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# Fabrication And Characterization of Natural Fiber Reinforced Polyester Composites

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***Abstract:*** *Fiber and filler reinforced polymer matrix composites are frequently used now a days for engineering applications such as aerospace, automotive, and marine where mechanical and tribological properties are of primary concern. The study on three-body abrasive wear behavior of silk fiber-unsaturated polyester composites has been investigated. The wear behavior was assessed by Rubber Wheel Abrasion Test rig(RWAT). The effect of abrading distance, viz., 300, 600, 900 and 1200 m and different loads of 24 and 36 N at 200 rpm have been studied. The wear volume loss and specific wear rate as a function of load and abrading distance were determined. The wear volume loss increases with increasing load/abrading distance. However, the specific wear rate decreases with increase in abrading distance and increases with the load. The wear surface of the samples has been examined using digital camera of 12 Megapixel.*
***Keywords :*** *three body abrasive wear, polyester composites, rubber wheel abrasion test rig*

## I. Introduction

Tribology is derived from the Greek word "TRIBOS", which means 'rubbing' or 'sliding'. It is the science and technology of interacting surfaces which are in relative motion with each other. It includes the study and application of principles of friction, lubrication and wear. For example, in automotive brake systems, high temperatures and pressures are generated at the contacting surfaces which affect the pad and disc materials, creating friction film between the surfaces, which consists of wear particles and volatile reactants from the pad and disc.

The tribological interactions of a solid surface's exposed face with interfacing materials and environment may result in loss of material from the surface. The process leading to loss of material is known as "wear". Major types of wear include abrasion, adhesion (friction), erosion, and corrosion. Estimated direct and consequential loss to industries in USA due to wear is approximately 1-2% of GDP. Wear can be minimized by modifying the surface properties of solids by one or more of "surface engineering" processes (also called surface finishing) or by use of lubricants (for frictional or adhesive wear).

Engineering applications often require unusual combination of properties, especially in aerospace, underwater and transportation. In response to engineering demands of high technology industries, the composite material provide combination of properties such as high strength-to-weight ratio, light weight, high modulus-to-weight ratio, high stiffness, good corrosion and chemical resistance which cannot be achieved by a single material. Composite materials are used on the basis of meeting specific performance criteria compared to conventional materials particularly in aerospace applications, where one is continuously looking for ways to lower the overall weight of the aircraft without decreasing the stiffness and strength of its components. Even if the composite material costs may be higher, the reduction in weight of the aircraft assembly and savings in the fuel costs make them more profitable.

The study of tribology is commonly applied in bearing design but extends into other almost all aspect of modern technology, even to such unlikely areas as hair conditioners and cosmetics such as lipsticks, powders and lip-gloss.Any product where one material slides or rubs over another is affected by complex tribological interactions, whether lubricated (e.g. hip implants and other artificial prosthesis) or lubricated (for example, high temperature sliding wear in which conventional lubricants can no longer be used and the formation of compacted oxide layer glazes have been observed to protect against wear).

## II. Literature Review

Composite materials are finding applications in different areas which lead to development of advanced composites. The following information give an overview on recent developments in the study of composite materials, evaluating their mechanical and tribological performance under various conditions, by reinforcing fibers and incorporating different fillers.

**Pavithran et al.,[1]** have reported on the impact properties of oriented sisal fiber-polyester composites. Uni-directionally aligned sisal fiber-polyester composites containing @ 0.5 volume fraction of sisal fiber were prepared from unsaturated polyester pre-pregs. Impact strength of the composites was measured by Charpy test in a pendulum impact-testing machine using a pendulum load of 0.4 kgs. They have compared the work of fracture of sisal fiber polyester composites to those of composites containing other natural fibers. It can be seen that sisal fiber composites have the maximum work of fracture followed by pineapple fiber composite. Banana and coir fiber composite have comparatively low work of fracture. It is a generally accepted fact that the toughness of a fiber reinforced composite is mainly depending on the fiber stress-strain behavior. Strong fibers with high failure strain impart high work of fracture on the composites. From the above table it is interesting to note that, among sisal, pineapple and banana fiber reinforced polymer composites, sisal fiber-polyester composites is likely to give high work of fracture because of the high toughness of sisal fiber which is found in agreement with the experimental results. However, the large difference observed between banana and pineapple fibers is not explained by taking into account of their comparative mechanical properties. Similarly, very low toughness cannot be expected for coir composites because of the high toughness of the fiber. They have also studied the variation in impact properties of various natural fiber composites with microfibrillar angle of the fiber.

