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An Investigation on Wear, Hardness and Impact Behaviour of Hybrid Composites

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Abstract: According to the environmental aspects, the combinations of natural and synthetic fibers has been used for making eco-friendly products. The present investigation has been made develop and characterize a new class of composites with a polymer called epoxy-resin as the matrix and Hemp and synthetic fibers (Carbon, E-glass, Kevlar) are the reinforcing material. These materials are fabricated using hand layup technique to frame a fallowing hybrid composite, 1) Hemp/Carbon/Epoxy 2) Hemp/E-glass/Epoxy 3) Hemp/Kevlar/epoxy composites of 3mm thickness to find the various mechanical properties (wear, hardness and impact strength) of produced samples as per ASTM Standards. For defining relative significance of measured norms pairwise comparison was done. Wear, Hardness and Impact properties are carried out. The effect of fiber loading and length on mechanical properties like wear, hardness and impact strength of composites is studied. In these fallowing conditions shows a better property. The result on this study indicated that Hemp/Kevlar/Epoxy composite shows better impact mechanical properties compare to another two hybrid composites. Hemp/E-Glass/Epoxy composite shows better wear and hardness properties compare to another two hybrid composites. Hemp/Carbon/Epoxy composite shows intermediate properties compare to Hemp/E-Glass/Epoxy and Hemp/Kevlar/Epoxy composite.
Keywords: Hemp, Carbon, Glass, Kevlar, Epoxy, Wear, Hardness, Impact test

I. INTRODUCTION

In the recent decade extensive studies on preparation and properties of polymer matrix composite (PMC) replacing the synthetic fiber with natural fiber like Hemp, Jute, Sisal, Pineapple, Bamboo and Kenaf were carried out. These plant fibers have many advantages over synthetic fibers (E-glass, carbon and Kevlar) like renewable, environmentally friendly, low cost, light weight. Hybrid composites made from blending of natural and synthetic fibers in a polymer matrix show synergistic effect on properties which cannot be achieved from normal composites. Hybrid composite materials are used in many engineering applications such as Automobile, structural and aerospace industry uses in many of the interior and exterior applications. Considering ease of manufacturing methods under the wider choice of fabrication techniques, hybrid composites are developed wherever it can contribute for the enhancement of functional requirement simply by replacing the existing materials.

A. Definition of Composite

A composite is a material system consisting of two or more phases on a macroscopic level, whose mechanical properties are designed to be superior to those of the constituent material acting independently. It is composed of two or more distinct phases. Matrix phase and reinforcing phase.

1) *Matrix Phase:* The primary phase, having a continuous character, is called matrix. Matrix more ductile and less hard phase. It holds the dispersed phase and shares a load with it.
2) *Reinforcing Phase*

B. Hybrid Composite

The second phase is embedded in the matrix in a discontinuous form. This secondary phase is called reinforcing phase. Dispersed phase is usually stronger than the matrix. A consolidation of more than one sort of fiber in a solitary lattice is known as a cross breed composite. The mixture composite creates high firmness and strength in contrast with the person built up material. Generally, one of the fiber types is having a low modulus, and cost such as hemp, jute, coir, or bagasse, is hybridized with the fiber of high modulus and strength, such as glass, carbon or Kevlar fiber to reduce the use of synthetic fiber.

C. Potential Applications of Hybrid Composites

1) *Aerospace Applications:* Performance fighters Space structures, control surfaces in aircraft Primary structural parts in high performance fighters, spacecraft, small passenger aircraft parts, aircraft interiors, Radomes; rocket motor casings
2) *Automotive Applications:* Door panels, glove box, instrument panel support, insulation, seat back rest panel, trunk panel and seat surface/backrest Internal engine cover, engine insulation, sun visor, interior insulation, bumper, wheel box, and roof cover, cargo floor tray
3) *Sports Equipment's:* Tennis rockets, Golf clubs, baseball bats, helmets, hockey sticks, fishing rods, boat hulls, wind surfing boards, water skis, racing shells, paddles, yatching rope, speed boats, scuba diving tanks, race cars reduced weights
4) *Medical Field:* Wheel chairs, Crutches, Hip joints, Heat valves, Dentistry
5) *Military Applications:* Military helmets, Bullet proof vests, Impact resistant vehicles, Lighter and less detectable ships
6) *Marine Applications:* Ship and boat, Hulls, Masts Instruments panels, Hydrofoils, Hovercrafts, Propellers, Propulsion shafts, Rudders, Piping, Ventilation ducts

