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Enactment of Fiber Reniforced Hybrid Epoxy Composite for Passenger Car Bumper Beam

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Abstract: These days, fuel economy and emission petrol control of passenger vehicles are two critical challenges. The most effective approach to improve fuel efficiency with the front and rear parts of a vehicle are equipped with bumpers, which are crucial in low-speed collisions because they serve as low-speed energy absorbers. Sacrificing safety is to employ fiber reinforced composite materials in the body of cars. The fascia is a major element that is designed to absorb abrupt or impact loads that are imparted to automobiles either purposefully or accidentally. The objective for the incorporation of the bumper is when a collision suspends a vehicle to abrupt or impact loads, it is employed to absorb crash energy and is beneficial again for safety of the driver passengers as well as for the vehicle. In this work, a novel composite bumper beam which will be made of hybrid (natural and synthetic) fiber epoxy composite material embedded with multi walled carbon nanotubes to improve the bending stiffness. The major goal of the current investigation is to determine the impact of nano carbon tubes on the mechanical characteristics of jute/glass/epoxy hybrids and banana/glass/epoxy hybrids. The samples manufactured using a hand layup method and a variety of stacking sequences. Experimentations for three quasi-static 3-point bending test as well as fracture toughness will be conducted. Also, water absorption capability in reinforced materials will be measured. Based on the results, the bumpers are proposed for the Indian passenger cars.

1. Introduction

Initially A composite substance is the combination of more than one material chemically/ physically, suitably arranged or distributed sides or phases, which separates their interface.These characteristics are not depicted in isolation by any of the components. Mostly composite materials have a bulk phase, called the matrix, which is continuous, and one dispersed, phase called the reinforcement which is non- continuous.

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These are usually stronger and harder. Composite materials provide characteristics and are multifunctional material systems not obtainable from any discrete material.

1.1 Classification of composites:

Composites are categorized into four groups on the basis of matrix material. They are:

i. Composite Metal Matrix
ii. Ceramic Matrix Composite
iii. Composite Polymer Matrix

1.2 Bumper:

In the context of cars, the term "fascia" typically refers to the front or rear bumper cover, or the plastic panel that covers the area between the hood and the windshield. It is also sometimes used to describe the dashboard or instrument panel in the interior of the car. The fascia of a car is usually designed to be aerodynamic, stylish, and protective. Itcan be made of various materials, such as plastic, fiberglass, or carbon fiber, and may be painted to match the color of the car's body. The fascia also includes openings for headlights, fog lights, grilles, and other featuresthat help to enhance the car's appearance and functionality. Additionally, some car manufacturers may use the term "fascia" to refer to the entire front or rear assembly of the car, including the bumper cover, grille, and other components as shown in fig. 1.

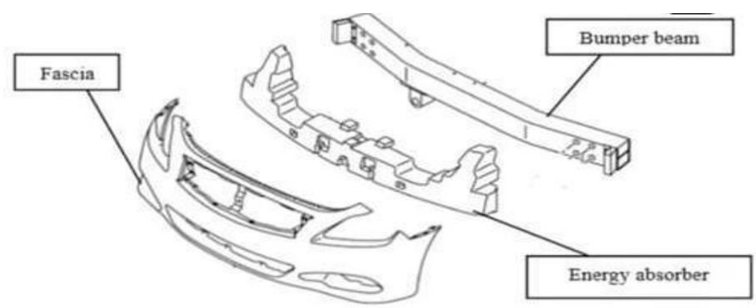

Fig. 1. General assembly of bumper

1.3 Fibre:

It is a piece of material that is long, thin and flexible, like a length of thread. Fiber Polymers may be pulled into long filaments with a length to width ratio of at least 100:1 Fiber comprises of natural and artificial fiber.

1.3.1 Fibrous composites:

Composites with short fiber reinforcementconsist of a matrix that is strengthened by a phase separation in the manner of discontinuous fibers that have a diameter of 100 inches and a length of 100 inches. They fall under category

a) Composites with unpredictable fiber direction.
b) Composites having desired fiber orientation.