**Kamaker et al.,[2]** reported that using 3wt% MAHgPP (type G-3002, with an average molecular weight of 40,000 and containing 6 wt% of Maleic anhydride, from Eastman Chemical products, Kingston, TN) as coupling agent in Jute/PP composite increases composite mechanical properties. The tensile strength is doubled from 29.82 MPa to 59.13 MPa and the bending strength increases from 49.97 MPa to 87.66 MPa in composite with 50 wt% fiber content.

**Gassan et al.,[3]** showed that the tensile, flexural and dynamic strength increase up to 50% but impact energy decreases due to the lower energy absorption in the interface of jute/PP composite when jute fibers are treated by 0.1wt% MAHgPP solution in toluene for 5min at 100°C. In a comparable system, the tensile strength increases from 40 MPa to 69 MPa for a viscose/PP composite using 6 wt% Exelor PO1015 as a coupling agent.

**Divakara et al.,[4]** have looked at the correlation between micro structure and micro rheological parameter of various silk filaments and the changes in micro crystalline filaments. The changes in micro crystalline parameters of raw wild varieties of silk fibres like tasar, muga and eri. Have been studied using wide angle X-ray scattering technique and a line profile analysis. A method involving an exponential distribution has been used to compute the micro structural parameters for the crystallite. In addition, a home built open microscope set-up is also used for determining the micro rheological parameter for all the three silk varieties in solution form. A comparative study reveals interesting correlation in the relative strength of the varieties of silk fibres in both crystalline form and in solution. Further, the findings also reveal that muga is stiffer than the other non-mulberry silk varieties and this is observed in both the forms. In view of above, muga silk is recommended for the production of technical textiles.

**Murugesh Babu et al.,[5]** found that muga exhibits the highest density followed by tasar and eri among the non-mulberry silk varieties. This suggests that the degree of crystallinity and crystallite orientation are high in muga as compared to other varieties.

### 1.1 Aim and Scope of Study

From the thorough literature survey, it is obvious that many attempts have been made to include different natural fibers like, sisal, jute, hemp, areca, coconut sheath in different polymers. Also clear is the fact that the research on silk fibers into thermoset polymers is scarcely reported and further they focus on a few specific issues only. Thermoset polymer matrices showed good results with a variety of natural fiber systems due to its good spreading efficiency and the resultant improved adhesion. With a view to obtain better mechanical and tribological properties, the investigation will be taken up on the basis of the optimized constituents with unsaturated polyester.

Methodology:

1) To evaluate the mechanical properties of natural fiber reinforced USP composites.
2) To evaluate the dynamic mechanical analysis of (DMA) natural fiber reinforced USP composites.
3) To evaluate the effect of abrading distance, applied load and speed on wear volume loss and specific wear rate of natural fiber reinforced USP composites.
4) To investigate the mechanisms that govern the fracture and worn surfaces of natural fiber reinforced USP composites.

## 2. Materials, Fabrication And Testing Of Composites

### 2.1 Materials

**Table 3.1** Materials used for composite materials

| Samples | Material Density(g/cc) | Resin (wt. %) | Fiber content (wt. %) | |
|---|---|---|---|---|
| | | | Glass fiber | Silk fiber |
| 18SF-USP | 1.1856 | 82 | - - | 18 |
| 22SF-USP | 1.1824 | 78 | - - | 22 |
| 26SF-USP | 1.1792 | 74 | - - | 26 |
| 5SF+38GF-USP | 1.7052 | 57 | 38 | 5 |
| 5SF+30GF-USP | 1.598 | 65 | 30 | 5 |
| 5SF+25GF-USP | 1.531 | 70 | 25 | 5 |

### 3.2 Fabrication Methods

**The different types of fabrication methods are**

- Hand layup technique.
- Spray layup technique.
- Vacuum bagging technique.
- Resin transfer moulding.
- Filament winding technique.
- Pultrusion technique.
- Compression moulding.

