Wear Characteristics of Epoxy Based Hybrid Composites Reinforced with Short Hair Fibers and Glass Micro Spheres

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Abstract: This paper reports on the sliding wear behavior of a class of hybrid composites consisting of epoxy, short human hair fibers and glass micro-spheres. Human hair is a biological waste which creates many environmental problems due to its low rate of degradation. But it also has many unique properties like low thermal conductivity, higher strength in tension, unique chemical composition, higher elasticity, scaly surface etc. Although a number of ways are in place for the utilization of waste human hair such as in fertilizers and pesticides, in cosmetic industries, artwork, fabrics, stuffing toys, house hold items etc., its use in polymers as a reinforcing element has not been researched properly. In view of this, the present work makes an attempt to fabricate a class of hybrid polymer composites reinforced with short human hair fibers (SHF) and solid glass micro-spheres (SGM). SGM (10wt.%) filled epoxy matrix composites are prepared with four distinct fiber loading (0, 2, 4, 6 wt. %). Mechanical properties such as tensile, compressive and flexural strengths are evaluated by conducting tests as per appropriate ASTM standards. Using a friction and wear test rig of pin-on-disc type sliding wear tests are performed on these composites as per ASTM G99. Four process parameters and each at four levels are considered for the experimentation. In order to identify the significant control factors influencing the wear rates of these composites a design of experiment approach based on Taguchi's orthogonal array is adopted. Effects of SGM and hair fiber reinforcement on the mechanical and wear characteristics of epoxy have been studied. The test results are compared with those obtained for composites with only SHF reinforcement under similar test conditions. It is found that while reinforcement of short hair fiber enhances the wear performance of epoxy, addition of SGM further improves it. Armed with a fairly good wear resistance, these composites can possibly have potential applications such as in brake shoes, brake pads etc.

Keywords:Epoxy composites; human hair fiber;solid glass micro-spheres; sliding wear test;

