IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁙ Impact Factor 8.066 ⁙ Peer-reviewed / Refereed journal ⁙ Vol. 10, Issue 6, June 2023

DOI: 10.17148/IARJSET.2023.10609

Research & Development of Safety Helmet Using Composite Materials

ANIKET ANJIYANAND KAMBLE[1], ADITYA RAJU DESHMUKH[2], SUMAN RAJENDRA GAWDE[3], GAURAV SHASHIKANT KULKARNI[4], Prof. N.S. Biradar[5]

Student, of Mechanical Engineering, JSPM's Imperial College of Engineering and Research, Wagholi, Pune[1-4]

Assistant Professor, Department of Mechanical Engineering, JSPM's Imperial College of Engineering and Research, Wagholi, Pune[5]

Abstract: This century has witnessed remarkable achievement in green technology in materials science through the development of composite materials. The development of high performance engineering products made from composite material is increasing worldwide day by day. Nowadays, more than ever companies are faced with opportunities and choices in material innovation. This Review provides an overview of natural fiber with synthetic fiber reinforced composite focusing on fiber glass and jute fiber and sources, processing method, characterization of fibers, matrices and their mechanical performance. This review focuses on the design and development of hybrid composite material for development of industrial safety helmet. This industrial safety helmet having same properties as helmet exist in market but reduction in weight and by introducing hybrid composite material. It is also focus on future research, recent development and application and concludes with key issues that need to be resolved. This articles critically summarizes the essential finding of the mostly readily utilized reinforced fiber in hybrid composite material.

I. INTRODUCTION

Over the last thirty years composites materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composite industry. It is obvious, especially for composite, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals.

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has becomes prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armouring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shaft, support beams of highway bridges and even paper making rollers. For certain application, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc.

II. LITERATURE SURVEY

Pramendra Kumar Bajpai[1] , had studied on "Fabrication of Glass/Jute/Epoxy Composite Based Industrial Safety Helmet". This research paper focused on the development and characterization of hybrid glass/jute reinforced epoxy composite for industrial safety helmet. The total numbers of fiber layers are fixed and by varying the weight percentage of matrix and different fiber layers. Five different composites were manufactured using hand lay-up technique. One layer

DOI: 10.17148/IARJSET.2023.10609

of glass and three layers of jute reinforce epoxy hybrid composite achieved maximum flexural strength of 100.78 MPa. Three layer of glass and one layer of jute reinforce epoxy hybrid composite achieved maximum impact strength of 72.24 J/m. The study results shows that 3-Glass 1-Jute fiber reinforced epoxy composite which has maximum impact strength can be used to replace theexisting industrial safety helmet material. Hand lay-up technique has been used for the fabrication of composites specimen and industrial safety helmet. Open mould plastic boardwas used for the fabrication of composite. The epoxy was thoroughly mixed with hardener(curing agent) in a suitable proportion. First plastic board was covered by non-reactive thinplastic sheet to give fine surface finish. After that, silica gel was applied on the plastic sheetto avoid sticking of polymer to surface.

R.A. Braga[2] , had studied on "Analysis of the mechanical and thermal properties of jute and glass fiber as reinforcement epoxy hybrid composites". This work describes the study to investigate and compare the mechanical and thermal properties of raw jute and glass fiber reinforced epoxy hybrid composites. To improve the mechanical properties, jute fiber was hybridized with glass fiber. Epoxy resin, jute and glass fibers were laminated in three weight ratios (69/31/0, 68/25/7 and 64/18/19) respectively to form composites. The tensile, flexural, impact, density, thermal and water absorption tests were carried out using hybrid composite samples. This study shows that the addition of jute fiber and glass fiber in epoxy, increases the density, the impact energy, the tensile strength and the flexural strength, but decreases the loss mass in function of temperature and the water absorption. Morphological analysis was carried out to observe fracture behavior and fiber pull-out of the samples using scanning electron microscope. Fabric jute fibers and glass fibers were reinforced in epoxy resin to prepare the composites. The jute fibers and the epoxy resin have a modulus of about 55 and 3.42 GPa respectively and have density of 1.38 and 1.65 g/cm3 respectively. The process of manual mixture proportions that has been used for resin and hardener was 10 (ten) parts resin to 1 (a) curing agent, or hardener. It took 20 to 30 min to work with a mixture until the mixture began its process of polymerization. Some steps were necessary in order to obtain a perfect lamination of the plate and also ensure a better finish in the play and avoid places where the resin does not fully impregnate.

