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Experimental Investigations on Mechanical and Wear Behaviour of Hybrid Polymer Matrix Composites

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ABSTRACT
This work aims to create new hybrid polymer matrix composites with kevlar, carbon, and glass fibres acting as reinforcements and epoxy resin serving as the matrix material. Hand layup method was used to prepare the fibre reinforced polymer matrix composite (FRP) laminates. In order to assess the wear properties, the samples were prepared and tested using Taguchi's Design of Experiments approach—L9 Orthogonal Array.Better wear properties have been attained by increasing the thickness of hybrid polymer matrix composite laminate, which can be used in many applications in the automotive industry and in engineering structures. The experimentation has shown that sample 3 sequence (CKCKC) has a lower wear rate than the other samples.

Key Words: FRP laminates, Kevlar, carbon, glass fibers

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I. INTRODUCTION

Composites, which are currently used as the main load-bearing parts and components, typically have a fibre or particle phase that is stiffer and stronger than the continuous matrix phase of life. The matrix acts as a conduit for the transfer of loads between fibres; in some cases, the matrix may even be required to deliver transverse loads to the fibre. The matrix provides reinforcement stiffness because it is more ductile than the fibres [1-3]. When produced effectively, new combined materials display stronger strength than would be typical for each individual material. In addition to their structural qualities, composites are used in electrical, thermal, and environmental applications [4-6].In general, polymers' mechanical properties are insufficient for many structural purposes. Their stiffness and rigidity are particularly low when compared to ceramics and metals. These challenges are resolved by mixing polymers with other fabrics. Second, processing polymer matrix composite laminates does not necessitate high pressure or high temperatures. The equipment needed to create composites with a polymer matrix is also less complicated. For more structural applications, polymer matrix composites gradually evolved and quickly gained popularity.The apparent performance of graphene in some systems can provide significant reinforcement of the final material, while the parameters that strongly affect the nano composites are thoroughly reviewed [7-9]. The thermoset and thermoplastic polymer types are two that are frequently used. This is found to be true across a wide range of polymer matrices. Theoretical predictions have been made using experimentally obtained mechanical properties, such as tensile strength and compressive Kevlar-49 thermoplastic based composite configurations.To provide guidelines for the selection of composites by designers, systematic costing analyses of the relevant thermoplastic composites have been carried out on a continuing basis. According to the study, the Kevlar-49 fibre correlation was both experimental and theoretical. The carbon direction, then Kevlar fibre, had the best wear characteristics and modulus. At 45 psi, high ductility related to fibre rotation was noted. On the residual strength of run-out samples and fracture modes, interesting findings were also provided [10,11].

II. METHODS AND MATERIAL SELECTION

Material characteristics like tensile strength were taken into consideration when choosing the materials. The common materials are chosen over layup with different configurations. Below is a list of the various factors that went into the materials' choice.

2.1. Fiber selection

Glass fibre is a substance made of a number of very fine glass fibres. Throughout history, glass manufacturers have experimented with glass fibres, but it wasn't until the development of finer machine tools that commercial production of glass fibres became feasible. When used as a thermal insulating material, glass fibre is specially manufactured with a bonding agent to trap numerous small air cells. Kevlar fibre, which has a high tensile strength-to-weight ratio and is five times stronger than steel [6], is used in a variety of products, including bulletproof jackets, racing sails, and bicycle tyres.High rigidity, high tensile strength, low weight, high chemical resistance, high temperature resistance, and low thermal expansion are just a few of the benefits of carbon fibres. Carbon fibre is very well-liked in the fields of aerospace, civil engineering, military, and motor sports thanks to these characteristics and other combat sports. But their cost is high when compared to fabrics of a similar quality. Figs. 1-3 depict the various fibres used in conjunction with epoxy.

2.2. Polymer matrix material selection

Metal coatings, electronic/electrical components/LEDs, heavy-voltage electrical insulators, brush manufacturing, fiber-reinforced plastic materials, and structural adhesives are just a few of the many uses for epoxy and hardener (HY 951). Epoxy might be applied as glue. Excellent fusion of mechanical attributes, corrosion resistance, and dimensional stability, better adhesion. Hardener is a curing agent for epoxy or fibreglass. To facilitate healing, epoxy resin needs a hardener, also referred to as a catalyst, which is the substance that, when mixed with resin, hardens the adhesive. The final properties and suitability of the epoxy coating for the particular situation are determined by the precise selection and blending of the epoxy and hardener components.

2.3. Fabrication of hybrid fiber reinforced polymer matrix composite laminates

The hand-lay-up method, which is the simplest polymer processing method, was used to create the laminates. Using a plywood base as the mold's foundation, a sheet is tapped onto it, and a 50 mm square wooden wall is nailed to it for support.

