Hybridization Effect on Mechanical Properties and Erosion Wear of Epoxy-Glass Composites

Raffi Mohammed, B Ramgopal Reddy, Abdul Siddique Shaik, J.S. Suresh

Abstract*: In this research work the mechanical and erosion wear behavior of E-Glass fiber reinforced epoxy based hybrid composites were determined. Fillers like coal fly ash (CFA), Coal powder (CP) and mixture of coal fly ash and coal powder (CFA-CP) at different weight proportions of 0wt%, 5wt% and 10wt% were mixed with Epoxy Resin and composites were fabricated by manual hand lay-up technique with 50wt% of Glass Fiber as reinforcement and the prepared composites were cut in to specimens as per ASTM standards for mechanical characterizations like tensile, flexural, ILSS, Impact and Hardness properties and erosion wear behavior. Experimental analysis shows that the tensile strength of unfilled Epoxy-Glass composites is maximum (252.189MPa) where as for 10wt% coal fly ash filled epoxy-glass composites tensile modulus is maximum (7.823 GPA). The flexural strength and ILSS are 750.54 MPa and 25.188 MPa respectively for 10 wt% CP filled hybrid composites. The impact strength and hardness are 2100 J/m and 62Hv for 10wt% CFA-CP filled epoxy composites. Coming to erosion wear behavior of composites filled with CFA-CP have exhibited maximum erosion wear resistance when compared with CFA filled epoxy composites. It is observed that with the increase in weight percentages of the filler material. The mechanical properties and erosion wear resistance of the composites were enhanced. Hence, for structural applications filler materials mixed Glass- Epoxy hybrid composites can be used in place of plain glass fiber reinforced epoxy composites due to the enhanced properties of composites.

Keywords: Glass fiber, Coal Fly ash (CFA), Coal Powder (CP), Mechanical Characterization, Erosion.

I. INTRODUCTION

In many of the advanced engineering applications polymer composites are emerging materials in place of metals based composites due to their ease of fabrication, economic viability, light weight, high strength, easy availability of good choice of materials from both thermoset and thermoplastic varieties[1-3].The particles mixed with thermoset/thermoplastics as reinforcement along with E-Glass fibers are called as fillers. Filler inclusion in composite materials lowers the consumption of expensive binder material/matrix material and physical/mechanical properties will be improved [4]. Addition of filler to polymers improves heat distortion temperature, mold shrinkage, stiffness, hardness and toughness and also reduces the fabrication cost [5]. Epoxy resins are used in coatings composites as matrix material, high performance applications, structural adhesives and other applications of engineering because of their excellent thermal and mechanical properties, high corrosion and chemical resistance, ability to be fabricated under a verity of conditions and low shrinkage on curing [6]. Composites prepared with glass fiber as reinforcement and various coal powders as fillers at 2.5 wt%, 5 wt%, 7.5 wt% with the increase in weight percentage of filler addition to the epoxy/polyester resins mechanical properties were improved [7]. Improvements in mechanical properties depends on interfacial bonding between fiber, filler with matrix material, filler size, shape and weigh percentage [8]. In automobiles, mining, space ships, sports kits, structures manufacturing and equipment of marine polymer composites reinforced with fibers are used as fabricating materials due to their resistance to abrasion, corrosion, wear, erosion, high strength to low weight ratio and low cost of manufacturing. In present research work epoxy based hybrid composites are prepared by utilizing E-Glass fiber as reinforcement, coal fly ash/coal powder/ coal fly ash and coal powder and fillers. Here coal powder/coal fly ash is hazardous industrial wastes from powder plants which are causing severe environmental effects while disposing them in large scale. To overcome this situation these industrial wastes are being utilized in bricks manufacturing and composite manufacturing to enhance the strength [9-11].