M.R. Bambach[3] had studied on "Compression strength of natural fibre composite plates and sections of flax, jute and hemp". Natural fibres such as flax, jute and hemp have been utilized for thousands of year's, however have only recently been considered for fibre-resin composites. A major motivation for such an application is their superior sustainability attributes compared with traditional building materials. Population rise continues to place increasing demands for new infrastructure.

Meanwhile, public concerns about the environment, climate change, energy consumption and greenhouse gas emissions, place increasing demands for the use of sustainable materials in infrastructure. While there is a wealth of knowledge in the materials aspects of natural fibre composites, relatively few studies have investigated their potential for structural applications. This paper presents an experimental and analytical study of natural fibre composite plates and channel sections consisting of flax, jute and hemp fibres and subjected to pure compression.

The intrinsic mechanical properties are shown to be relatively modest. However, the buckling and post- buckling responses are shown to be stable, the ultimate condition is reached in a stable and predictable manner, and failure ensues in a gradual and ductile process. These characteristics show promise for the use of natural fibre composite sections in lightstructural applications such as in the residential and light commercial markets. Additionally, the analytical effective width mechanics model shows promise for use as a design techniquefor estimating their compression strength.

III. METHODOLOGY

Step 1: Selection of matrix material
Epoxy CT-556 resin belonging to the Epoxide family was taken as the matrix. AH-951 was used as the hardener.

Step 2 : Selection of reinforcement
Natural fiber-Jute mat and Synthetic fiber-Glass fiber was taken to fill as reinforcements in the polymer composite.

DOI: 10.17148/IARJSET.2023.10609

Fig. Material for Helmet manufacturing

Step 3 : Preparation of helmet mould:

In that the base, firstly wash with water and clean by smooth cloth. Then wax is introducing on all over the surface by hand or by small smooth cloth. After introducing wax on the plain surface, PVC gel coat is apply on the surface. This PVC gel coat is used to resist the sticking of mould on surface by making thin layer in between them. After that the helmet who's mould is to be form, is fix on plain surface with the help of M-Seal or other sticky materials. After that the helmet is clean by smooth cloth and coated with wax with the help of hand or by small smooth cloth.

Fig. Fixing helmet on surface

Then PVC gel coat is applying over the whole surface of helmet. After that the helmet is dividing in to two symmetrical parts and make partition in between them by using non-sticky material like, plastic sheet coated with get coat etc. Then finishing gel is pouring on it to get high surface finish on inner side of mould. This gel spread over whole surface of helmet and kept for 2- 3 hours at room temperature for curing.

After curing, apply mix of resin and hardener in proper proportion on helmet surface and pain surface near helmet. Then glass fiber sheets place on it layer by layer with mixture of resin and hardener in between them. For getting certain thickness of mould, apply certain layer of glass fiber on helmet. After that, the mould kept to the 5-6 hour in room temperature for curing. After curing, this same process repeat on remaining side. And after second side is complete, mould kept to the 10-15 hours at room temperature for solid curing and after that helmet remove carefully from the mould and mould is ready.

Step 4 : Manufacturing of helmet:

After the mould is ready, the manufacturing process of helmet can be start. First clean the mould by smooth cloth and remove unwanted particles of material. After cleaning, apply wax on inner side of mould by hand or by small smooth cloth. Then apply PVC gel coat to resist sticking of helmet in the mould. Keep helmet mould at it is in room temperature for 30-45 minutes for curing gel coat. Then for manufacturing of helmet keep glass fiber one layer sheet at bottom and apply mixture of resin and hardener with proper proportion like 10:1 or 10:2. Then apply mixture over glass fiber until

DOI: 10.17148/IARJSET.2023.10609

whole layer will wet by mixture. After that, keep jute one layer over glass fiber layer in mould and apply mixture same as earlier, whole mat should be wet. This process repeat until required thickness or required layer is not obtaining

Fig. Manufacturing of helmet

After introducing certain layer in mould with mixture of resin and hardener, whole setup is cover with thin plastic sheet before it curing. After plastic sheet, breater is introducing on it. The all sides of mould are seal with sealing tape. After that, make one or two opening in setup for pump the air from mould by means of vacuum pump. The vacuum pump is use for creating vacuum inside the mould or whole setup and also create the vacuum pressure inside the mould. Keep this condition mould for 10-12 hours for complete curing of inside layer of helmet.