II. PROCESSING METHODS AND MATERIAL

1) *Reinforcing Fibre:* Hemp fabric 500gsm, Carbon fabric 200gsm, E-glass fabric 200gsm, Kevlar fabric 200gsm
2) *Matrix System:* Epoxy Resin (lapox L-12 Atul ltd) Hardener K-6
3) *Molding Process:* Hand lay-up process followed by Room temperature moulding
4) *Reinforcements:* Matrix ratio: 55:45

A. Calculation of Number Of Fiber Layers For The Laminates

Table.1: Material Properties

Sl. No.	Material	Density (g/cm^3)	Volume fraction (%)	Ultimate Tensile strength (Mpa)	Modulus (Gpa)
1	Hemp Fiber	1.46	0.275	550	13
2	Glass Fiber	2.66	0.275	2000	80
3	Carbon Fiber	1.8	0.275	4500	250
4	Kevlar Fiber	1.44	0.275	3620	76
4	Epoxy	1.2	0.45	60	4.4

Number of fiber layers used for each hybrid composite specimen

- Hemp/Carbon / Epoxy laminate 3mm thickness = 8 layers
- Hemp/E-glass / Epoxy laminate 3mm thickness = 10 layers
- Hemp/Kevlar / Epoxy laminate 3mm thickness = 8 layers

1) Processing Technique

Hand Layup Process for Laminates Preparation

Hand Layup process is used in the manufacture of Hybrid Composite Reinforced with Epoxy Polymer Composite and is a manually performed in open moulding technique.

a) Mold is prepared as per dimensions, which is made of wooden material.
b) Put the Mylar sheet on it until the layup is finished to prevent sticking the specimen into the mould. The resin and the hardener of required quantities are taken in a previously weighed empty bowl. They are mixed properly in the bowl using a paint brush. The mixture is used immediately in the preparation of the laminate which otherwise would start gelatin.
c) A highly polished flat mould was cleaned and wiped dry with acetone.
d) PVA wax was applied and was left for 20 minutes to dry. The wax was then applied in order to form a thin realizing film.
e) A small quantity of resin system was coated on the mould surface and then a layer of the fabric (300 x 300mm) already cut was placed on that.
f) The resin system was applied on the fabric to wet it and then the next layer of fabric was placed. use the roller to apply pressure and helps to removal of the voids.

g) The same procedure was followed till the required layers were placed ensuring adequate impregnation.
h) The mylar sheet was sticked on the topmost ply and specimen war rolled using roller. Repeat the same procedure for other two composites.
i) The cast of each composite is stored for 24 hours under a load of approximately 30 kg before it is removed from the mould cavity.
j) After room temperature curing, the specimens were hardened. The hardened specimens are ejected from the mould.
k) For charecterization of physical and mechanical properties, specimens are cut as per ASTM standards.

2) Preparation of Specimens as per ASTM Standards

Table.2: ASTM standard specimens

Tests	ASTM Standards	Specimen specification
Wear	D99	Ø10mmX 3mm thickness
Hardness	D2240	20mm X 20mm X 3mm
Impact	D256	12.7mm X 65mm X 3mm

B. Mechanical Testing Of Composites

1) Wear Test as Per ASTM D 99 Standard: 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. 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. The material loss from the composite surface is measured using a precision electronic balance with accuracy + 0.1 mg and the specific wear rate (mm^3/N-m) is then expressed on volume loss basis as Wear rate(W) and specific wear rate (Ks) as follows.

1. $vollume\ loss\ in\ mm3 = \frac{\Delta m}{\rho}$ X1000 (mm^3)

2. $Wear\ rate\ W = \frac{\Delta m}{\rho L}$ (mm^3/mm)

3. $Specific\ wear\ rate\ WS = Ks = \frac{\Delta m}{\rho L Fn}$ (mm^3/N-m)

Where,

Dm is the mass loss in the test duration (gm)
r is the specimen density of the composite (gm/cm^3)
L is the total distance while sliding in (m)
t is the test duration (sec).
Vs is the sliding velocity (m/sec)
FN is the average normal load (N).

2) 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)

3) Izod Impact Test as Per ASTM D256 Standard: The Izod Impact test is carried out according to ASTM standard D256 to find out impact strength of the hybrid specimen. Capacity up to 25J, discharge edge of pendulum-150^0. the specimen prepared was 65x12.7x3mm for Impact quality of hybrid composites.