Long-fiber reinforced composites have amatrix that is strengthened by an evanescent phase made of continuous fibers.

i. Fibers are oriented in a single direction.
ii. Fibers oriented in two directions (woven).

As part of this research work we have done lot of literature survey meanwhile it was helpful us to do move work forward and corresponding literature as mentioned below.

Pathania (2019) et al. The density is lesser in E-glass i.e 1983 kg/m^3 and Tensile strength is 490 Mpa whereas steel density is 7850kg/m^3 and tensile strength is 520 Mpa. E-Glass Epoxy fibre also showed well results rather than steel. And the cost of the bumper beams can be reduced by more than 50%.

Moghaddam (2011) et al. A commercial short-fiber composite bumper made of GMT material (glass fibre epoxy) with a mechanical spring is designed under frontal impact test. It is revealed that by utilizing this mechanical energy absorber the bumper is able to convert about 80% of kineticimpact energy to spring potential energy and release it to environment in the low impact velocity.

Davoodi (2010) et al. y enhancing the impact property, a hybrid of kenaf/glass fibres might be used in vehicle structural elements like the bumper beam. Additionally, by enhancing the structuraldesign parameters, the impact property may be enhanced.

2. Materials and methods:

2.1 Epoxy Resin:

The composites can be laminated using any resin one factor that needs to be taken while picking a resins is its viscosity. Faster lamination is possible with lower viscosity because permanent reinforcement may be included more quickly. Although higher viscosity resins canalso be selected, careful preparation would be needed. A prevalent type for the resin is diglycidyl ether of bisphenol A (DGEBA). 24 The deformations and fracture toughness are generally lowered, while the tensile modulus, transition temperature of glass, thermal stability, and chemical resistance are all enhanced. A lot of mechanical and aeronautical constructions employ epoxy resin. Epoxy resin has a numberof benefits, including

i. Excellent adhesion to metal and glass fibers
ii. No volatile substances present while curing.
iii. Good chemical and solvent resistance; low shrinkage while curing

2.2 Mould:

Typically, a mould is required when employing the lay-up technique to create components in order to position the layer inside or outside and get the desired form. The mould pattern is shown in fig. 2. To retain the flat base of the layup, we did not utilize a mould but rather a tabletop.

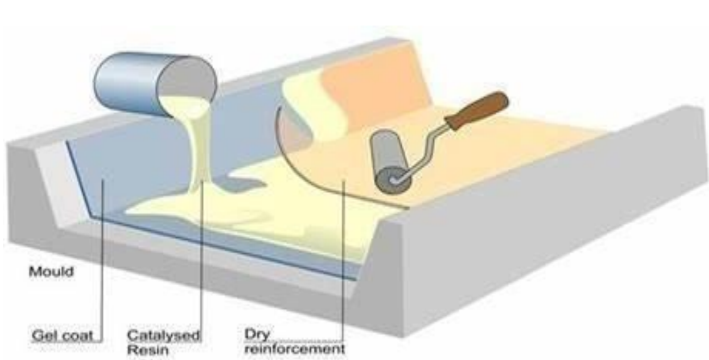

Fig. 2 Mould pattern

2.3 Release agent

Prevents resin from sticking to the mould. Here the table top was covered with plasticsheeting toast as the release agent. Some other release agents used in industry are:

i. Waxes
ii. Spray releases
iii. Release films
iv. Internal releases (added to gel coat or resin system)

Since they can function as contaminants if unintentionally included into the composite lay-up, releaseagents are often placed to the composites moulds or equipment in a separate defined area.

2.4 Specimen preparation

In order to attain our objectives, prepared various specimens of different compositions by varying the fiber pattern as per the sandwich patterns which as follows in table 1.