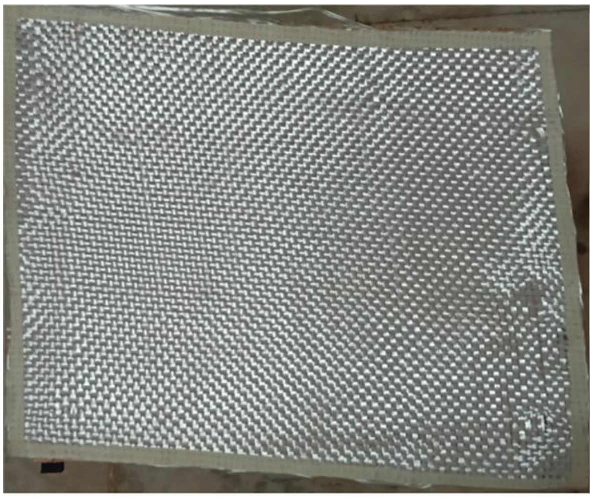

Fig. 1. Glass fiber.

Fig. 2. Kevlar fiber.

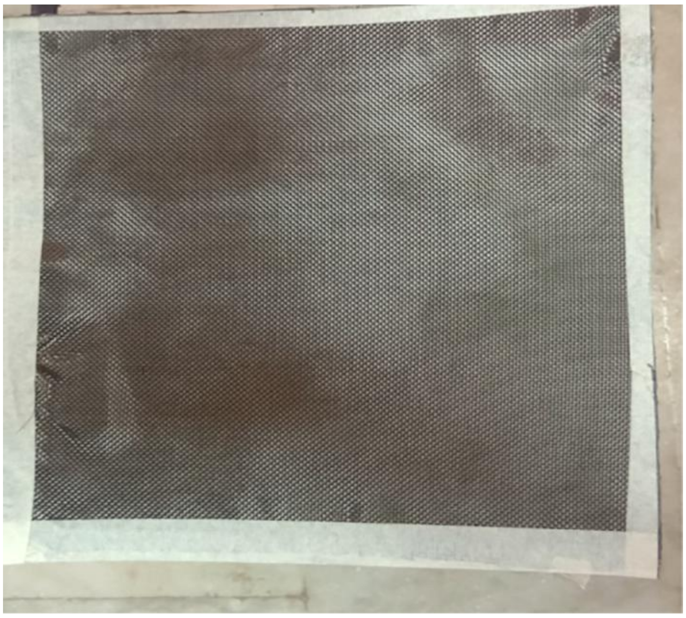

Fig. 3. Carbon fiber.

The fibre mats were stacked in the order depicted in Table 1 after the fibre resin had been applied with a brush and roller. By pressing out the trapped air and voids, rollers increase the density of the collected layers. Accelerators and catalysts were used to cure the substance at room temperature.

2.4. Taguchi's experimental design

Experiments using the L9 Orthogonal Array were conducted. The Taguchi Technique is the most effective tool for DOE. It gives manufacturing a quick, efficient, and organised approach. Taguchi uses fewer experiments to model the responses when compared to the conventional method in Experiments. This technique uses the Signal- to-Noise Ratio (S/N), which has the excellent property of choice [12,13]. The levels of the process variables are shown in Table 2.

Table 1: Sequence of Composite laminates.

Samples	Sequence of composite laminate	% of Carbon filler
Sample -1	G-K-G-K-G	5
Sample -2	K-G-K-G-K	10
Sample -3	C-K-C-K-C	15

2.5. Wear test-pin on disc

The laminates are used to create pins with a diameter of 6 mm and a length of 40 mm. The disc's counter face is made of AISI 4140 steel. Wear tests have been performed under dry sliding conditions in accordance with ASTM G99-05 standards at ambient room temperature. Acetone has been used to clean the pins and discs prior to testing [14]. The disc is attached to the holding unit, the pin is inserted into its holder, and the pin sample is fixed perpendicular to the disc surface.The timer has been set to the targeted outcome. The specimen and load were in contact during the test. When the necessary sliding distance had been covered, the test was terminated. The weight loss of the pin is used to calculate the wear rate [15]. Fig. 4 depicts a photo of the pin-on-disc wear testing apparatus that was employed in this study.

Table 2: Process Parameters and their levels.

Level	Sliding Speed (m/s)	Sliding Distance (m)	Load (N)	Reinforcement (%)
1	0.5	300	15	5
2	1.0	600	30	10
3	1.5	900	45	15

III. RESULTS AND DISCUSSIONS

Since the adhesion force was reduced by the reinforcement filler, carbon, hybrid composites exhibit better friction behaviour. The wear rate of hybrid composites is displayed in Table 3. The composite materials' increased strength and hardness from the addition of fibre and filler particles may be what caused their decreased friction coefficient. With 15% carbon fillers, the composite has the least amount of friction. Epoxy composites' wear behaviour when various fillers are added improves wear resistance. Composites made of fibre and polymer have excellent bonding.