The Impact strength as calculated using fallowing formulae.

$$Impact\ strength\ (J/mm) = \frac{Average\ load\ \ break\ (J)}{Thickness\ of\ the\ specimen(mm)}$$

III. RESULTS AND DISCUSSION

The mechanical properties of

1) Hemp fabric/Carbon fabric /Epoxy resin
2) Hemp fabric /E-Glass fabric /Epoxy resin
3) Hemp fabric/Kevlar fabric/Epoxy resin of 3mm thickness hybrid strengthened epoxy composites have been concentrated in three kinds of tests in this section. Wear, Hardness and Impact properties are characterized.

Table.3: Tabulation of Wear Test Results

Sl. No.	Specimen	Density	Sliding distance	Wear volume	Wear rate	Sp. Wear rate
		g/cc	m	mm^3	mm^3/mm	$mm^3/N\text{-}m$
1	H/C/E 1	1.4367	500	6.96039535	1.39208E-05	0.00069604
2	H/C/E 2		1000	14.61683024	1.46168E-05	0.000730842
3	H/C/E 3		1500	25.05742326	1.67049E-05	0.000835247
4	H/G/E 1	1.673	500	5.977286312	1.19546E-05	0.000597729
5	H/G/E 2		1000	12.55230126	1.25523E-05	0.000627615
6	H/G/E 3		1500	19.1273162	1.27515E-05	0.000637577
7	H/K/E 1	1.3375	500	8.224299065	1.64486E-05	0.00082243
8	H/K/E 2		1000	17.19626168	1.71963E-05	0.000859813
9	H/K/E 3		1500	27.6635514	1.84424E-05	0.000922118

Comparison of Wear rate Results of 1) Hemp/Carbon/Epoxy 2) Hemp/E-Glass/Epoxy and 3) Hemp/Kevlar/Epoxy laminate composites (3mm thickness) under different Sliding distance.