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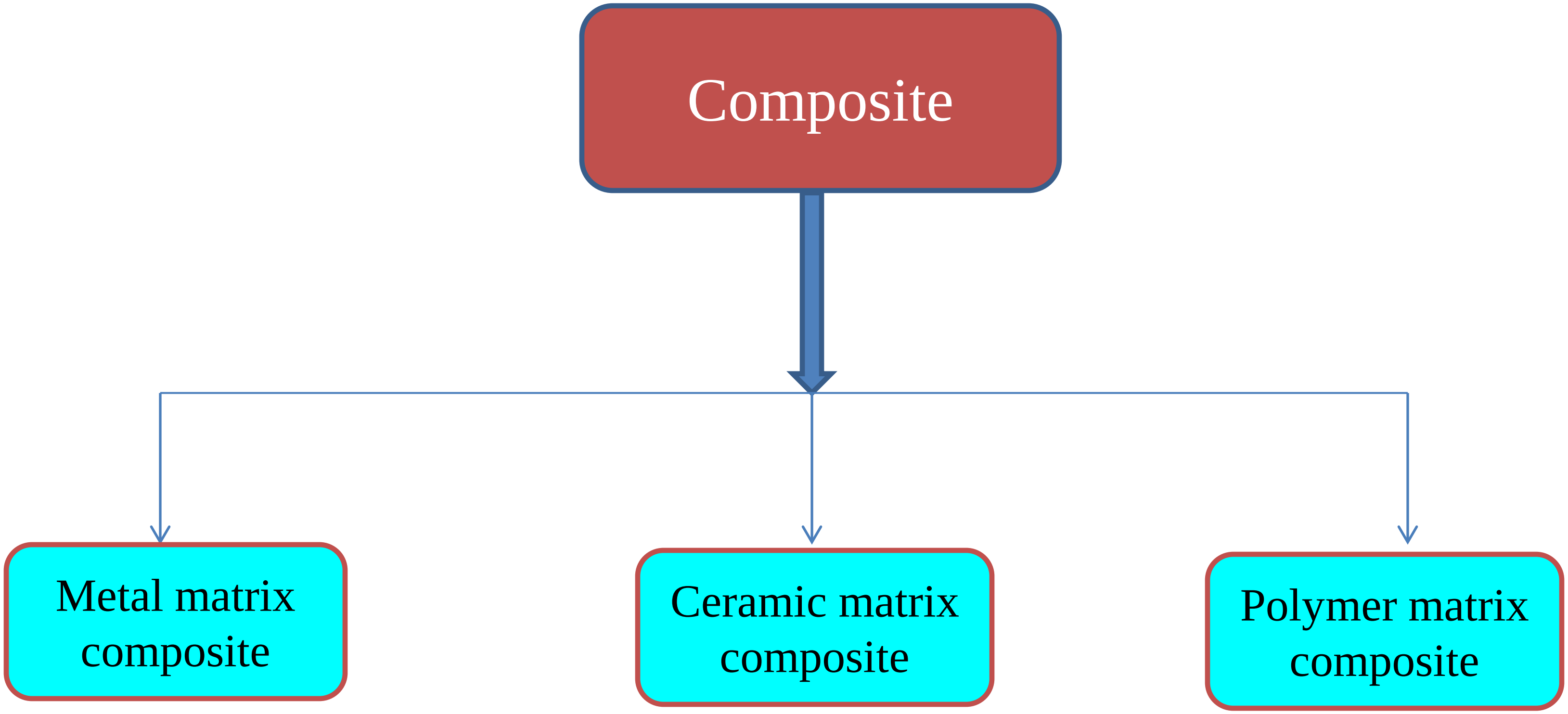
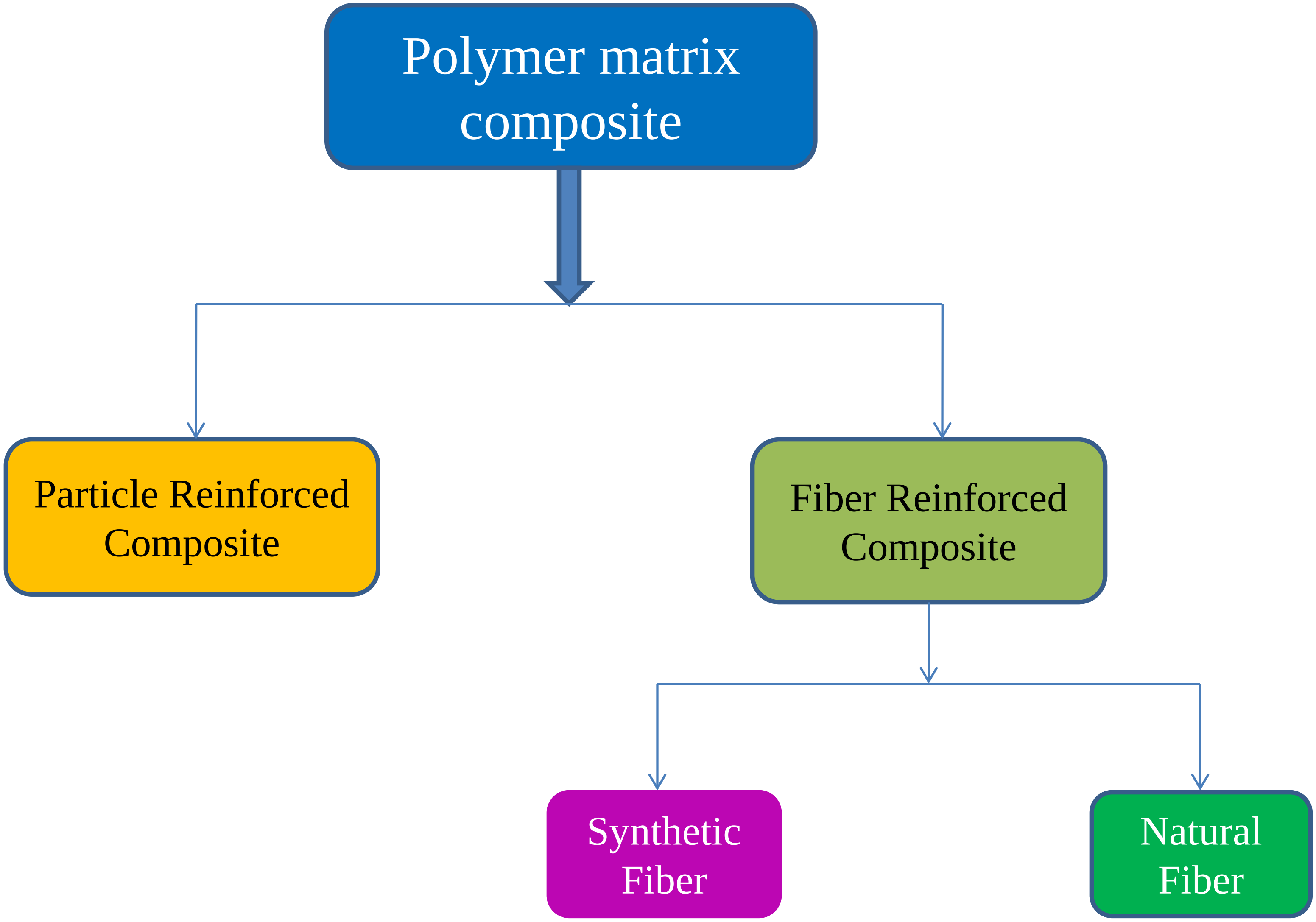
INTRODUCTION

COMPOSITE

Composite is made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The characteristics can even be more powerful than each of the individual constituent materials. The individual components remain separate and distinct within the finished structure.