Table 1: Compositions of different composites prepared based upon Sandwich

Serial. No	**Composite**
1	Glass-Jute-Jute-Rami-Rami-Glass
2	Jute-Glass-Glass-Rami-Rami-Jute
3	Rami-Jute-Jute-Glass-Glass-Rami
4	Glass-Rami-Rami-Jute-Jute-Glass
5	Jute-Rami-Rami-Glass-Glass-Jute
6	Rami-Glass-Glass-Jute-Jute-Rami

3. Experimental Setup

The combination of different fibers have to be now prepared as per the testingthat we have choosen and all the specimens should follow the standards shown in fig. 3.

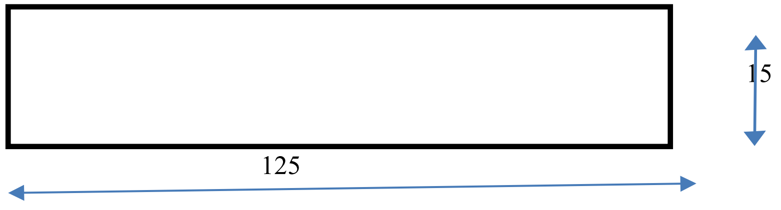

Fig. 3. Specimen dimensions

Specimen Preparation:
Ensure that the work area is clean and free of dust, dirt, and debris. Prepare the mould by applying a release agent to prevent the composite from sticking to the mould.
Cutting and arranging materials:
Cut the reinforcing fibers, such as fiberglass or carbon fiber, to the desired shape and size.
Mixing the resin:
Mix the resin and hardener according to the manufacturer's instructions. Thoroughly stir the mixture to ensure that the resin and hardener are evenly distributed.

Applying the resin:
Apply the resin onto the reinforcing fibers using a brush or roller. Ensure that the resin saturates the fibers and that there are no dry spots.
Laminating:
Add additional layers of reinforcing fibers and resin onto the mold, following the desired sequence and orientation. Use a roller or squeegee to remove any air pockets or excess resin.
Curing:
Allow the composite to cure according to the resin manufacturer's instructions.This typically involves placing the mold in a temperature-controlled environment to allow theresin to harden.
Demolding:
Once the composite has cured, remove the part from the mold. Carefullypeel back the mold to avoid damaging the composite.
Trimming:
Trim any excess material from the edges of the composite using a saw orother cutting tool.
Finishing:
Sand the edges of the composite to smooth out any rough spots or sharpedges. Apply a finishing coat if desired. The finished specimens shown in fig. 4.

Fig. 4. Finished specimens

3.1 Mechanical testing:

After fabrication is completed the test specimens were subjected to various mechanical tests as per ASTM standards. The flexural test of composite is carried out using Electronic Tensometer shown in below figures. The flexural test is generally performed on flatspecimens. A uniaxial load is applied through both the ends. The ASTM standard test methodfor flexural properties of hybrid fiber composite has the designations Impact strength measurement is done on IZOD test on the composites using impact strength testing machine. Water absorption test is also performed on the specimens prepared.

Standards for bending test:

The standards for specimen do not vary depending on fiber orientation. For the bendingtest, ASTM D739 specimen standards are taken.

Bending specimen geometry:

The specimen configuration does not depend on the direction of the fiber. The fiber may be placed in unidirectional / multidirectional in consideration. The area of the specimen isrectangular. The cross sectional area is also rectangular. The required dimensions of the specimen are represented in table 2.

Table 2: Specimen geometry

Fiber Orientation	Width(mm)	Overall Length(mm)	Thickness (mm)	b length(mm)	Tab thickness (mm)
Multidirectional	15	125	4	0	0

3.2 Flexural testing:

Flexural testing, also known as bend testing or bending test, is a type of mechanical testused to evaluate the bending or flexural strength and stiffness of a material. This test involves applying a force to a sample of the material at a specific distance from its supports or points ofrestraint. Experimental setup for flexural strength shown in fig. 5.

Fig. 5. Tensometer

3.3 Impact strength testing:

A mechanical test called an impact analysis is performed to determine whether a product or product can survive rapid loading or shocks loading. Experimental setup for impact strength shown in fig. 6.In this test, an object or materialis put to a significant intensity, typically by having a load or a pendulum dropped onto it.