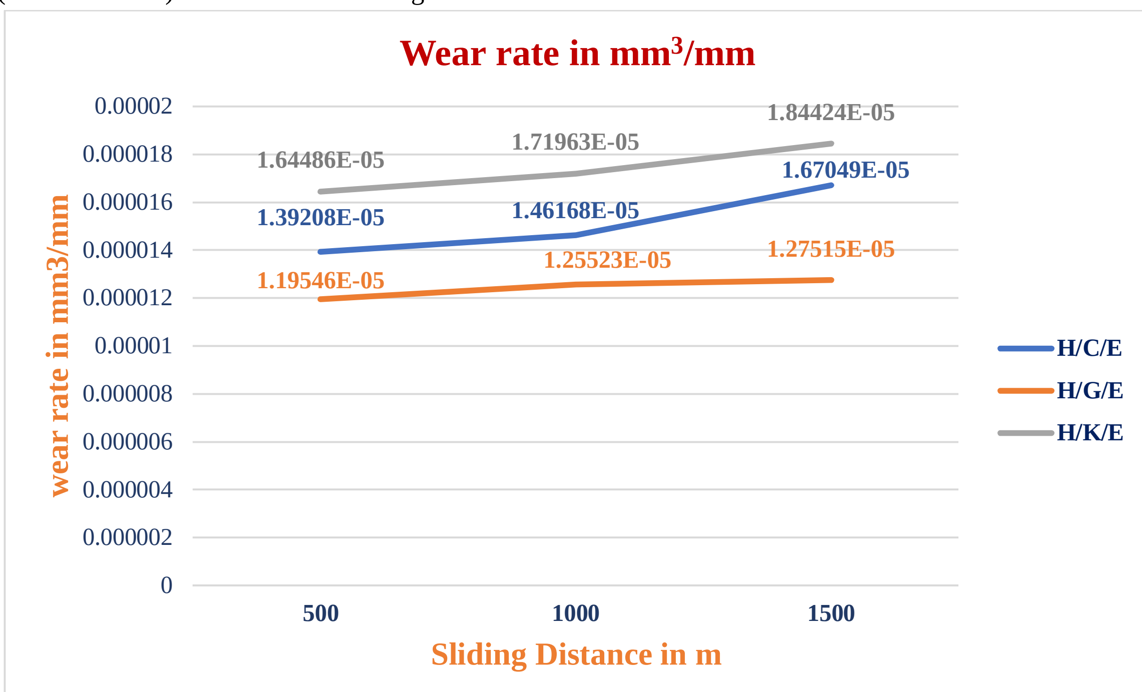

Figure.1(a) Wear rate of Hybrid composites

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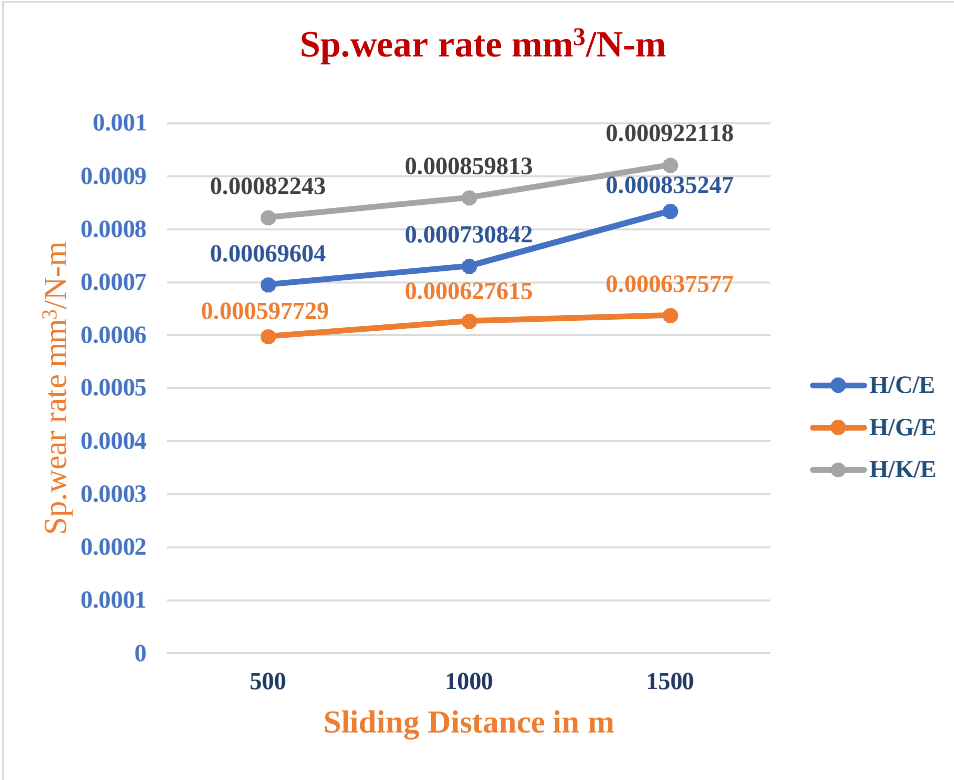

Figure.1(b) Specific Wear rate of Hybrid composites

- From the above Graph Fig.1(a) and 1(b), it clearly shows that the wear rate and Sp. Wear rate is gradually increases with increasing sliding distance for all composites. In that Hemp/Glass/Epoxy laminates shows less wear rate compare to other two laminates.
- Hemp/Kevlar/Epoxy laminate shows more wear rate compare to other two laminates. Hemp/Carbon/Epoxy laminates shows intermediate values between Hemp/Glass/Epoxy and Hemp/Kevlar/Epoxy laminate composites.

Table.4: Tabulation of Shore D Hardness Results

Sl. No.	Sample	Shore D Hardness Number
1	Hemp/Carbon/epoxy	**85.66**
2	Hemp/E-glass/epoxy	**93.83**
3	Hemp/Kevlar/epoxy	**84**

Comparison of Shore D Hardness Test Results of 1) Hemp/Carbon/Epoxy 2) Hemp/E-Glass/Epoxy and 3) Hemp/Kevlar/Epoxy laminate composites (3mm thickness)