Polymer matrix composite
Particle Reinforced Composite
Fiber Reinforced Composite
Synthetic Fiber
Natural Fiber

Advantage Of Natural Fiber Over Synthetic Fiber

- Low cost
- Abundantly available
- High toughness
- Low density
- Good specific strength properties
- Biodegradability
- Acoustic and thermal insulators
- Good moldability
- High recyclability

Natural Fiber

Fiber Extracted from Plants

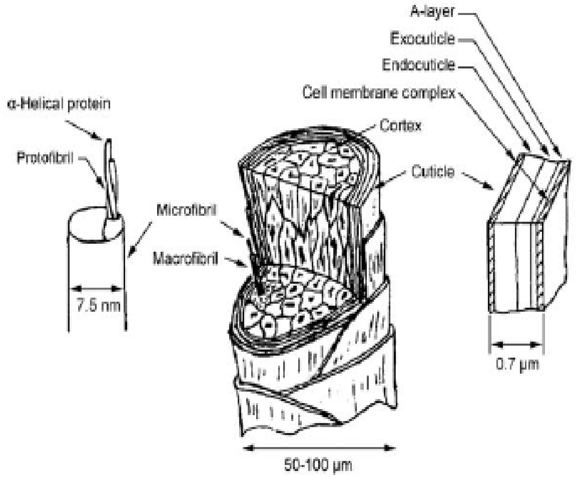
- Jute, sisal, hemp, bagasse, palm and bamboo etc.
- Mostly cellulose based.

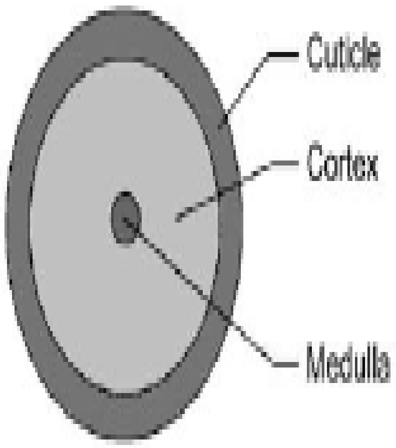
Fiber Extracted from Living Spices

- Fish Scales, feathers, human hair etc.
- Mostly Keratin protein based.

Hair Fiber

Human hair is a biological fiber with well characterized microstructure. It has many unique properties like high tensile strength, thermal insulation, unique chemical composition, elastic recovery, scaly surface etc. Primary constituent of human hair fiber is keratin protein. Keratin protein is made up with long chain of amino acids like cytosine, serine, glutamine, threonine, glycine, leucine, valine and arginine. Hair fiber is composed of three main structures cuticle, cortex and medulla. The cuticle is outermost part of hair fiber. Cortex is the cylindrical part after the cuticle which occupies 75% of area. Medulla is the thin cylindrical layer at the center of human hair.





USE OF WASTE HAIR

1. Fashion, Theatre, and Cosmetics Industry
    - Wigs, hair extensions, eyelashes, moustaches, beards etc.
    - For making cosmetic brushes
2. Agriculture
    - Fertilizer
    - Pest Control
3. Pharmaceuticals
    - Wave lotions and wound healing formulations
    - Hydrolyzed hair keratin (Hair care products)
    - Ethno medicinal uses (treating burns, wounds, and scars)
4. Textiles, Fiber Stuffing, and Other Artifacts
    - Stuffing Toys
    - Fabrics
    - Ropes
    - Artwork
5. Food Industry

Objective of present work

1. Fabrication of epoxy-SHF composites and epoxy-SHF-SGM (10 wt.%) hybrid composites with different wt.% SHF.

2. Mechanical characterization of these composites.

3. Performing dry sliding wear test on these composite.

4. Finding out the significant control factors influencing the wear rates of these composites using Taguchi's experimental design approach.