After 10-12 hours, remove all side sealing and all setup. Remove helmet from mould slowly and carefully. Keep helmet for 10-15 hours for complete curing of helmet and after that post processing is require like remove excess material, surface finish etc. on helmet. After that helmet is ready for use.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁙ Impact Factor 8.066 ⁙ Peer-reviewed / Refereed journal ⁙ Vol. 10, Issue 6, June 2023

DOI: 10.17148/IARJSET.2023.10609

Fig. Helmet after giving finishing touches.

IV. SYSTEM DESIGN

Various materials selected are:

- Jute Mat (12 x 12)
- Glass Faber
- Epoxy Resin (CT-556)
- Hardener (AH-951)

Weight Proportion:

For every 100 parts of resin we take 1.5 parts of cobalt and 1.5 parts of hardener. Cobalt increases the bondability of the hardener with the resin and increases the setting of polymer. The amount of resin for fiber is layer is obtained by trial and error method. Approximately, one part of artificial fibers requires five parts of resin and one part of natural fiber requires ten parts of resin.

Sequence of layer:

The sequence of layer in composite play an important role in obtaining specific properties. So sequence is important point of design. The best results are obtain for GJGJGJG sequence consider by below table.

Symbol	Stacking Sequence	TS (MPa)	Eb%	TM (MPa)	BS (MPa)	BM (MPa)	IS (kJ/m²)
J5	JJJJJ	88.4	8	3602	123.9	5182	20.97
G5	GGGGG	165	13.3	2553	301.2	8700	63.49
H5	JGJGJ	120.5	9.9	4331	178	5477	37.56
H6	GJGJG	124.5	11.3	3278	217.4	7786	46.36
H7	JGJGJG	129.2	12.7	3049	242.4	7712	42.39
H8	JGJGJGJ	143.5	10.9	3179	195.8	5126	48.66
H9	JGJGJGJGJ	145.2	12.8	4867	180.3	5099	56.51

GSM:

GSM stands for gram per square meter measured for fabric. GSM is the matric measurement, of the weight of the fiber. In knitting fabric it is the main parameter. It is controlled by loop length. If loop length increases GSM will decreases and vice versa. GSM is calculated as bellows,

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⁑ Impact Factor 8.066 ⁑ Peer-reviewed / Refereed journal ⁑ Vol. 10, Issue 6, June 2023

DOI: 10.17148/IARJSET.2023.10609

$$GSM = \frac{\text{Weight in grams}}{\text{Area in } m^2}$$

GSM is simply measurement of weight of fabric. This measurement helps one decide on the best weight to buy considering the usage of the material at hand. The higher the GSM number, the denser the fabric will be. For example, if the lable on a linen shirt reads 180-200 GSM the shirt material would be thick and would probably keep are warm on warmer days, the best pick would be a shirt that is 130-150 GSM.

Sr.no	Fabric	L (M)	W (M)	Weight (grams)	GSM (gms/M^2)
1	Random	0.305	0.305	28	300
2	Woven glass fiber	0.305	0.305	32	350
3	Jute	0.305	0.305	26	280

V. TESTING

Specimen preparation as per ASTM standards:
The samples are cut to the following dimensions as per ASTM standards for testing for testing shown in the table 5.1

Sr.No.	ASTM Code	Mechanical Test	Sample Dimensions (mm)
1	ASTM-D790	Flexural	100 x 15x4
2	ASTM-D638	Share Strength	200x25x4

Mechanical Testing of Composite Specimens:
Mechanical properties such as ultimate tensile strength (UTS), Young's modulus. Flexural strength (FS), Flexural modulus, Inter laminar shear strength (ILSS) of carbon and glass fiber reinforced vinyl ester composites are computed from the test conducted using universal testing machine (UTM) **(Fig 5.2)** in accordance to ASTM standards for specimen preparation. The 10 ton capacity UTM machine used for testing was supplied by PRAJ Metallurgical Laboratory, Pune, India. UTM specifications are shown in Table 5.2.