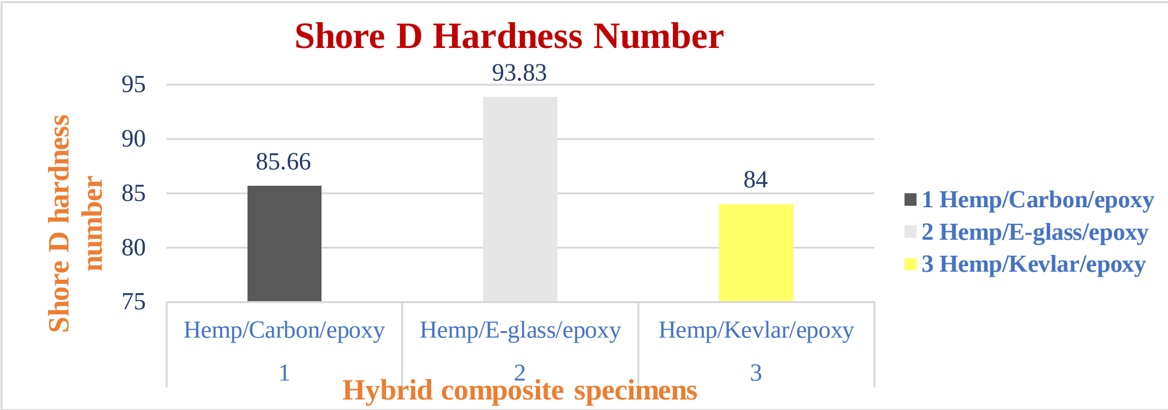

Figure.2 Shore D Hardness numbers of Hybrid composites

- From the above Graph Fig:2 it is clear that Hemp/E-Glass/Epoxy laminate having 3mm Thickness shows more Shore D Hardness numbers of 93.83 and Hemp/Kevlar/Epoxy shows less Shore D Hardness numbers of 84.
- Shore D Hardness number of Hemp/Carbon/epoxy composite is 85.66which is less than Hemp/E-glass/epoxy and more than to Hemp/Kevlar/epoxy composite.
- Hemp/Carbon/Epoxy composites indicates intermediate values between Hemp/E-Glass/Epoxy and Hemp/Kevlar/Epoxy

Table.5: Tabulation of Impact Test Results

Sl. No.	Sample	Impact Energy in Joules	Impact strength in J/mm
1	Hemp/Carbon/epoxy	7.06	2.353
2	Hemp/E-glass/epoxy	3.93	1.310
3	Hemp/Kevlar/epoxy	8.86	2.953

Comparison of Impact Energy of 1) Hemp/Carbon/Epoxy 2) Hemp/E-Glass/Epoxy and 3) Hemp/Kevlar/Epoxy laminate composites (3mm thickness)

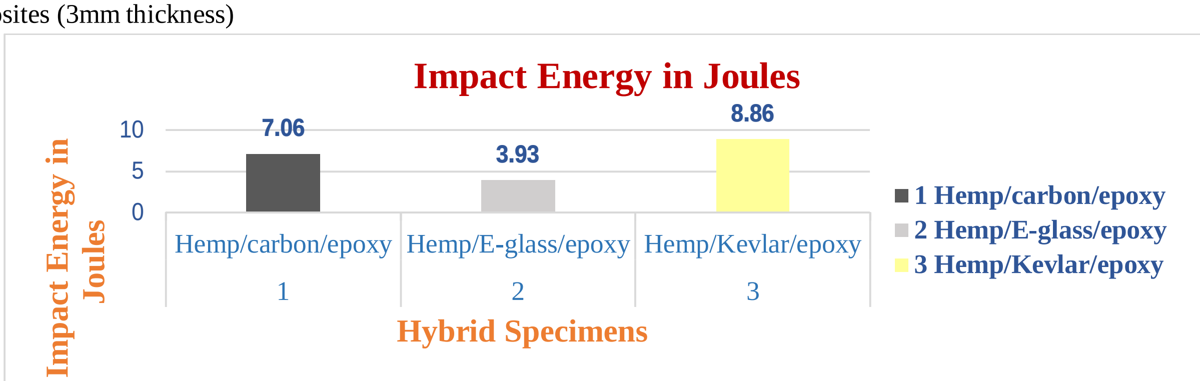

Figure.3 Impact Energy of Hybrid composites

- From the above Graph Fig:5.12 it is clearly shows that specimen Hemp/Kevlar/Epoxy laminate having 3mm Thickness shows more Impact Energy is 8.86 J compare to other two specimen composites.
- Hemp/E-glass/Epoxy laminate composites show less Impact Energy is 3.93 J than the other two specimen composites.
- The Impact Energy of Hemp/Carbon/epoxy composite is 7.06 J which is more than Hemp/E-glass/epoxy and less than to Hemp/Kevlar/epoxy composite

Comparison of Impact Strength of 1) Hemp/Carbon/Epoxy 2) Hemp/E-Glass/Epoxy and 3) Hemp/Kevlar/Epoxy laminate composites (3mm thickness)