5. Exploring the possibility of using these composites in suitable application areas.

EXPERIMENTAL DETAILS

Composite Fabrication

Hand lay-up method

Epoxy Resin + Hair Fiber = Composite

Sample	Composition
1	Epoxy + 0 wt% SHF
2	Epoxy + 2 wt% SHF
3	Epoxy + 4 wt% SHF
4	Epoxy + 6 wt% SHF

Hand lay-up method

Epoxy Resin + Hair Fiber + Solid Glass Microsphere = Hybrid Composite

Sample	Composition
1	Epoxy + 10 wt. % SGM+0 wt% SHF
2	Epoxy +10 wt. % SGM+ 2 wt% SHF
3	Epoxy +10 wt. % SGM+ 4 wt% SHF
4	Epoxy +10 wt. % SGM+ 6 wt% SHF

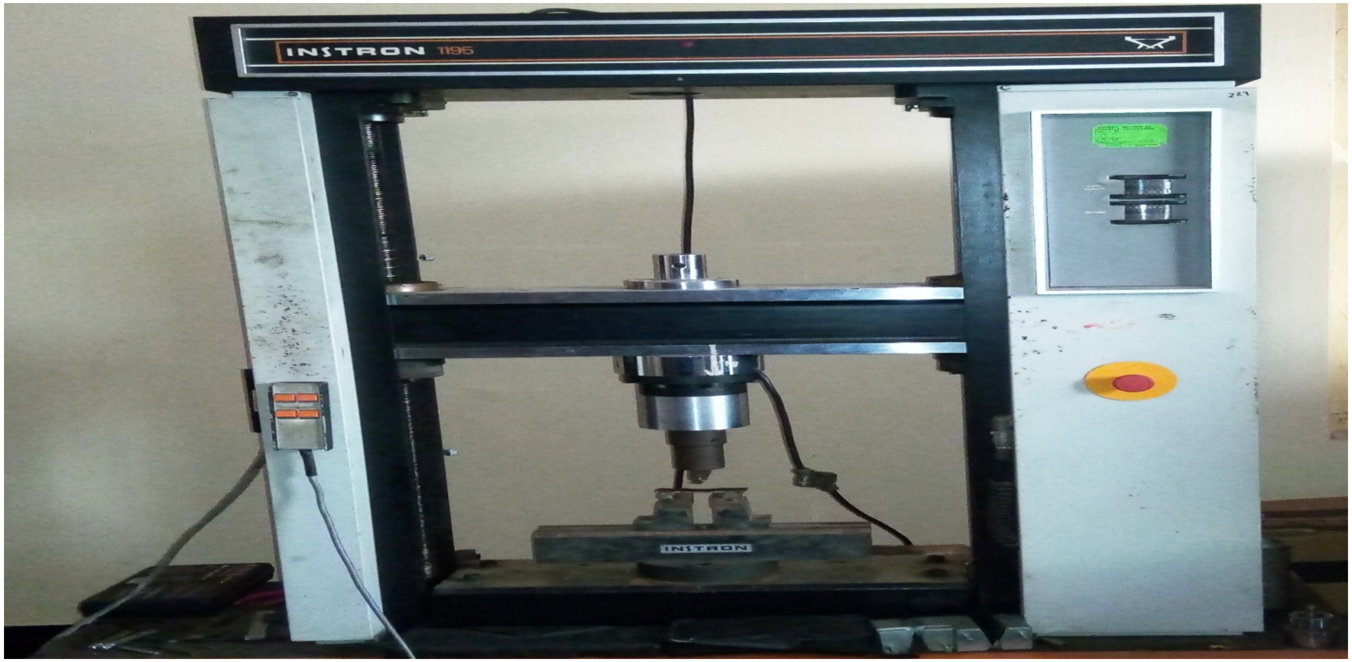
Tensile Strength

Tensile tests in the present work are conducted in Instron 1195 universal testing machine by maintaining 10 mm/min cross head speed. Composite specimens of required size as per ASTM E 1309 are used for the tests. Tensile strength of the composite samples is calculated from the results of the tests. Tests are conducted on three identical samples of each composition and the mean value of the three replications is reported as the tensile strength of that composite.

Tensile Strength Test In Instron 1195

Flexural Strength

Three point bend tests are performed in an Instron 1195 universal testing machine to obtain the bending strength of the composite samples. Composite specimen of size 80mm×20mm×4mm are prepared to conduct the test. Three point bending test is performed on three identical specimens of each composition and the mean value of the three replication is recorded as the flexural strength of the composite. During the test, 40 mm span length and 2mm/min cross head speed is maintained.