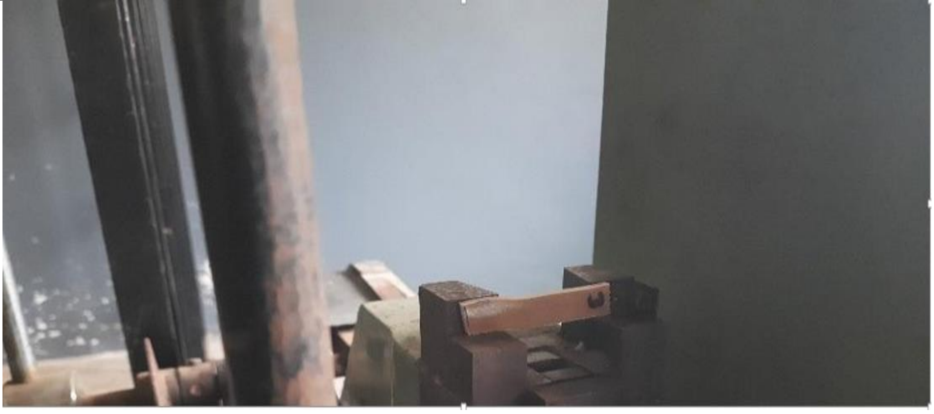

Fig. 6. Specimen loaded in impact specimen placed at points.

3.3 Water absorption test:

Water absorption testing is an important method to evaluate the performance of fiber composites, especially those that are used in environments with high humidity or exposure to water. The test involves measuring the amount of liquid that a material absorbs over a given period of time shown in fig. 7.

Fig. 7. Specimens meant for water absorption test

4. RESULT AND DISCUSSIONS:

The Results of impact strength and water absorption rate are discussed as follows

4.1: Flexural Test results:

The break loads observed by performing flexural test on all specimens by using Tensometer represented in following table 3.

Table 3: Composite pattern break load observed

Specimen Number	Composite Pattern	Break Load Observed(N)
1	Glass-Jute-Jute-Rami-Rami-Glass	274.6
2	Jute-Glass-Glass-Rami-Rami-Jute	139.2
3	Rami-Jute-Jute-Glass-Glass-Rami	294.2
4	Glass-Rami-Rami-Jute-Jute-Glass	255.0
5	Jute-Rami-Rami-Glass-Glass-Jute	168.6
6	Rami-Glass-Glass-Jute-Jute-Rami	188.3

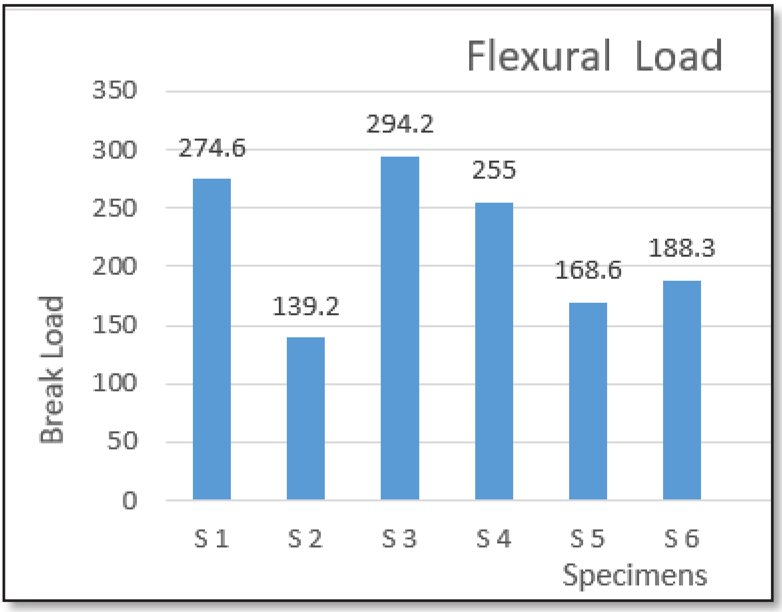

Fig. 8 Graphical representation of break loads of all specimens

It is observed that from the fig. 8, the S-3 (Rami-Jute-Jute-Glass-Glass-Rami) specimen withstand for high break load of 294.2 N among all the specimens.