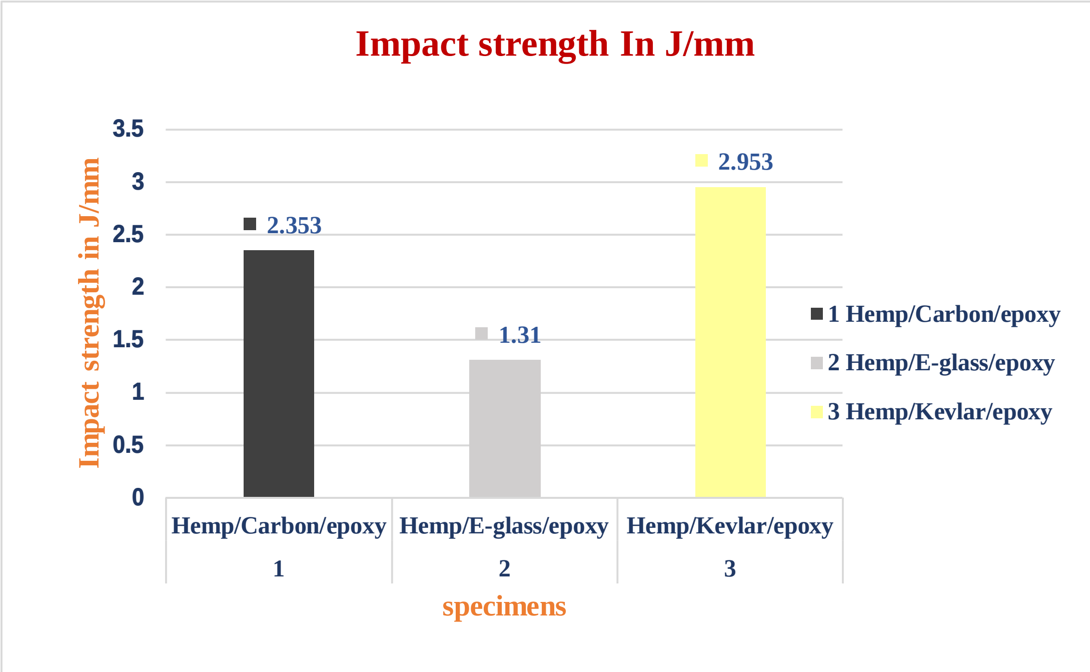

Figure.4 Impact Strength of Hybrid composites

- From the above Graph Fig:4 it is clear that specimen Hemp/Kevlar/Epoxy laminate shows more Impact Strength than the other two specimen composites.
- Hemp/E-glass/Epoxy laminate composites shows less Impact strength than the other two specimen composites.
- Hemp/Carbon/Epoxy composite shows intermediate value compare to above specimens.

Table.6: Comparison of Wear, Hardness and Impact Energy of Hybrid Composites

Sl. No	Sample	Mean Hardness Number	Average Impact Energy in J	Average Impact Strength in J/mm	Wear Rate mm^3/mm (10^{-5})	Sp. wear Rate mm^3/N-m
1	Hemp/Carbon/epoxy	85.66	7.06	2.353	1.670	0.000835247
2	Hemp/E-glass/epoxy	93.83	3.93	1.310	1.275	0.000637577
3	Hemp/Kevlar/epoxy	84	8.86	2.953	1.844	0.000922118

Comparison of Wear, Hardness and Impact Properties Hybrid composites.

- From the Fig.5.it clearly indicates that hardness increases, the wear rate decreases and impact strength also decreases.
- Hemp/E-Glass/Epoxy shows more hardness, less specific wear rate and less impact strength.
- the hardness decreases the specific wear rate increases and impact strength increases.
- Hemp/Kevlar/Epoxy shows less hardness, more specific wear rate and more impact strength due to toughness of Kevlar fiber.
- Hemp/Carbon/Epoxy shows intermediate values in all range of wear, hardness and Impact properties.