Flexural Strength Test In Instron 1195

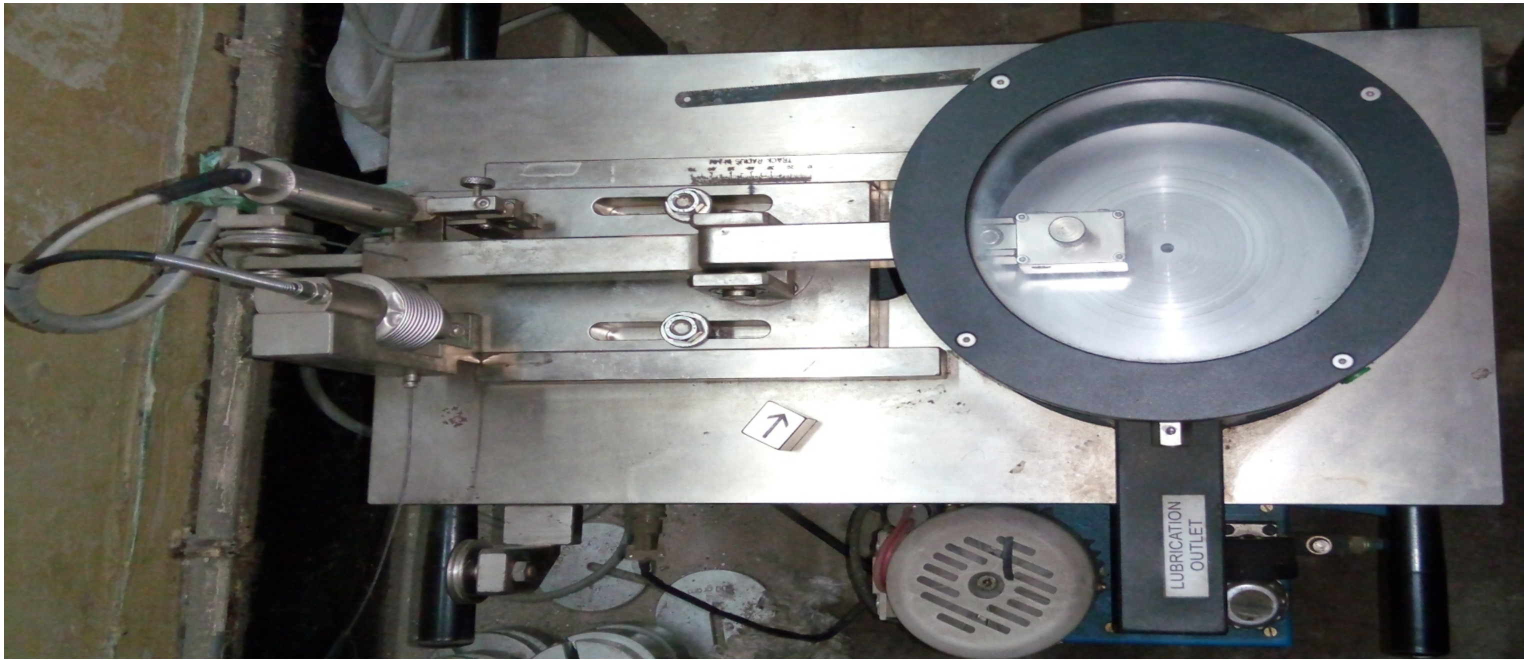
Compressive Strength

Static uniaxial compression tests are carried out in a inInstron 1195 Universal Testing Machine to obtain the compressive strength of the composite samples. Composite specimens of required dimension as per ASTM D 695 standard are used for the test. During the test, 1 mm/min crosshead speed is maintained and the compression is stopped when the specimen shows signs of failure. Compression test is performed on three identical specimens of each composition and the mean value of the three replications is reported as the compressive strength of that composite.

Compressive Strength Test In Instron 1195

Sliding Wear Test

Composite samples of required size as per ASTM G99-05 are used to conduct the dry sliding wear tests. These tests are performed in a friction and wear test rig of pin-on-disc type. A hardened ground steel disc is used as the counter body and through a lever mechanism normal load is applied. During any particular test run, the disc rotates at a specific RPM while the specimen is held stationary. As per Taguchi L_{16} array, tests are performed with four different sliding velocities and each at four distinct normal loads.