3.2.1 Hand Layup Technique

Silk fiber fabric which is compatible to unsaturated polyester resin was used as the reinforcement. The unsaturated polyester resin was mixed with hardener in the ratio of 100:12 by weight. Dry hand layup technique was employed to produce the composites. The stacking procedure consists of placing the fabric one above the other with the resin mix well spread between the fabrics. This step used ten layers of silk fiber fabric resulting in the final laminate of 2.5mm. A porous Teflon film was placed on the completed stack. To ensure uniform thickness of the samples a spacer of size 3mm was used. Allow to cure for a day at a room temperature and later post cured at 70°C for about 10 hours. The panel so prepared has a size of dimension 150mm×150mm×6mm. Abrasion test samples of dimension 75mm×25mm×6mm were cut from the laminates using a diamond tipped cutter. The procedure is as shown in the Fig. 3.1.

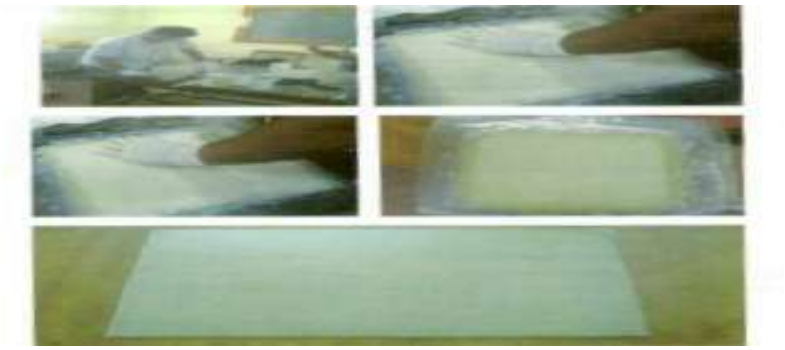

**Fig. 3.1** Stages of Fabrication of USP based Natural fiber reinforced composites

### 3.4 Preparation Of Materials For Testing

➢ **With Ageing:** dipping into sea water

- Cut the fabricated samples into 75mmX25mm.
- Note down the initial weight of the samples.
- Then dip all the samples into the sea for one week.
- After one week final weight of the samples were noted down.
- They were carried out for testing.

➢ **Without Ageing:**

- Cut the fabricated samples into 75mmX25mm.
- Note down the weights of the samples.

Then the samples are carried out for testing.

**3.5 Dynamic Mechanical Analysis**

A dynamic mechanical thermal analyzer M K II of Polymer Laboratories was employed for dynamic mechanical property evaluation of the composites. The experiment was performed under tensile mode at a frequency of 0.1,1 and 10 Hz. The sample dimension was cut to 2cmX3cm and the gauge length of the sample 1.5cm. Then load the sample into the dynamic mechanical thermal analyzer M K II. The testing temperature ranged from 20°C to 160°C and the heating rate was 2 K/min. Apply 2% cyclic strain through entire temperature range. DMA records material response to deformation and hence we can analyze the plots such as storage modulus v/s temperature, loss modulus v/s temperature and damping values of composites v/s temperature. We can find the glass transition temperature based noticeable temperatures on the curves. The dynamic mechanical test rig used is shown in fig. 3.2.