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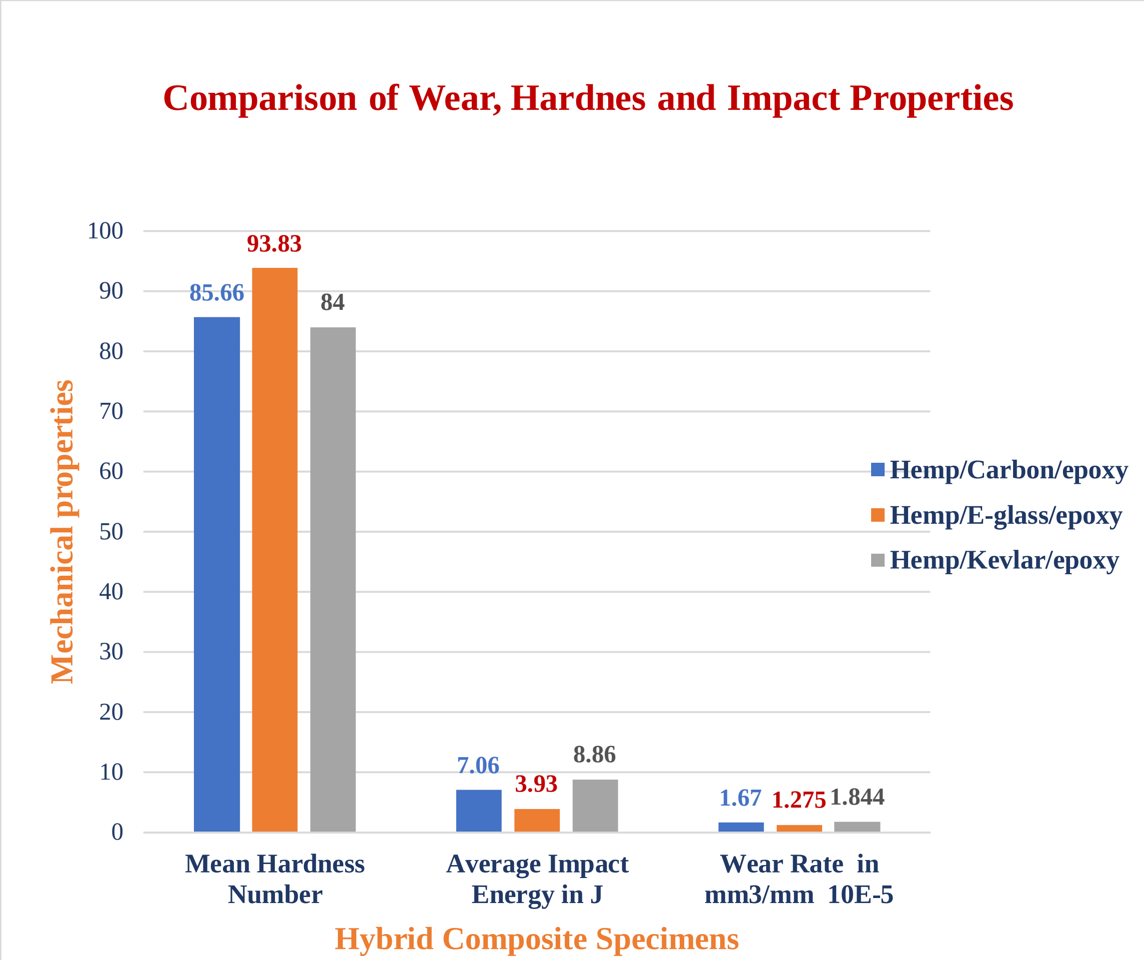

Figure.5: Comparison of Wear, Hardness and Impact Properties Hybrid composites

IV. CONCLUSIONS

A. Wear Rate

Wear rate of composites was investigated as per ASTM standard to know the wear characteristics. It is observed from the results that Hemp/E-Glass/Epoxy composite laminate exhibits less wear rate as compared to other two composite laminates.

Decreases in the wear rate is due to glass fiber is harder and more brittle in nature along with better bonding, adhesion and uniform dispersion of the fiber in the matrix. Hemp/Kevlar/Epoxy Composite laminate exhibits high wear rate due to the Kevlar fiber is less hard and ductile in nature and presence of pores at the interface between the fiber and the matrix and the weak interfacial adhesion.

Hemp/Carbon/Epoxy composite indicates the intermediate values between Hemp/E-Glass/Epoxy and Hemp/Kevlar/Epoxy Composites.

B. Hardness

Hardness of composites was investigated as per ASTM standard. From the experimental outcomes it is clear that the shore D hardness number is maximum in case of Hemp/E-glass/Epoxy composite compared to other two specimens. Hemp/Kevlar/Epoxy composite shows lesser Shore D hardness number compared to other two composite specimens. due to Kevlar has tougher compare to Glass fiber.

Hemp/Carbon/Epoxy composite shows the intermediate shore D hardness number compare to other two specimen which is greater than Hemp/Kevlar/epoxy and lesser than Hemp/E-glass/Epoxy composite.