4.2: Impact Test results:

Impact strength has been calculated based on impact energy and areas of specimens by using the formula (1) and shown in table 4.

Impact Srtength = Impact energy/Area of the specimen (1)

Table 4: Impact strength of specimens

Specimen Number	**Composite Pattern**	**Impact Energy (in J)**	**Area (in mm^2)**	**Impact Strength (N/mm^2)**
1	Glass-Jute-Jute-Rami-Rami-Glass	4.2	900	4.6
2	Jute-Glass-Glass-Rami-Rami-Jute	5.5	900	6.1
3	Rami-Jute-Jute-Glass-Glass-Rami	4	900	4.4
4	Glass-Rami-Rami-Jute-Jute-Glass	6.5	900	6.8
5	Jute-Rami-Rami-Glass-Glass-Jute	5	900	5.5
6	Rami-Glass-Glass-Jute-Jute-Rami	6	900	6.6

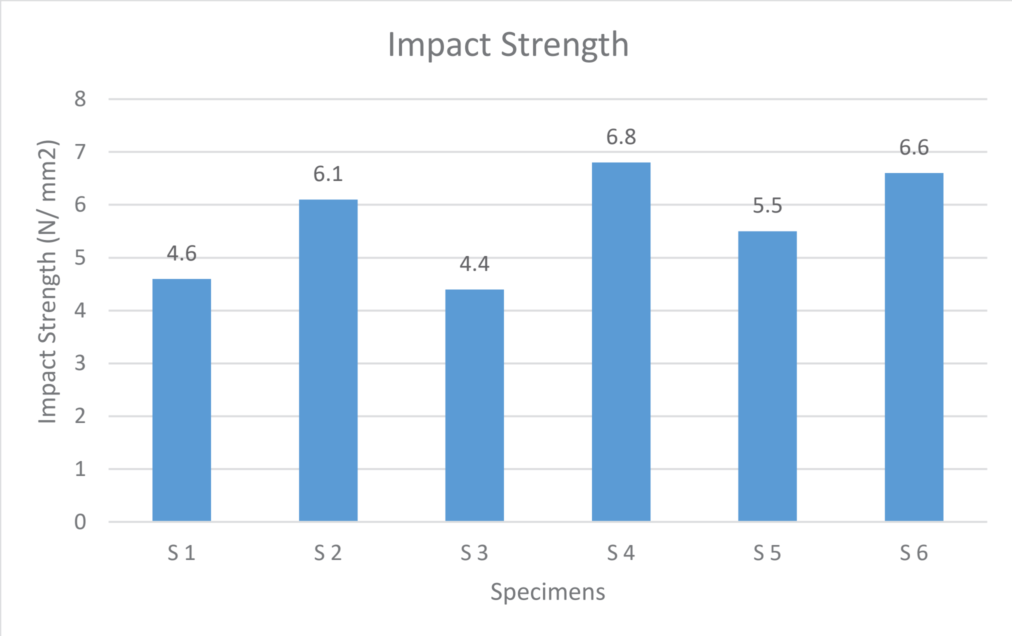

Fig. 9. Graphical representation of impact strength of all specimens

From the above graphical representations fig .9, among all the above specimens, the Glass-Rami-Rami-Jute-Jute-Glass (S-4) having high impactstrength of 6.8 N/mm^2.

4.3: Water Absorption Test Results:

The amount of water absorbed by the specimen is derived by the formula shown below and tabulated in table 5.