**Fig. 3.2** Dynamic Mechanical Analysis Test Rig

**3.6 Abrasive Wear Test**

The abrasive particle of 200-250 micron grade quartz is used as abrasive. The abrasive was fed at the contacting face between the rotating rubber wheel and test samples. The tests were conducted at rotational speed of 200 rpm. The initial weight of the sample was determined using a high precision digital electronic balance before it was mounted in the sample holder. The abrasives were introduced between the test sample specimens and rotating abrasive wheel composed of chlorobutyl rubber tree. The test sample was pressed against the rotating wheel at a specified force by means of lever arm while a controlled flow of abrasives abrade the test surface. The rotation of the abrasive wheel was such that its contacting face moves in the direction of sand flow. The pivot axis of the lever arm lies within a plane, which is approximately tangent to the rubber wheel surface and normal to the horizontal diameter along which the load is applied. At the end of the set test duration, the specimen was removed, thoroughly cleaned and again weighed (final weight). The difference in weight before and after abrasion was determined. The wear experiments were conducted under 24N and 36N loads at a constant sliding velocity of 2.3771m/s. Further the abrading distances were varied in steps of 300m to 1200m. For all abrading distances, the abrasion tests were carried out on the same wear track. The wear was measured by a loss in weight. Figure 3.3 shows the abrasive wear tester used.

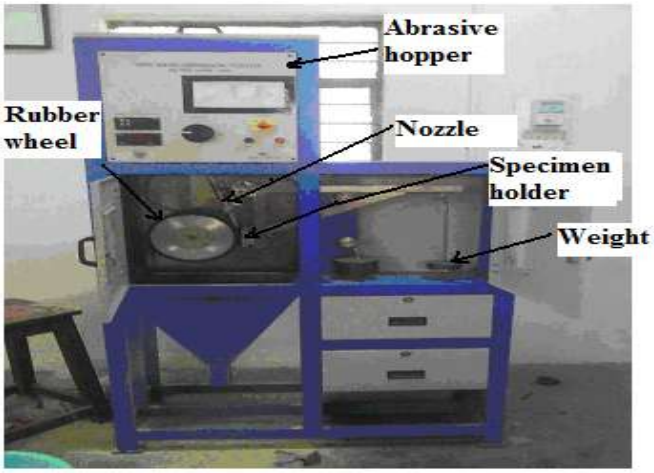


**Fig. 3.3** Dry sand abrasion wear tester

Sliding Velocity And Time

Sliding Velocity $v = \pi DN/(60 \times 1000)$= ($\pi$×227×200)/ (60×1000)

v=2.3771m/sec

For 300m abrading distance

Time=abrading distance/sliding velocity=300/2.3771=126.20sec

=2min 16sec

For 600m abrading distance

Time=abrading distance/sliding velocity=600/2.3771=252.52sec

=4min 22sec

For 900m abrading distance

Time=abrading distance/sliding velocity=900/2.3771=378.61sec

=6min 28sec

For 1200m abrading distance

Time=abrading distance/sliding velocity=1200/2.3771=504.81sec =8min 34sec

### 3.7 Abrasive Wear Test Conditions

**Abrasive wear testing for samples without ageing**

Load=24N and Speed=200rpm Composition: 18SF-USP

| Sl. No. | Abrading Distance(m) | Time(sec) | Weight Loss(gm) |
|---|---|---|---|
| 1 | 300 | 2'16" | 0.0604 |
| 2 | 600 | 4'22" | 0.1203 |
| 3 | 900 | 6'28" | 0.1554 |
| 4 | 1200 | 8'34" | 0.196 |

Load=36N and Speed=200rpm Composition: 18SF-USP

| Sl. No. | Abrading Distance(m) | Time(sec) | Wt. Loss(gm) |
|---|---|---|---|
| 1 | 300 | 2'16" | 0.1254 |
| 2 | 600 | 4'22" | 0.2408 |
| 3 | 900 | 6'28" | 0.3768 |

**Abrasive wear testing for samples with ageing**

Load=24N and Speed=200rpm Composition: 18SF-USP

| Sl. No. | Abrading Distance(m) | Time(sec) | Wt. Loss(gm) |
|---|---|---|---|
| 1 | 300 | 2'16" | 0.0685 |
| 2 | 600 | 4'22" | 0.1275 |
| 3 | 900 | 6'28" | 0.1987 |
| 4 | 1200 | 8'34" | 0.2215 |