II. MATERIALS AND METHODS

2.1 Materials required

i. Epoxy Resin (LY556) + Hardener (HY951) as matrix material
ii. E-Glass fiber as reinforcement
iii. Coal powder and coal fly ash as fillers (or) Epoxy modifiers
iv. Mould for composite fabrication
v. Roller for uniform distribution of epoxy resin on E-Glass fiber and for removing entrapped air present in E-Glass fiber.
vi. Silicone spray: Used for easy removal of composite from mould
vii. Al_2O_3 erodent in air jet erosion test rig for erosion wear test

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2.2 Methods

i. Fabrication of composite is done by manual hand lay-up technique

ii. Specimens are prepared as per ASTM standards by using conventional wire cutting machine.

iii. Mechanical properties like tensile strength, flexural strength were determined by Instron UTM as per ASTM D-638-III and ASTM D-790 respectively. Impact strength was determined by Izod impact testing machine as per ASTM D-256 and Hardness of the specimen is determined by Vickers hardness tester as per ASTM E-384.

iv. Development of a theoretical model for estimation of erosion wear rate.

v. Estimation of erosion wear rate by Air jet Erosion test Rig.

vi. Comparative analysis of erosion wear rate

The removal of material from the surface of the specimen due to the impact of erodent (or) particles is called as erosion [9]. Erosion wear rate mainly depends on composition and type of materials to be used for fabrication of composite, type and size of erodent and experimental/operating conditions of Air jest erosion rig.

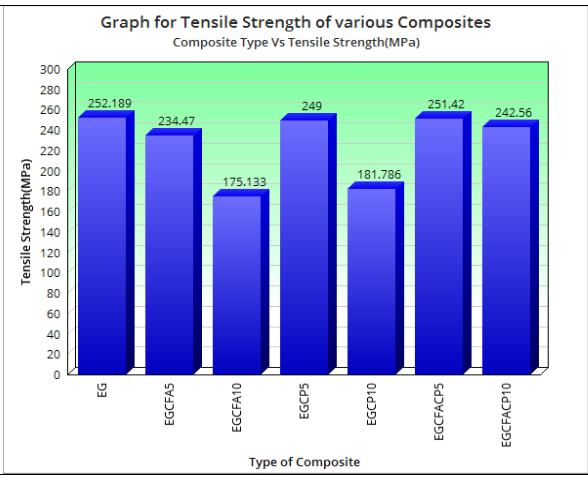
III. RESULTS AND DISCUSSION

3.1 Mechanical Characterization of Composites

The mechanical properties like tensile strength, tensile modulus, Flexural strength, impact strength and hardness are determined as per ASTM standards and the results are tabulated as shown in Table 3.1

Table 3.1 Composites Mechanical Properties

Composite Designation	Tensile Strength (MPa)	ILSS (GPa)	Flexural Strength (MPa)	Hardness (Hv)	Impact Strength J/m	Tensile Modulus (GPa)
EGCFACP5	251.42	19.208	624.36	51	1974	5.936
EGCFACP10	242.56	21.612	702.48	62	2100	6.725
EGCFA5	234.47	9.696	525.42	41	1340	5.85
EGCFA10	175.133	24.247	693.07	48	1250	7.823
EGCP5	249	9.013	488.4	47	1850	5.225
EGCP10	181.786	25.188	750.54	51	1750	5.665
EG	252.189	20.507	666.58	32	687.5	6.292

S.No	Graphs for various Mechanical Properties	Reason for Decrease /Increase of value in Graph
1		The declines in Tensile strength of composites are because of ▪ Presence of pores at the interface between filler particles and the matrix. The interfacing adhesion may be too weak to transfer the tensile stress. ▪ In the matrix base stress concentration results due to the irregular shaped particulates.
	Figure 1: Graph for Tensile Strength	

