 0% 0.5%, 1.0% and 1.5% volume fraction of SiC reinforcement in composites under different loads. The data Obtained from test was used to calculate the wear rate and coefficient of friction in composites under dry wear condition.

Sl. No.	%SiC	Sliding Distance (m)	Load (Kg)	Wear Rate
1	0	500	2	**19.955**
2	0	1000	2	**22.23**
3	0	1500	2	**24.505**
4	0.5	500	2	**15.23**
5	0.5	1000	2	**16.46**
6	0.5	1500	2	**15.25**
7	1	500	2	**11.68**

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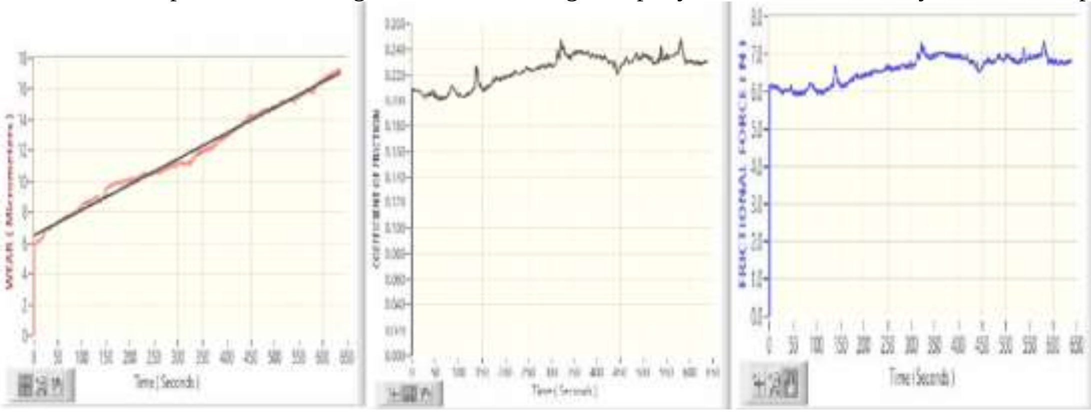
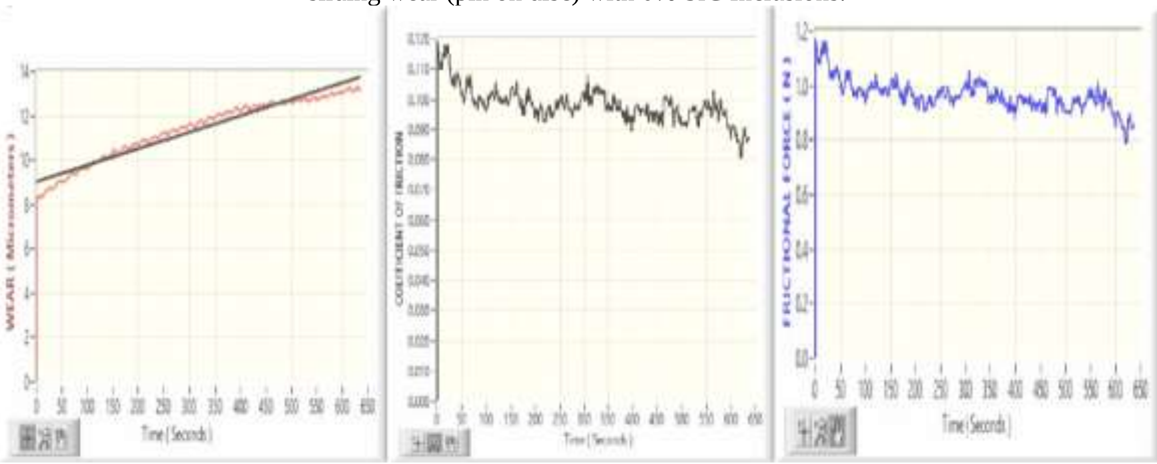
8	1	1000	2	**13.21**
9	1	1500	2	**12.12**
10	1.5	500	2	**9.3**
11	1.5	1000	2	**10.36**
12	1.5	1500	2	**10.3**