Load=36N and Speed=200rpm Composition: 18SF-USP

| Sl. No. | Abrading Distance(m) | Time(sec) | Wt. Loss(gm) |
|---|---|---|---|
| 1 | 300 | 2'16" | 0.1139 |
| 2 | 600 | 4'22" | 0.2008 |
| 3 | 900 | 6'28" | 0.2719 |
| 4 | 1200 | 8'34" | 0.3665 |

## III. Results

4.1 Dynamic Mechanical Analysis

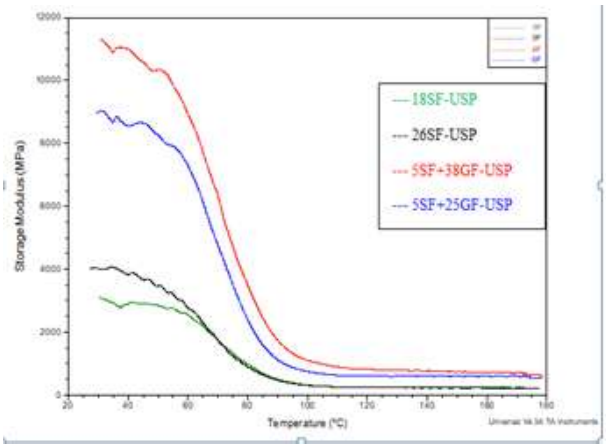


Fig. 4.1 Effect of temperature on Storage Modulus of polyester with different fiber content

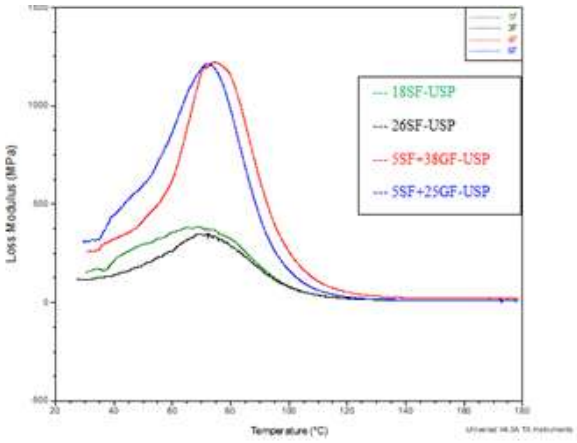


Fig. 4.2 The variation of loss modulus with temperature of composites with different fiber content