Pin-on-disc Friction and Wear Test Rig

Process parameters and their selected levels for dry sliding wear

Control Factors	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Units**
Sliding Velocity (A)	42	84	126	168	cm/sec
Normal Load (B)	5	10	15	20	N
Sliding Distance (C)	500	1000	1500	2000	m
Fiber Content (D)	0	2	4	6	Wt. %

Sliding wear rates of epoxy-SHF Composite

Test Run	Sliding Velocity(A)	Normal Load (B)	Sliding Distance(c)	SHF Content(D)	Sp. Wear Rate(10-4 mm3/N-m)	S/N Ratio (dB)
1	42	5	500	0	6.360	-16.0691
2	42	10	1000	2	3.700	-11.3640
3	42	15	1500	4	2.000	-6.0206
4	42	20	2000	6	0.698	3.1129
5	84	5	1000	4	3.685	-11.3287
6	84	10	500	6	1.861	-5.3949
7	84	15	2000	0	7.818	-17.8619
8	84	20	1500	2	3.668	-11.2886
9	126	5	1500	6	1.241	-1.8754
10	126	10	2000	4	2.000	-6.0206
11	126	15	500	2	5.000	-13.9794
12	126	20	1000	0	8.818	-18.9074
13	168	5	2000	2	6.418	-16.1480
14	168	10	1500	0	9.484	-19.5398
15	168	15	1000	6	1.861	-5.3949
16	168	20	500	4	2.763	-8.8276

Sliding wear rates of epoxy-SHF-SGM hybrid Composite

Test Run	Sliding Velocity(A)	Normal Load (B)	Sliding Distance(c)	SHF Content(D)	Sp. Wear Rate(10-4 mm3/N-m)	S/N Ratio (dB)
1	42	5	500	0	4.969	-13.9254
2	42	10	1000	2	2.247	-7.0321
3	42	15	1500	4	1.369	-2.7281
4	42	20	2000	6	0.457	6.8017
5	84	5	1000	4	2.174	-6.7452
6	84	10	500	6	1.187	-1.4890
7	84	15	2000	0	5.324	-14.5248
8	84	20	1500	2	1.797	-5.0910
9	126	5	1500	6	0.852	1.3912
10	126	10	2000	4	1.342	-2.5551
11	126	15	500	2	3.423	-10.6881
12	126	20	1000	0	5.916	-15.4406
13	168	5	2000	2	5.122	-14.1888
14	168	10	1500	0	6.507	-16.2676
15	168	15	1000	6	1.096	-0.7962
16	168	20	500	4	1.450	-3.2274

RESULTS AND DISCUSSION

Tensile Strength

The tensile strength of epoxy-SHF composites and epoxy-SHF-SGM hybrid composites are presented in Table 2. It is observed that the tensile strength of the epoxy-SHF composite increases with increase in the SHF content. However with the addition of 10 wt.% SGM, a marginal drop in tensile strength of the hybrid composite can be observed.

Tensile Strength(MPa)

Sample (wt % SHF)	Epoxy-SHF Composite	Epoxy-SHF-SGM Composite
0	65	63.5
2	81	79.3
4	94	92.8
6	112	111.2

Flexural Strength

Flexural strength of epoxy-SHF composites and epoxy-SHF-SGM (10 wt.%) hybrid composites are presented in Table 3. A consistent rise in flexural strength of composite with increase in SHF content is recorded. However with the addition of 10 wt.% SGM slight decrease in flexural strength of hybrid composites is observed.

Flexural Strength(MPa)

Sample (wt. % SHF)	Epoxy-SHF Composite	Epoxy-SHF-SGM Composite
0	58	56.3
2	71	69.7
4	86	84.9
6	99	98.1

Compressive Strength

The compressive strength of epoxy-SHF composites and epoxy-SHF-SGM composites with different wt.% of hair fibers are presented in Table 4. A marginal rise in compressive strength of epoxy-SHF composite with increase in SHF content is recorded whereas with the addition of SGM compressive strength of hybrid composite increases significantly.

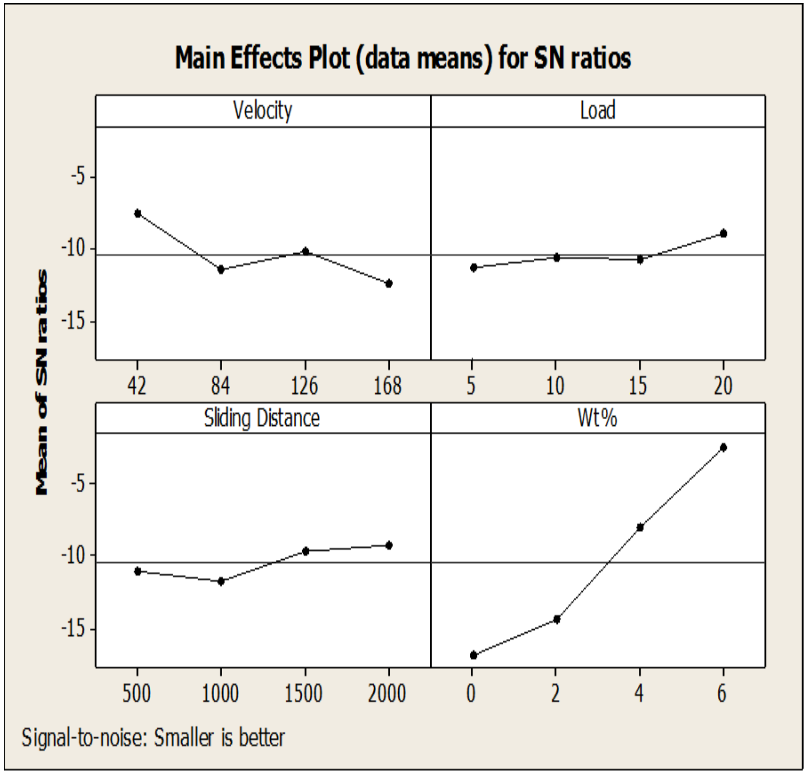
Compressive Strength(MPa)		
Sample (wt % SHF)	**Epoxy-SHF Composite**	**Epoxy-SHF-SGM Composite**
0	84	89
2	87	94
4	91	101
6	94	107

