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A STUDY OF GLASS FIBRE REINFORCED PLASTIC FOR USE AS A CAR BUMPER

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Abstract

Bumper is one of the main parts which are used as protection for passengers from front and near collision. The aim of this study was to analyze and study the comparison between steel and fibre reinforced plastic for use as a car bumper. The existing steel bumper is replaced with fibre reinforced bumper, due to its strength and weight reduction. In this project the design and fabrication of composite bumper made up of glass fibre reinforced plastic is carried out by which weight of the bumper can be reduced. Fabrication of composite bumper is analyzed and carried out by hand lay-up process by using E-Glass, epoxy resin, polyvinyl Alcohol (PVA). Fibre- reinforced bumper is analyzed using impact strength test. Compared to steel bumper, the fibre reinforced has higher factor of safety (FOS) and 80% less in cost. Fibre- reinforced bumper is found to have 64% From the fabrication when compared to steel bumper, it was found that the weight reduction of 53.8% is achieved using composite material. It was also found that fibre reinforced plastic has high strength, high fatigue resistance, it can withstand high creep and is corrosion resistance.

Keywords: Steel Bumper, Fibre Reinforced Plastic, E-Glass, Epoxy Resin, Polyvinyl Alcohol

Introduction

A bumper is a shield made of steel, aluminum, rubber or plastic that is mounted on the front and rear of a passenger car. Various studies have been conducted in order to find new material composition with desirable properties. Today's engineers are posed with a big challenge for the right selection of materials and selection of a manufacturing process for an application.

It is difficult to study all these materials individually; therefore a broad classification is necessary for simplification and characterization. By the selection of different types of components, and the possibility, to vary the volume fraction of the fibre orientation, a wide range of material properties of the resultant product can be produced.

This project results will be compared with two pervious student projects; Mohd Fitri and khairul Anuar, as to determine the improvement of this new hybrid composite over fibre glass reinforced plastic. The specification of the specimens is constant with the pervious project to make the comparism easier and more visible.

MohdFitri (2006), studied the determination of mechanical properties for polypropylene (PP) laminated on fibre glass (FG) reinforcement with epoxy resin ander tensile test.

The study show that the maximum stress and young modules values for polypropylene is higher compared to fibre glass. The maximum stress for fibre glass is 93.77mpa and fibre glass/polypropylene is 126.41mpa. This proves that the presence of polypropylene (PP) in fibre reinforcement had improved the strength of the composite. Khairul Anuar (2006) studied the impact testing analysis on fibre carbon (FC) fibre glass (FG)/epoxy laminate composite. The presence of fibre carbon decreases the damage growth of the laminates.

The arrangement of carbon fibre and glass fibre also gives different values to the impact energy 5 fibre glass and 5 fibre carbon layered alternately are lower in impact energy than 5 fibre glass/5 fibre carbon. The impact energy for fibre carbon/fibre glass (FC/FG) composite at full penetration is in the range of 27J to 33j. The glass fibre reinforcement experience full penetration at velocity 3.27mls with impact energy 28.35g.

Ramin Hosseinzadeh, mahmood mehrdadshokrieh and larrylessard (2005) studied the damage behavior of four type of fibre reinforcement subjected to drop weight impacts. Both thin and think glass fibre reinforcement show the weakest characteristic as it fail at under very low velocity impact and collapse seriously at high velocity but have high stability as it sustain a wide range of impact energy before seriously collapse.

Carbon fibre reinforcement show good strength under low velocity impacts but collapse unpredictably under high velocity impact. Carbon/glass fibre reinforcement is a hybrid composite show an optimized behavior which combing both carbon and glass advantage in strength and weight reduction.

Seongsikcheon, Jon Ho Chio and Dai Gil lee (2000) studied the development of the composite bumper beam for passenger car. This study has developed a new composite bumper beam that has two pads at the ends of the bumper. The materials used for this composite bumper is glass fibre epoxy composite except for the elbow section. The elbow section was made of carbon fibre epoxy reinforcement to increase bending stiffness. From the static bending test of the prototype composite bumper, it was found that the weight of the composite bumper beam was only 30% that of the steel bumper beam without sacrificing the static bending strength.

In the automobile or automotive industry, the most used materials is glass- filled polymer resins for plastic under hood components.

Glass fibre are the leading reinforcement fibre in plastic products due to their low cost and good performance and development such as high

performance short glass reinforced (HPGF) polypropylene by Denmark's Borealis group.

The second largest reinforced plastic used in glass material thermoplastic (GMT). A hybrid glass-GMT composite/ steel for instrument panel for ford, Volvo and Mazda is made of polypropylene/chopped glass fibre reinforcement and steel beam.