C. Impact Energy

Impact energy of hybrid composites was investigated as per ASTM standard. It is noticed that composite laminate Hemp/Kevlar/Epoxy exhibits improved impact energy as compared to other two composite laminates. This is due the better bonding, and improved adhesion between fiber and matrix interface. Hemp/E-Glass/Epoxy laminates exhibits lower impact strength due to harder and brittleness of glass fiber.

Impact energy in Hemp/Carbon/Epoxy laminate composites is lying between Hemp/E-Glass/Epoxy, and Hemp/Kevlar/Epoxy composite.

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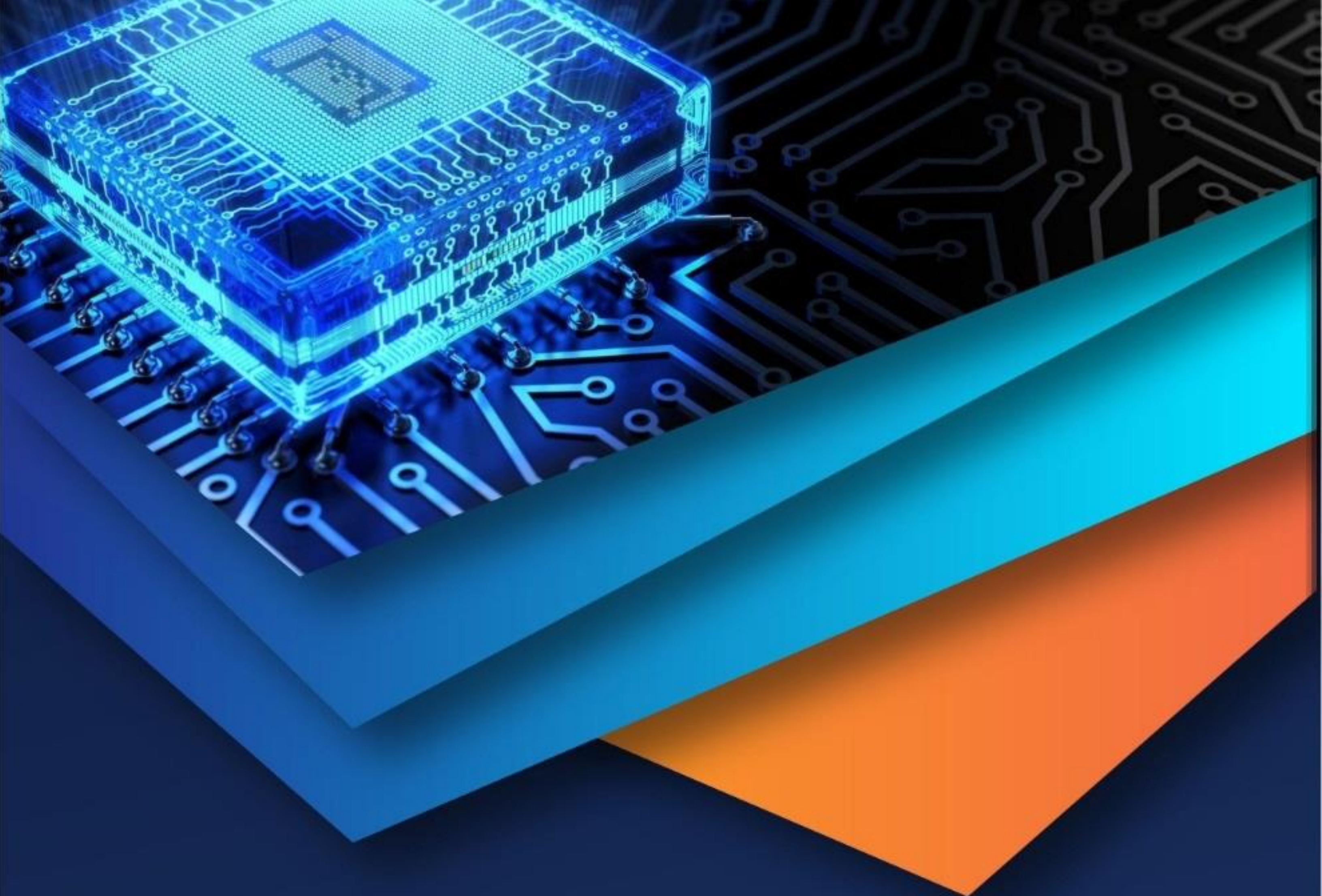

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