Percentage of water absorbed = (Final weight -Initial weight)/Initial weight

Table 5: Percentage of water absorption

Specimen Number	Composite Pattern	Before Absorption W in grams	After Absorption W in grams	Percentage of water absorbed (in %)
1	Glass-Jute-Jute-Rami-Rami-Glass	2.05	2.17	5.85
2	Jute-Glass-Glass-Rami-Rami-Jute	1.68	1.96	16.6
3	Rami-Jute-Jute-Glass-Glass-Rami	1.48	1.64	13.5
4	Glass-Rami-Rami-Jute-Jute-Glass	1.54	1.71	11.0
5	Jute-Rami-Rami-Glass-Glass-Jute	1.75	1.92	9.7
6	Rami-Glass-Glass-Jute-Jute-Rami	1.95	2.20	12.8

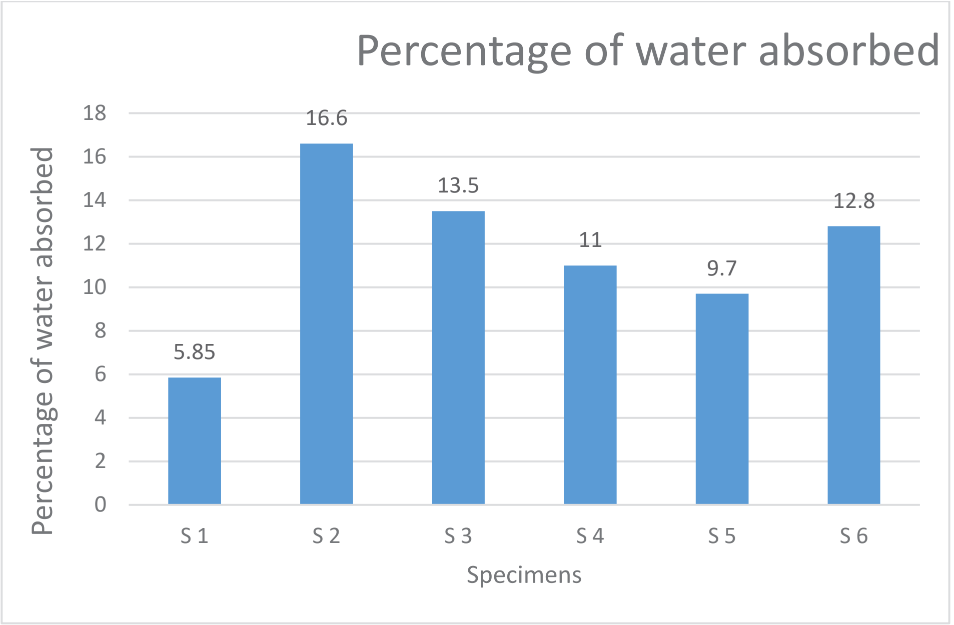

Fig.10. Graphical representation of water absorption test of all specimens

The above graph fig. 10 represents the weight of water absorption by different specimens, Glass-Jute-Jute-Rami-Rami-Glass specimen (S-1) has with less percentage of water absorption rate of 5.85 % among all the other specimens.

5. Conclusions:

- The project was carried out to investigate the flexural strength, impact strength and water absorption test of composite glass, jute and rami fibers reinforced.
- The effect of glass, jute and rami fibers on mechanical properties of composite was studied.
- The results found that the mechanical properties have a strong association with the composition of reinforcement material.
- The composite having pattern as fiber as composite matrix Rami-Jute-Jute-Glass- Glass-Rami – (294.2 N) has good flexural strength and peak load.
- The composite having patternas Glass-Rami-Rami-Jute-Jute-Glass – (6.8 N/mm^2) fiber as composite matrix has good impactstrength.
- The composite having pattern as Glass-Jute-Jute-Rami-Rami-Glass – (5.85%) as composite matrix has maximum water absorption capacity.
- The composite prepared by patternas Glass-Rami-Rami-Jute-Jute-Glass is the best suitable for the replacement of plastics as it is quite good in showcasing better results in all the above three tests performed.