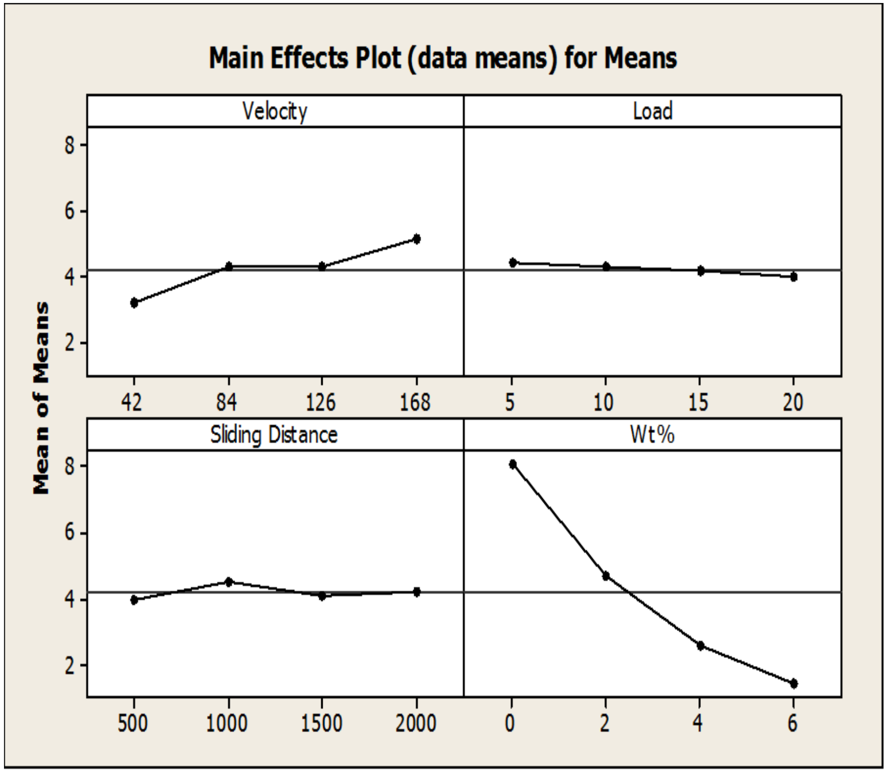
Sliding Wear Test Results

The specific wear rates of both epoxy-SHF composites and epoxy-SHF-SGM hybrid composites are presented in Table 2 and Table 3 respectively. The corresponding S/N ratios for all the specific wear rates of both the types of composites are also presented in these tables. Minitab 14 software is used for the design of experiment analysis. From the response table, it can be concluded that specific wear rates of both epoxy-SHF composites and epoxy-SHF-SGM hybrid composites is mostly affected by the SHF content and sliding velocity followed by the other two control factors.

Response table of epoxy-SHF composite

Level	Sliding Velocity	Normal Load	Sliding distance	SHF Content
1	-7.583	-11.355	-11.068	-16.863
2	-11.469	-10.580	-11.749	-14.427
3	-10.196	-10.814	-9.681	-8.049
4	-12.478	-8.975	-9.227	-2.386
Delta	4.895	2.380	2.522	14.477
Rank	2	4	3	1