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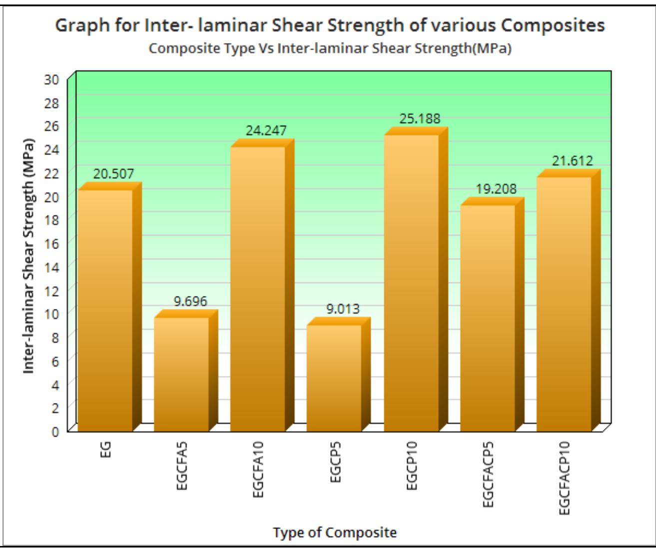
<td>
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<td>Composite EGCP10(40 Wt % Epoxy Resin + 50 Wt % Glass Fiber + 10 Wt %CP) Exhibited Maximum ILSS As Shown In Graph It May Be Due To
• Fine Particles Which Gives Better Adhesive Strength Compared To Other Fillers & Decrease In ILSS Might Be Due To The Poor Dispersion Of Micro Sized Particulates.</td>
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<td colspan="2">Figure 2: Graph for ILSS</td>
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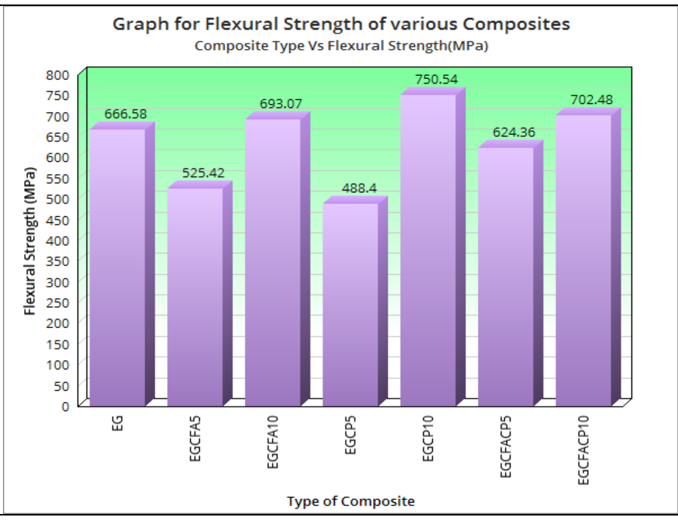
<td>
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<td>Composite EGCP10 (40 wt % Epoxy Resin+50 wt %Glass Fiber+10 wt %CP) Exhibited Maximum Flexural Strength as shown in Graph it may be due to
• Fine particles which give better adhesive strength compared to other fillers & decrease in F.S might be due to the poor dispersion of micro sized particulates.</td>
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<td colspan="2">Figure 3: Graph for Flexural Strength</td>
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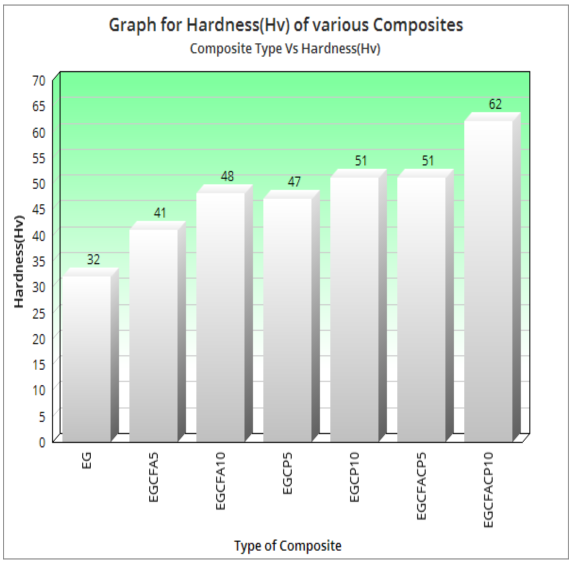
<td>
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<td>Composite EGCFACP10 (40wt %Epoxy Resin + 50 wt % Glass Fiber + 10 wt % CFACP) Exhibited maximum Hardness of 62Hv and for remaining composites hardness is decreased. With the addition of filler hardness was increased.
• This is because during the compressive loading in hardness test the reinforcement phase (i.e. filler and glass fiber) and matrix phase are pressed together tightly in such a way that the interface can transfer pressure more effectively which results in enhancement of hardness.</td>