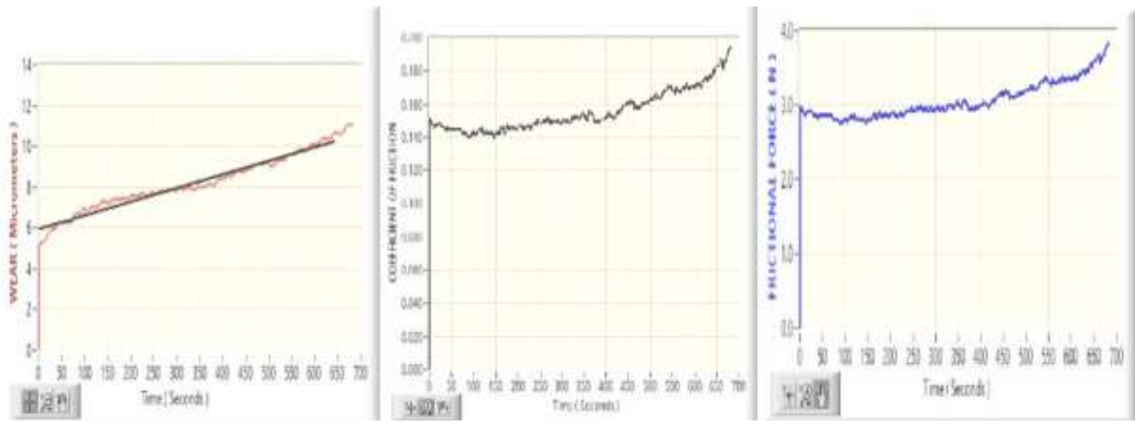
Table 1: Wear rate on pin on disc sliding wear of Kevlar E-glass epoxy and SiC reinforced hybrid nanocomposites.



Graph 1: Wear Rate, Coefficient of friction and frictional force curves determining the tribological properties under sliding wear (pin on disc) with 0% SiC Inclusions.



Graph 2: Wear Rate, Coefficient of friction and frictional force curves determining the tribological properties under sliding wear (pin on disc) with 0.5% SiC Inclusions.



Graph 3: Wear Rate, Coefficient of friction and frictional force curves determining the tribological properties under sliding wear (pin on disc) with 1% SiC Inclusions.

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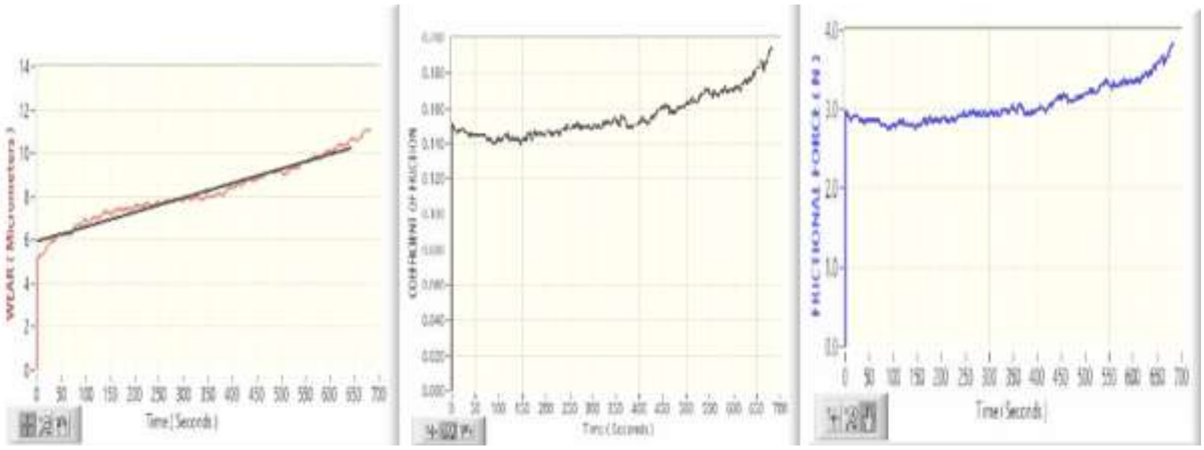

Graph 4: Wear Rate, Coefficient of friction and frictional force curves determining the tribological properties under sliding wear (pin on disc) with 1.5% SiC Inclusions.