Fig. 4. Photograph of pin on disc wear testing machine.

Table 3: Experimental Results

S.No	Sliding Speed (m/s)	Sliding distance(m)	Load (N)	% of carbon filler	Mass loss Pin (g)	Wear rate (mm^3/m)
1	0.5	300	15	5	0.0061	0.000153
2	0.5	600	30	10	0.003	2.88E-06
3	0.5	900	45	15	0.00016	1.9E-06
4	1.0	300	30	15	0.00088	3.13E-0
5	1.0	600	45	5	0.00037	4.64E-07
6	1.0	900	15	10	0.00018	1.15E-07
7	1.5	300	45	10	0.00536	1.03E-05
8	1.5	600	15	15	0.00042	7.46E-07
9	1.5	900	30	5	0.000818	6.84E-07

Composites made of fibre and plastic are the best. When fibre content was added, the rate of wear decreased. Four wear mechanisms—matrix wear, fibre wear, fibre fracture, and interfacial deboning—dominate the process of wear rate for fiber-reinforced polymer matrix composites under dry sliding conditions. With an increase in load, the wear rate and wear volume decline. For filler hybrid composites, it can be seen that the wear rate is very low. Fig. 5 demonstrates that as sliding distance, sliding speed, load, and reinforcement percentage are increased, the wear rate decreases.Because the composite transfer surface acts as a protective cover and helps to reduce wear rate, higher sliding speed results in lower wear rate. Reduced active penetration depth and gradual transition from two body to three body wear are the results of the accumulation of wear debris in the spaces between the pin and disc during sliding wear with increased load.

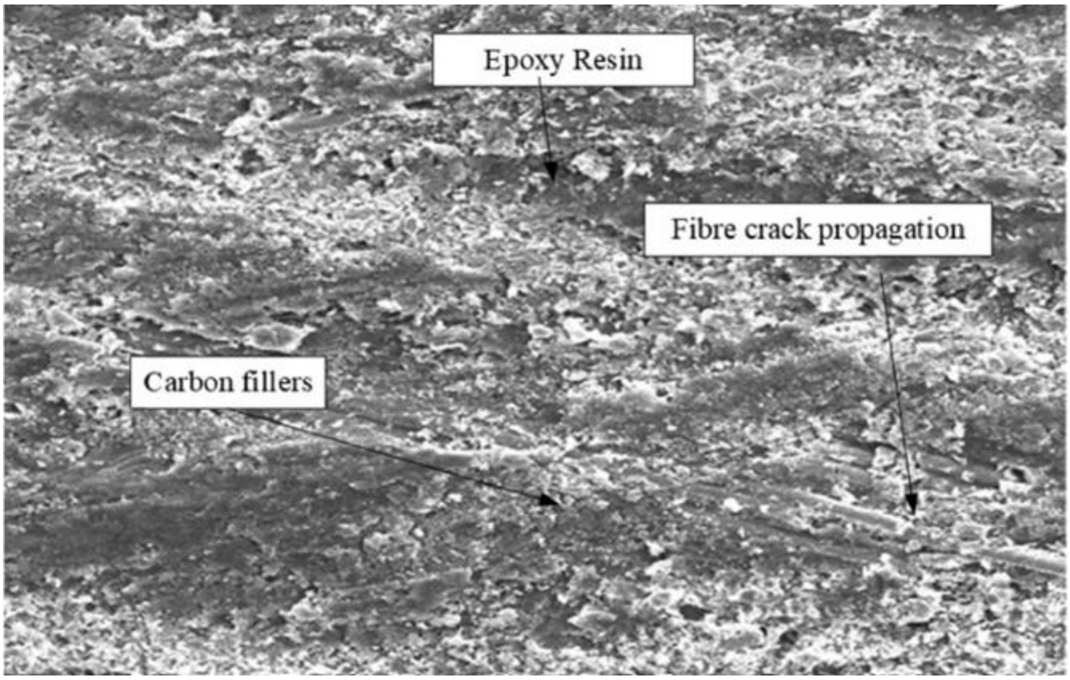

Fig. 5. Microstructure of worn-pin surfaces of the specimens.