**4.2 Abrasive Wear Studies**

Tribological Properties

**Wear Volume For 24N Without Ageing**

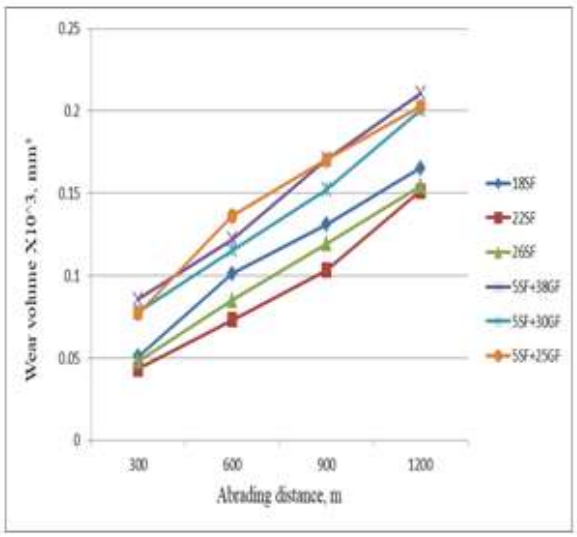


Fig. 4.4 Wear volume v/s Abrading distance for 24N load without ageing

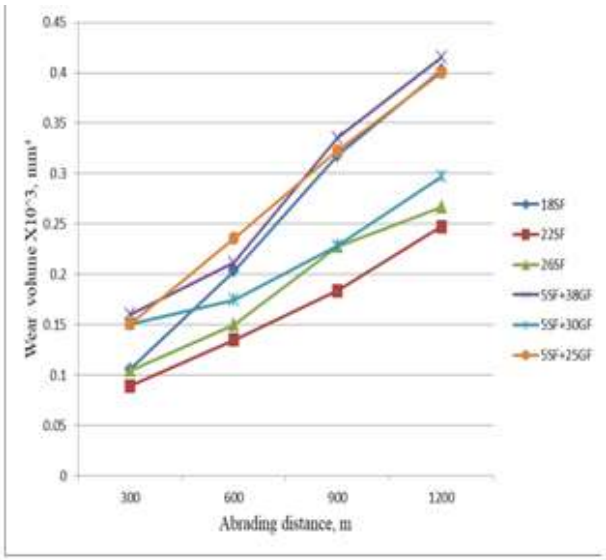


Fig.4.5 Wear volume v/s Abrading distance for 36N load without ageing

**Specific Wear Rate For 24N Without Ageing**

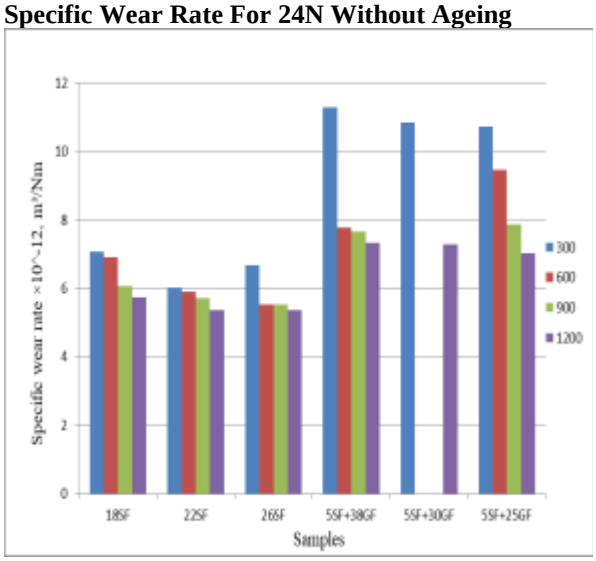


Fig. 4.6 Specific wear rate v/s Samples for 24N load without ageing

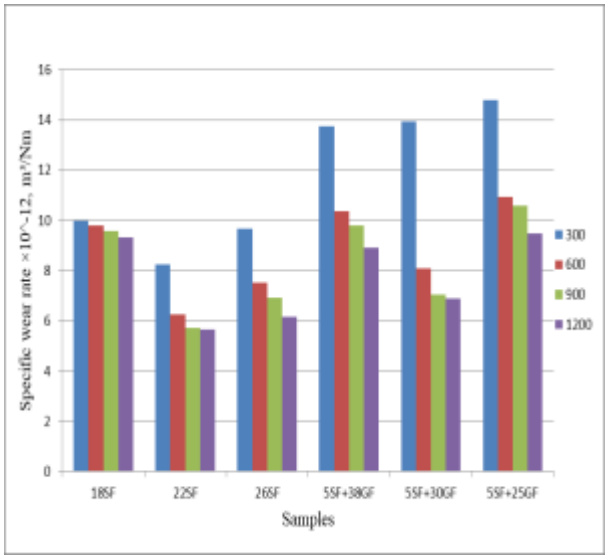


Fig. 4.7 Specific wear rate v/s samples for 36N load without ageing

## IV. Conclusion

The following conclusions can made from the present investigation:

- In case of as-cast compositions the better results were shown for 22SF-USP and the same result were drawn in case of ageing.
- In case of as-cast compositions the composition 5SF+38GF-USP showed inherent results while in case of ageing the inherent results were shown by 5SF+25GF-USP.
- Wear volume increases with the increase in load and abrading distances while specific wear rate decreases with the increase in abrading distances.
- In case of dynamic mechanical analysis, storage modulus increases with increase in fiber content while it decreases with increase in temperature i.e. storage modulus value is maximum for 5SF+38GF-USP and minimum for 18SF-USP
- Loss modulus peak values increases with the increase in fiber content and it is maximum for 5SF+38GF-USP.

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