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<td colspan="2">Figure 4: Graph for Hardness</td>
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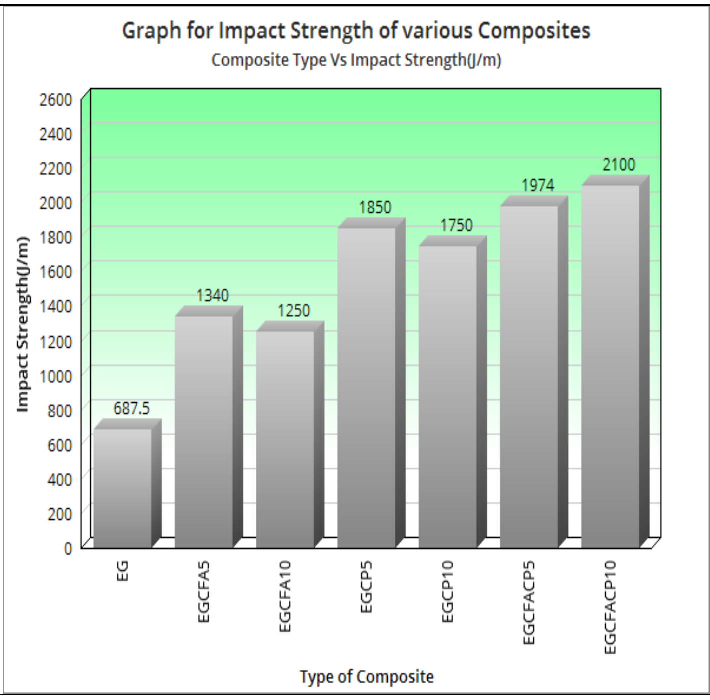
<td>
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<td>The Impact strength of Composite EGCFACP10 (40wt %Epoxy Resin + 50 wt % Glass Fiber + 10 wt % CFACP) is 2100J/m and decreased for other filled and unfilled composites. The decrease in impact strength is due to
• Decrease in energy absorbing capacity with filler addition, the decrease in energy absorbing capacity in composite is due to the reason that the mobility of polymer chain is constrained by the filler content which reduces the ability to deform freely and makes the material less ductile.</td>
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<td colspan="2">Figure 5: Graph for Impact Strength</td>
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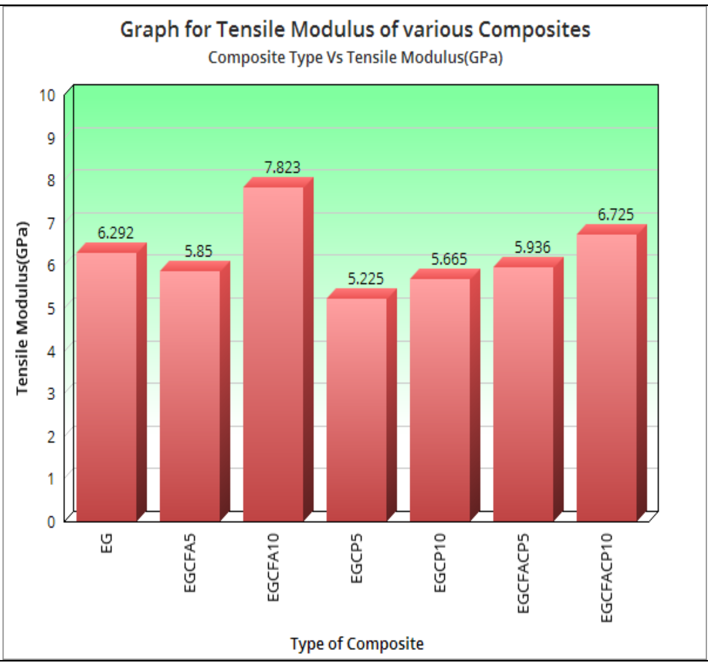
<td>
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<td>The declines in Tensile modulus of composites are because of
▪ Presence of pores at the interface between filler particles and the matrix. The interfacing adhesion may be too weak to transfer the tensile stress.
▪ In the matrix base stress concentration results due to the irregular shaped particulates.</td>
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<td colspan="2">Figure 6: Graph for Tensile Modulus</td>
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3.2 Erosion Wear Behavior of Hybrid Composites