After removing the loose debris from the carbon filler and HPMC samples with water, a SEM micrograph (Fig. 5) was taken to show the microstructure of the specimen's worn surfaces. The optimization technique's confirmation test comes as its last step. Using Taguchi Design of Experiments, the best conditions were determined for carrying out the confirmation experiment as well as for estimating the wear rate. S2, D3, L3, R3 values of Sliding Speed 1 m/s, Sliding Distance 900 m, Load 45 N, and 15% reinforcement are the ideal parameters for obtaining the lowest wear rate. The experimental value is 6.01 X 10^{-5} mm^3/m while the predicted wear rate is 5.06 X 10^{-5} mm^3/m.

IV. Conclusions

Utilizing the hand lay-up method, novel fibre reinforced hybrid polymer matrix composite laminates were created. It has been found that sample 3's hybrid polymer matrix composite (CKCKC) has better wear characteristics than the other samples, and applications for this kind of material exist in the automotive industry. The worn pin microstructure of hybrid polymer matrix composite pins was investigated using SEM analysis.

REFERENCES

[1]. Dimitrios G. Papa Georgiou, Ian A. Kinloch, Robert J. Young, Mechanicalproperties of graphene and graphene-ased, Nanocompos. Prog. Mater. Sci. 90 (2017) 75–127.

[2]. NoorfaizalYidris, Effect of fiber loading directions on the low cycle fatigue of intraply carbon-
Kevlar reinforced epoxy hybrid composites, Compos. Struct. 130 (2019) 183–190.

[3]. K. Senthilkumar, N. Saba, N. Rajini, M. Chandrasekar, M. Jawaid, SuchartSiengchin d,Othman Y. Alotman, Mechanical properties evaluation of sisal fibre reinforced polymer composites: a review, 436 (2018) 68–75.

[4]. Thomas L. Attard, Li He, Hongyu Zhou, Improving damping property of carbonfiber reinforced epoxy composite through novel hybrid epoxy-polyureainterfacial reaction, Compos. B 150 (2018) 83–90.

[5]. MeltemAltinKaratas_, Hasan Gökkaya, A review on machinability of carbon fiber reinforced
polymer (CFRP) and glass fiber reinforced polymer (GFRP) composite materials, Defence
Technol. 120 (2019) 85–95.

[6]. A.N. Dickson, J.N. Barry, K.A. McDonnell, D.P. Dowling, Fabrication of continuous carbon,
glass and Kevlar fibre reinforced polymer composites using additive manufacturing, Addit.
Manuf. 16 (2017) 146–152.

[7]. S.L. Valença, S. Griza, V.G. De Oliveira, E.M. Sussuchi, F.G.C. De Cunha, Evaluation of the
mechanical behavior of epoxy composite

reinforced with Kevlar plain fabric and glass/Kevlar hybrid fabric, Compos. Part B Eng. 70 (2015) 1–8.

[8]. G.O. Young, Synthetic structure of industrial plastics (Book style with papertitle and editor), in Plastics, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw- Hill, pp. 15–64, 1964.

[9]. K. Karthik, T. Raja, S. Prabu, R. Ganesh, Mechanical properties of carbon-epoxy with ceramic particles on composite, Int. J. Appl. Eng. Res. 10 (13) (2015) 33826–33830, ISSN 0973-4562.

[10]. K. Karthik, R. Ganesh, T. Ramesh, Experimental investigation of hybrid polymer matrix composite for free vibration test, Int. J. Mech. Eng. Technol. 8(8) (August 2017) 910–918, ISSN Print: 0976-6340.

[11]. K. Karthik, T. Ramesh, J. Thamilarasan, C.H. Prasanna Sai, Study of mechanical properties on polymer matrix composite materials, Int. J. Mech. Prod. Eng. Res. Dev. (IJMPERD)Trans stellar, Special Issue (2018) 87–93.

[12]. J. Udaya Prakash, S. JebaroseJuliyana, P. Pallavi, T.V. Moorthy, Optimization of wire EDM process parameters for machining hybrid composites (356/B4C/Fly Ash) using Taguchi technique, Mater. Today:. Proc. 5 (2) (2018) 7275–7283.

[13]. J. Udaya Prakash, S. JebaroseJuliyana, M. Saleem, T.V. Moorthy, Optimisation of dry sliding wear parameters of aluminium matrix composites (356/B4C) using Taguchi technique, Int. J. Ambient Energy (2018), https://doi.org/10.1080/01430750.2018.1525590.

[14]. S. Ananth, J. Udaya Prakash, R. Krishna Murthy, K.V. Arun Pillai, T.V. Moorthy, Tribological behaviour of grey cast iron–EN31 steel contact under sliding conditions, Trans. Indian Inst. Met. 73 (3) (2020) 793–798.

[15]. J. Udaya Prakash, S. Ananth, G. Sivakumar, T.V. Moorthy, Multi-objective optimization of wear parameters for aluminium matrix composites (413/B4C) using grey relational analysis, Mater. Today:. Proc. 5 (2018) 7207–7216.