In the above graphs, material clearly exhibited the wear characteristics namely, wear rate, coefficient of friction and frictional force acting on composite specimens with different percentage of integration of Silicon Carbide.

In the graphs it is seen that, wear rate is significantly decreasing in composites, due to the reason that carbon fibers in combination with epoxy LY 556 and SiC offers comparatively high interlaminar bonding strength thus results in stiffness and offers resistance against material removal.

Whereas Kevlar, E-glass epoxy and SiC reinforced composites offers less resistance against wear, this is because of the soft and flexible nature of Kevlar fibers resulted in softer interface to the contact surface thus wear rate is found to be comparatively high.

On other hand it is also observed that, increase in percentage of SiC, increases the wear resistance, which states hardness coupled with stiffness is offered when SiC are added to composites.

6.2 Hardness Test of Kevlar, E-glass and epoxy SiC Reinforced Polymer Matrix Composites.

Sl. No.	SAMPLE	SHORE D HARDNESS NUMBER	MEAN SHORE D HARDNESS NUMBER
1.	Kevlar/E-glass/epoxy/0%Sic	80.5	**81**
		81	
		81.5	
2.	Kevlar/E-glass/epoxy/0.5%Sic	85	**84.83333333**
		84.5	
		85	
3.	Kevlar/E-glass/epoxy/1%Sic	85.5	**85.5**
		85	
		86	
4.	Kevlar/E-glass/epoxy/1.5%Sic	88.5	**88.3333333**
		89	
		87.5	

Table 2: Hardness Value on Shore D Hardness Test of Kevlar, E-glass epoxy and SiC reinforced hybrid nanocomposites.

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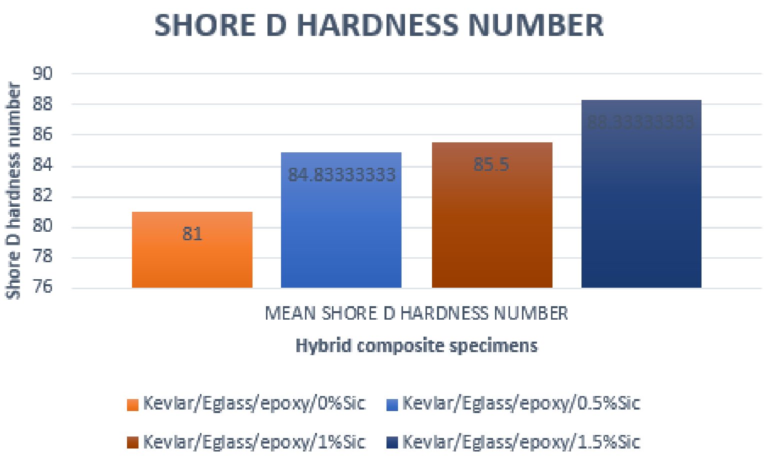

Fig 5: Shore D Hardness Values.

In the above graphs, material clearly exhibited that the hardness values are linearly increasing on composite specimens with different percentage of integration of Silicon Carbide. On other hand it is also observed that, increase in percentage of SiC, increases the Hardness value.

IV. CONCLUSION

In the investigation, characteristics of Kevlar, E-glass Epoxy Hybrid Polymer matrix nano composites with varied integration of Silicon Carbide (SiC) as particulate inclusion, following conclusions were drawn.

- Post fabrication, the composite laminates were systematically cured, as per the recommendations of the resin manufacturer for LY 556 Epoxy resin.
- The sliding wear of Nano composite is seen to be decreasing with the increase in Silicon Carbide(SiC) as the cause of particulate reinforcement leading high coefficient of friction from specimen whereas the interfacial bonding of matrix and fibrous reinforcement has overcome the CoF and thus interfaced the sliding friction with fibers and thus the influence of Silicon Carbide(SiC) has considerably reduced the wear rate just by strongly binding the matrix and fibers, thus resulting in reduced material degradation by adhesion under the influence of Silicon Carbide(SiC).
- It is also observed that Kevlar, E-glass SiC and Epoxy Reinforced exhibit high wear rate this is because Kevlar fibers are chemically synthesized polymeric fibers, it won't withstand more in tension as like carbon.
- It is clearly Observed that, as increase in percentage of SiC, increases the Hardness value.

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