The erosion wear behavior of epoxy based hybrid composites filled with CFA/CFACP is determined by Air Jet Erosion Test Rig under operating conditions like velocity of impact, standoff distance and impingement angle at weight percentages of 0, 5 and 10 of CFA/CFACP fillers from the Table 3.2 CFA filled epoxy based Hybrid composites exhibited a mean erosion wear rate of 1181.5 mg/kg having S/N Ratio of -61.0162 dB where as CFACP filled epoxy based hybrid composites exhibited mean erosion wear rate 591.353 mg/kg having S/N Ratio of -50.5165 dB. Theoretic erosion wear rate of these composites were found by the theoretical model developed. The theoretic mean erosion wear rate of CFA filled composites is 1274.787 mg/kg where as for CFACP a filled hybrid composite is 620.811 mg/kg. The comparative erosive wear behaviors of epoxy based hybrid composites filled with CFA/CFACP are shown in Figures 7&8.

Table:3.2 Theoretical and Experimental Erosion Wear Behaviour of Hybrid Composites

Operating Variables				Erosion wear Rate(mg/Kg)			
Velocity of Impact (m/sec)	Wt% of filler	S.O.D (mm)	Impingement Angle (Degrees)	$(CFA)_{Exp}$	$(CFA)_{thr}$	$(CFACP)_{Exp}$	$(CFACP)_{thr}$
30	0	25	30	1305.63	1388.692	1305.63	1388.692
30	0	35	60	991.348	1054.416	991.348	1054.416
30	0	45	90	1328.217	1412.716	1328.217	1412.716
30	5	25	60	1219.87	1299.333	436.83	439.8489
30	5	35	90	732.27	779.9703	289.72	291.7222
30	5	45	30	589.79	628.2091	126.87	127.7468
30	10	25	90	833.87	933.9421	66.66	67.72703
30	10	35	30	958.64	1073.686	49.46	50.25171
30	10	45	60	1116.46	1250.446	72.43	73.58939
50	0	25	60	1530.11	1627.454	1530.11	1627.454
50	0	35	90	1678.58	1785.369	1678.58	1785.369
50	0	45	30	1128.89	1200.708	1128.89	1200.708
50	5	25	90	1496.04	1593.492	372.89	375.467
50	5	35	30	882.168	939.6327	314.68	316.8547
50	5	45	60	1381.2	1471.172	445.66	448.7399
50	10	25	30	639.09	715.7867	83.46	84.78543
50	10	35	60	839.48	940.2254	137.66	139.8462
50	10	45	90	829.119	928.621	74.92	76.10981
60	0	25	90	1664.95	1770.872	1664.95	1770.872
60	0	35	30	1309.83	1393.16	1309.83	1393.16
60	0	45	60	1010.9	1075.212	1010.9	1075.212
60	5	25	30	1855.87	1976.762	413.24	416.0959
60	5	35	60	2105.33	2242.472	473.82	477.0945
60	5	45	90	1343.75	1431.282	320.56	322.7754
60	10	25	60	1094.75	1226.13	153.26	155.7132
60	10	35	90	777.229	870.5037	96.24	97.78052
60	10	45	30	1258	1408.972	89.72	91.15615