Parameter	Specification
Capacity	10 tones
Load Frame	Mild steel C channel with double ball screw mechanism pre-loaded ball screw with zero backlash coverd with bellow
Mounting	Free standing
Length measurement	Rotary encoder mounted on to the screw rod
Length resolution	0.01
Cross head speed	0.1 to 100 mm/min
Controls	Emergency off, up and down key

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified ⁜ Impact Factor 8.066 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 10, Issue 6, June 2023
DOI: 10.17148/IARJSET.2023.10609

Input power	220V +- 10% VAC, 50HZ, 1500 VA
Net weight	225 kg
Grippers	Tensile, Compression, Three point bending
Length accuracy	+-0.1 mm

Share Strength Testing of Composite:
One of the most common testing method, Share testing is used to determine the behavior of the sample, while an axial stretching load is applied. These types of test may bed performed under 25* ambient condition to determine the Share properties of material Share strenght is performed on a variety of materials including metals, plastic, elastomers, paper, composites, rubber fabrics, adhesives, films, etc. Share strength testing is commonly used to determine the maximum load that a material or a product can withstand. Share strength may be based on a load value.

Here in Share strength test ASTM D-638 was used to prepare specimens however, in ASTM D-638 dumble shaped specimens were given in type 1- type 5. However rectangular specimens were used in this testing because if we make dumbel shaped specimen, fiber will break. Hence the purpose of putting the fiber material will defiet. Hence, rectangular samples were prepared.

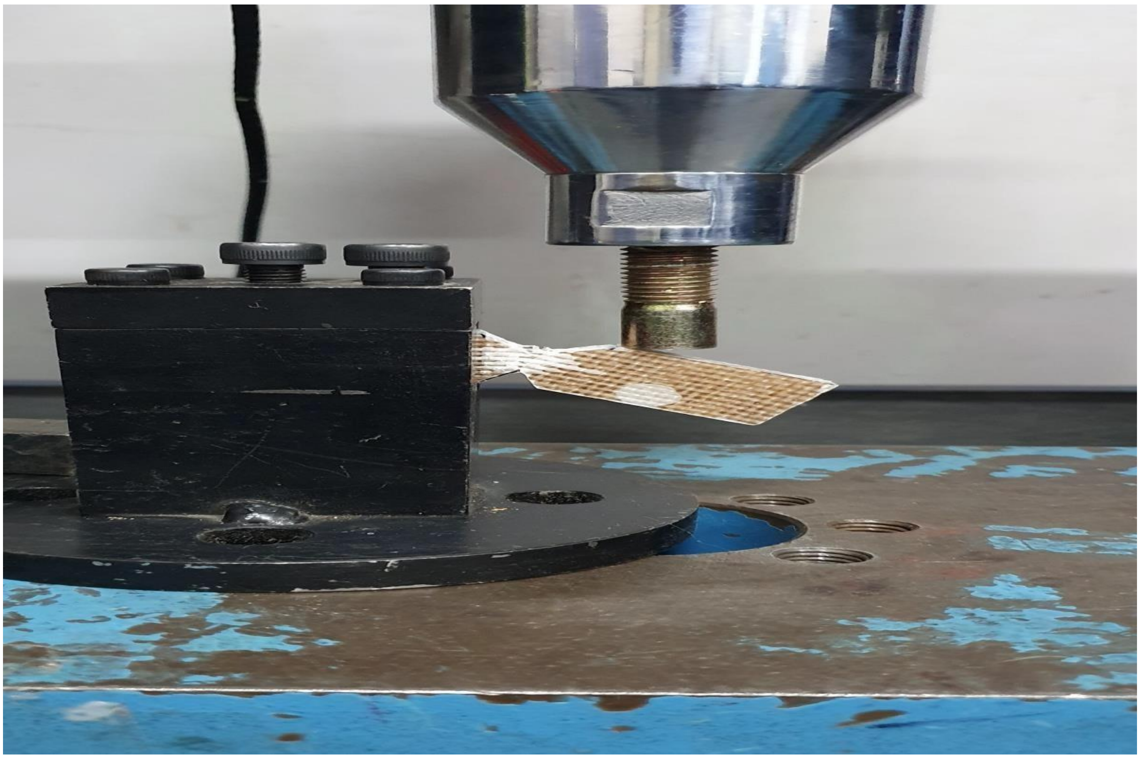

Fig 5.2: Shear stren test specimen

DOI: 10.17148/IARJSET.2023.10609

VI. RESULTS

Shear Strength Results:

Sr. No.	Type of laminate	Shear strength (MPa)
1.	Hybrid composite laminate	20.444
2.	Natural composite laminate	14.676

Flexural Strength Result:

Sr. No.	Type of laminate	Flexural strength (MPa)
1.	Hybrid composite laminate	128.143
2.	Natural composite laminate	36.086

VII. CONCLUSION & FUTURE WORK

Conclusion:

From the observations and result of laminates and helmet under shear strength, flexural, bending testing. The various conclusions are taken out which are as follows :

- From result of laminates, we concluded that the maximum properties (share strength and flexural strength) are obtain at GJGJGJG sequence and the maximum properties are obtained at 90^0 ply angle or orientation of reinforcing material.
- The helmet made by hybrid composite material having potential to replace existing material in market for helmet because, from result of helmet testing, we conclude that the highly specific strength is obtained from hybrid composite helmet.
- The specific strength and properties are larger in the mixture of natural fiber and synthetic fiber composite than any natural composite or glass composite.
- The shear strength and flexural strength of hybrid composite laminate is large in number than natural composite laminate.
- The helmet made of hybrid composite material is light in weight than plastic helmet, due to that hybrid composite helmet potential to replace existing helmet made from plastic and the hybrid composite material will be alternative on existing plastic material.
- From results, we concluded that the mechanical properties are improved by using jute in composite material. The jute improve specific strength of composite material and just reduce the cost of the material because jute is available in low cost.
- The hybrid composite material of jute and glass fiber gives best results than natural composites. The helmet is made from hybrid composite material is low in cost than existing material helmet if there is mass production.
- From this project, we can conclude that the hybrid composites materials has potential to replace or provide alternative over existing material without losing strength and properties.

DOI: 10.17148/IARJSET.2023.10609

REFERENCES

K.Sabeel Ahmed "Tensile, flexural and interlaminar shear properties of woven jute and jute-glass fabric reinforced polyester composites".

M.Ramesh "Comparative Evaluation on Properties of Hybrid Glass Fiber- Sisal/Jute Reinforced Epoxy Composites".

REFERENCES

[1] "Characterization of ABS composites reinforced short glass fiber" Ankul Oriya and Rohit Rajvaidya. IJRET [International Journal of Research in Engineering and Technology]-2015.

[2] Design and Analysis of Industrial Helmet"Anil Kumar and Y. K. Suresh babu. International Journal Of Computational Engineering Research,Vol-3,Issue-12-2013.

[3] Application of finite element analysis to helmet design" Terry Smith, John Lenkeit and Jim Boughton. International Union of Theoretical and Applied Mechanics proceedings on impact biomechanics. 2005.

[4] "Feasibility of optimizing bicycle helmet design safety through the use of additive manufactured TPE cellular structures" S. P. Soe, P. Martin, M. Jones , M. Robinson and P. Theobald, Springer-Verlag London 2015

[5] "Effects of the Mechanical Properties of the Shell and Liner on the Shock Absorption of Helmets" Yusuke Miyazaki, Sadayuki Ujihashi, Tomohiko Jin, Shinichirou Akiyama and Ko Cheol Woong. Tokyo Institute of Technology, Tokyo, Japan.

[6] Improving thermal properties of industrial safety helmets" Yeh-Liang Hsu, Chi-Yu Tai and Ting-Chin Chen. Elsevier-International Journal of Industrial Ergonomics 26 [2000] 109}117. 1999.

[7] "Impact analysis on composite helmet by using FRC and glass using ANSYS tool" Amal Thomas, Dr.P.Suresh, J. Anish Jafrin Thilak and N.Subramani. International Research Journal of Engineering and Technology [IRJET] 2017

[8] "Mechanical Properties of Glass Fiber Reinforced Polyester Composites" M. S. EL-Wazerya, M. I. EL-Elamya and S. H. Zoalfakarb. International Journal of Applied Science and Engineering 2016

[9] "Mechanical Characterization of Thermoplastic ABS /Glass Fiber Reinforced Polymer Matrix Composites" Divakar H, R Nagaraja and Guruprasad H L. International Journal of Engineering Research and Technology [IJERT] 2015

[10] Mechanical behaviour of glass and carbon fiber reinforced composites at varying strain rates and temperatures C.Elanchezhian, B.Vijaya Ramnath and J.Hemalatha. Elsevier-2014

[11] Rethinking the safety of jockey helmets: a statistical comparison of different composite laminate helmet shells" Bernd Fuernschussa, Everson Kandareb, Anton Saboa and Toh Yen Pangb. Elsevier. 2016.

[12] "Impact Attenuation Capabilities of Football and Lacrosse Helmets" Katherine M. Breedlove, Evan L. Breedlove, Thomas G. Bowman and Eric A. Nauman. Journal of Biomechanics. 2016.