References:

1. Davoodi, M.M., Sapuan, S.M., Ahmad, D., Ali, A., Khalina, A. and Jonoobi, M., 2010. Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam. *Materials & Design*, *31*(10), pp.4927-4932.
2. Mohammadi, H., Ahmad, Z., Mazlan, S.A., Faizal Johari, M.A., Siebert, G., Petrů, M. and Rahimian Koloor, S.S., 2023. Lightweight Glass Fiber-Reinforced Polymer Composite for Automotive Bumper Applications: A Review. *Polymers*, *15*(1), p.193.

3. Prabhakaran, S., Chinnarasu, K. and Kumar, M.S., 2012. Design and fabrication of composite bumper for light passenger vehicles. *International Journal of Modern Engineering Research*, *2*(4), pp.2552-2556.
4. Neelima, V., Rao, J.B.B., Viswatej, K. and Tech, M., 2016. Design and Analysis of Bumper Beam with Composite Materials. *Int. J. Mag. Eng. Technol. Manag. Res*, *3*, pp.253-259.
5. Adesina, O.T., Jamiru, T., Sadiku, E.R., Ogunbiyi, O.F. and Beneke, L.W., 2019. Mechanical evaluation of hybrid natural fibre–reinforced polymeric composites for automotive bumper beam: a review. *The International Journal of Advanced Manufacturing Technology*, *103*, pp.1781-1797.
6. Mohammadi, H., Ahmad, Z., Mazlan, S.A., Faizal Johari, M.A., Siebert, G., Petrů, M. and Rahimian Koloor, S.S., 2023. Lightweight Glass Fiber-Reinforced Polymer Composite for Automotive Bumper Applications: A Review. *Polymers*, *15*(1), p.193.
7. Cheon, S.S. and Choi, J.H., 1995. Development of the composite bumper beam for passenger cars. *Composite structures*, *32*(1-4), pp.491-499.
8. Olorunnishola, A.A.G. and Adubi, E.G., 2018. A comparative analysis of a blend of natural jute and glass fibers with synthetic glass fibers composites as car bumper materials. *IOSR J. Mech. Civ. Eng*, *15*, pp.67-71.
9. Paramasivam, C. and Venugopal, R., 2022. Design and development of glass/basalt fiber reinforced composite material for automobile applications. *Journal of Industrial Textiles*, *51*(1_suppl), pp.1668S-1681S.
10. Marzbanrad, J., Alijanpour, M. and Kiasat, M.S., 2009. Design and analysis of an automotive bumper beam in low-speed frontal crashes. *Thin-walled structures*, *47*(8-9), pp.902-911.
11. Ragupathi, P., Sivaram, N.M., Vignesh, G. and Selvam, M.D., 2018. Enhancement of impact strength of a car bumper using natural fiber composite made of jute. *i-Manager's Journal on Mechanical Engineering*, *8*(3), p.39.
12. International Journal of Advances in Engineering and Management (IJAEM) Volume 3, Issue 8 Aug2021, pp: 761-773 www.ijaem.net.
13. International Journal of Engineering andManagement Research Available at: www.ijemr.net Volume-4, Issue-4, August-2014, ISSN No.: 2250-0758 Page Number: 98-101.
14. Hosseinzadeh R, Shokrieh MM, Lessard LB. Parametric study of automotive composite bumperbeams subjected to low-velocity impacts. Compos Struct 2005;68:419
15. World Academy of Science, Engineering and Technology International Journal of Mechanical andMechatronics Engineering Vol:5, No:4, 2011
16. Department of Mechanical and Manufacturing Engineering, University Putra Malaysia, 43400 UPMSerdang, Selangor, Malaysia.
17. https://www.researchgate.net/publication/330753890_Enhancement_of_Impact_Strength_of _a_Car_B umper_using_Natural_Fiber_Composite_made_of_Jute
18. https://www.researchgate.net/publication/355372238_Conceptual_design_and_analysis_of_ a_car_bu mper_using_finite_element_method.
19. https://firstratemold.com/automotive-bumper-design/