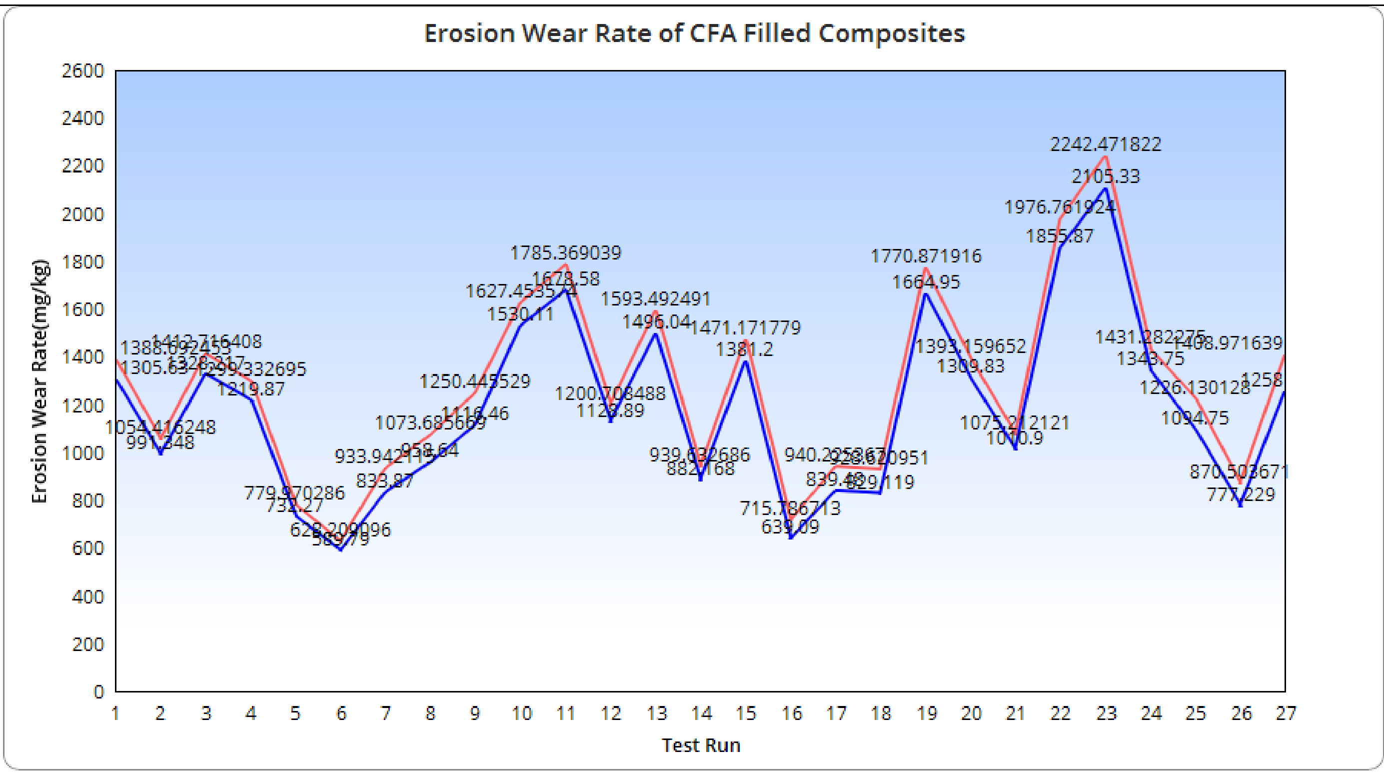

Fig.7 Comparative Graph for Theoretical & Experimental Erosion Wear Rate of CFA Filled Epoxy Based Hybrid Composites