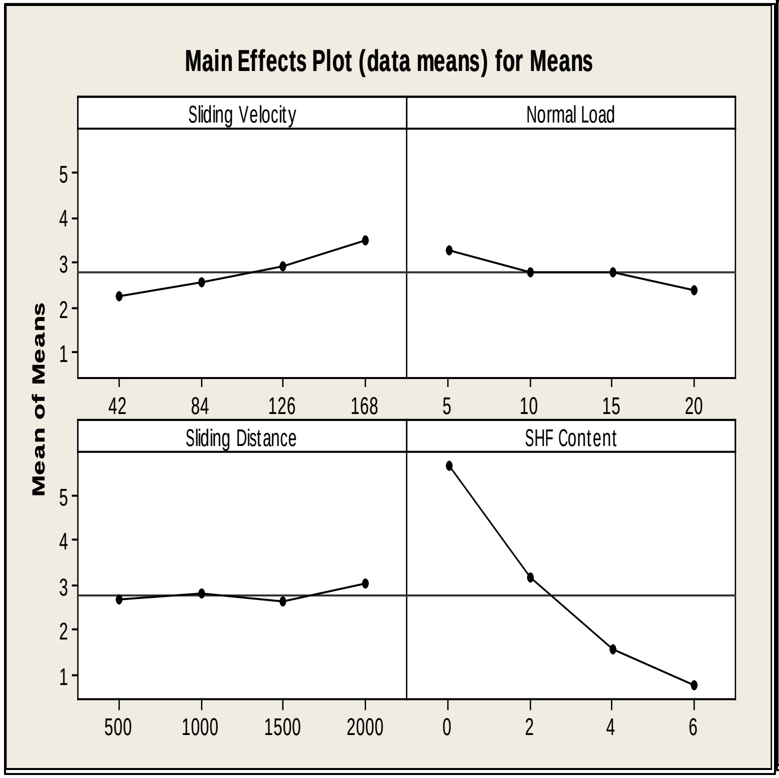


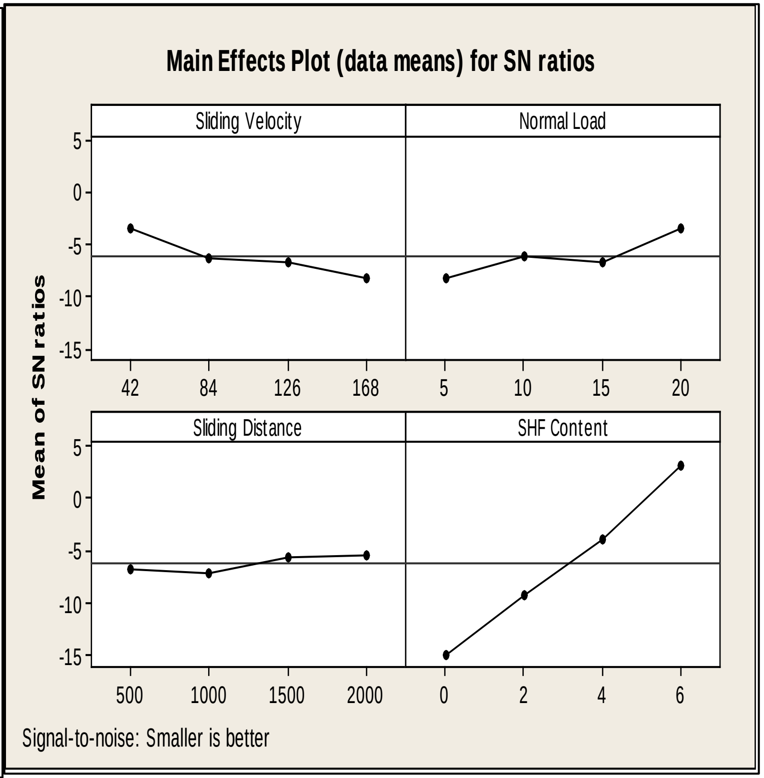


Main effects plots of epoxy-SHF composite

Response table of epoxy-SHF-SGM hybrid composite

Level	Sliding Velocity	Normal Load	Sliding distance	SHF Content
1	-4.221	-8.367	-7.332	-15.040
2	-6.962	-6.836	-7.504	-9.250
3	-6.823	-7.184	-5.674	-3.814
4	-8.620	-4.239	-6.117	-1.477
Delta	4.399	4.128	1.830	16.516
Rank	2	3	4	1





Main effects plots of epoxy-SHF-SGM hybrid composite

Conclusions

- The present experimental and analytical investigation shows that wear performance of the epoxy-SHF composite can be improves significantly with the addition of solid glass microsphere.

- Hair fiber content and sliding velocity are the most influencing factors affecting the sliding wear rate of both epoxy-SHF and epoxy-SHF-SGM hybrid composites.

- Compressive strength of the epoxy-SHF composite can be largely modified with the addition of SGM.

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Thank You