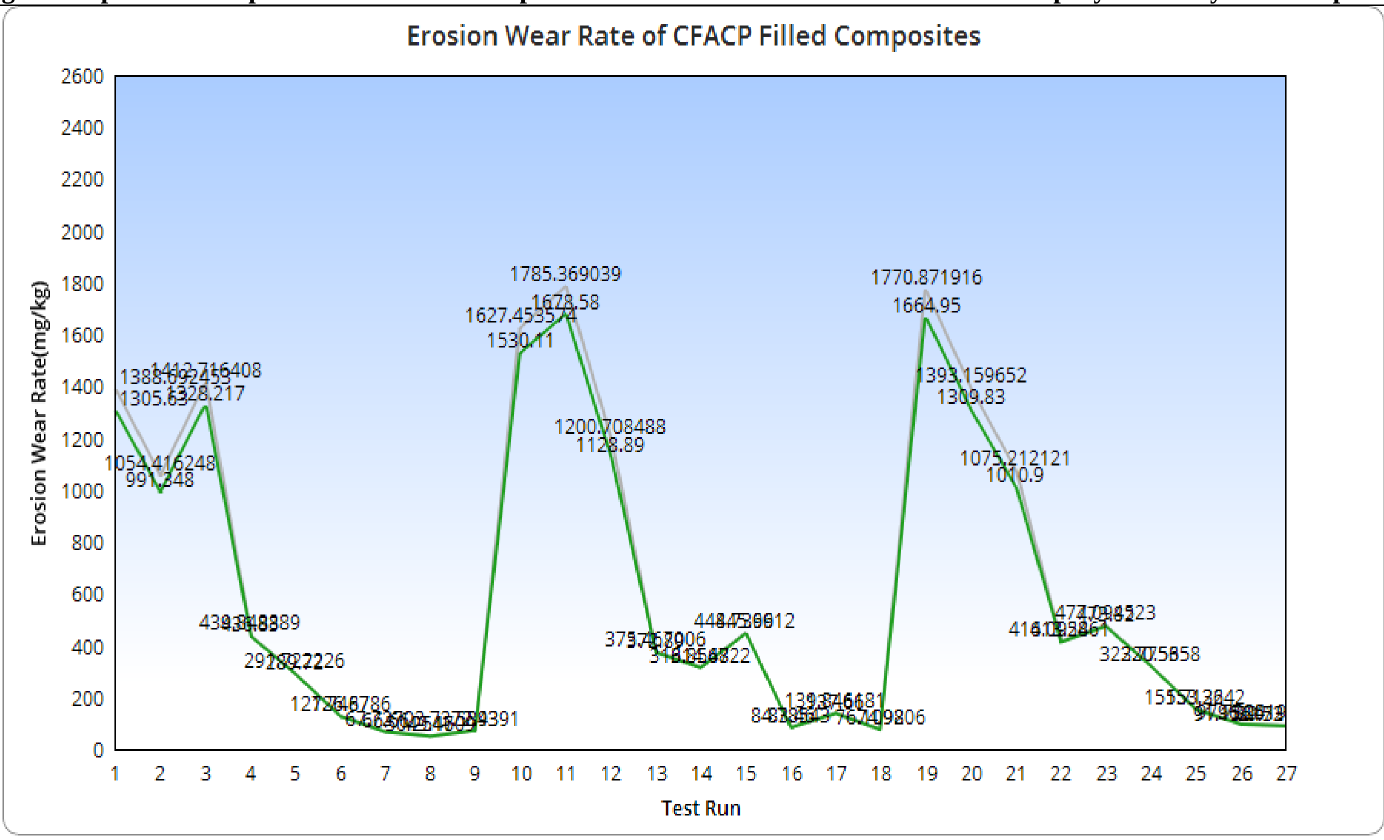

Fig.8 Comparative Graph for Theoretical & Experimental Erosion Wear Rate of CFACP Filled Epoxy Based Hybrid Composites

IV. CONCLUSIONS

(1) Fabrication of CFA/CFACP filled Hybrid composites has been done by manual Hand lay-up process.

(2) Mechanical characterization of composites has been done and reasons for increase/decrease in mechanical properties were discussed.

(3) Theoretical and experimental results of erosion were compared and the % error for CFA filled composites is 7.317% and for CFACP filled composites is 4.745%

(4) The erosion wear resistance is more for CFACP filled composites when compared with CFA filled composites.

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