This technology reduces 2-3kg, reduced overall manufacturing costs 12%, and improves noise/vibration/ harshness (NVH) and crash performance. The current composite research is and glass fibre reinforced plastic which offer high stiftness, low density and great weight reduction.

Generally, a composite materials is composed of reinforcements (Fibres, particles, feakes, and fillers) embedded in a matrix (Polymers, metals or ceramics). The matrix holds the reinforcement shapes while the reinforcement improve the overall mechanical properties of the matrix. When design properly, the resulting materials exhibit better strength than the constituent materials.

Glass Fibre

The aim of fibre reinforced plastics is to combine the stiffness and strength of fibrous materials. This material has corrosion resistance, low density and mould ability. The majority of reinforced plastic produced today are glass reinforced epoxy or polyester resins, both of which are thermosetting

Glass fibres have also been used with thenolics, silicones, polystyrene and polyvinyl chloride (PVC), Glass fibres are the obvious choice as reinforcing agents, principally because of the relative ease with which high strength can be obtained in fibre a few microns in diameters. It is possible to produce composite with a range of strength according to glass content and nature of the reinforcement. The epoxy resins have however shrinkage than the other resins.

Palanikumar et al (2006) demonstrated that the users of fibre reinforced plastics (FRP) are facing difficulties when machining it, because knowledge and experience for conventional materials cannot be applied for such new materials, whose machinability is different from that of conventional materials. Thus it is desirable to investigate the behavior of FRPS during machining process.

Sakumal et al (1983) and Bhatnagar et al (1988) studied how the fibre orientation influence both the quality of the machine surface and tool wear.The machinability of composite materials is influenced by the type of fibre embedded in the composites, and more particularly by the mechanical properties.

According to Koing (1985) measurement of surface roughness in fibre reinforced plastics in less dependable compared to that in metals because protruding fibre tips may lead to incorrect results. Additional errors may result from the looking of the fibres to the stylus.to Remulu et al (1994) carried out a study on machining of polymer composites and concluded that higher cutting speeds give better surface finish.

Materials and Methods

Design Considerations

Design of Composite Bumper

For designing the composite bumper an already existing ambassador steel bumper is used as mould. Dimensions are assumed as same as that of steel bumper for fabrication,

Dimensions and Properties of Existing Steel Bumper

Effective length = 0.975m

Total length = 2.055m

Thickness = 0.002m

Effective breath = 0.078m

Total breath = 0.172m

Weight = 5.16kg

Material =mild steel (Chromium Coated)

Tensile strength = 460MPa (design data book)

Density = 7800kg/m³

The moment for steel and composite bumper is assumed to be same. Therefore the moment for steel is

$\frac{M}{1y} = \frac{0}{}$

Where,

M =Bending moment (Nm)

I = Moment of inertia (m^4)

O = Tensile strength (N / (m ^ 2)

Y = d / 2,

d = Thickness of the bumper (m)

b = breadth of bumper (m)

Moment of inertia for rectangular section:

$I = bd^3 / 12$

There are three sections in the bumper l_{1} I_{2} I_{3} respectively,

I{1}, = 0.058x * 0.002 ^ 3 / 12 =3.86 x 10.^ 11 m^ 4

I{2} = 0.078 x 0.0023/12 = 5.2 x10-" m²

I{3} = 0.058 x 0.0023/12 = 3.86x10-1" m²

$1 = l_{1} + l_{2} + l_{3} = 1.2932*10^{-10}\ m^4$

Tensile strength of the steel = 460 * 10 ^ 6 * N / (m ^ 2) (from PSG data book)

The moment equation,

M/(1.2932 * 10-1) = 460.106/ 0.002/2

M = 59.4872NM

Fig. 2.1 Existing steel bumper.

Thickness of the Composite Bumper

Thickness of the composite bumper can be determined by the formular,

M = 0

1y

There are three individual sections, so to find them individually by using above formula,

$59.4872/((0.058 * x*d_{1}^3)/12) = (490 * 10^6)/(d_{1}/2)$

$d_{1} = 3.543 * 10^{-3} * m$

$59.4872/(0.078 * x*d_{2}^3) * 12 (490 * 10^6)/(d_{2}/2)$

$d2 = 3.055^ * 10^{-3} * m$

$59.4872\ 0.058xd\ 1^3\ 12 = (490 * 10^6)/(d_{1}/2)\ d_{3} = 3.543 * 10^{-3} * m$

Average thickness $(d) = d_{1} + d_{2} + d_{3} / 3 = 3.38mm$

A layer of E-glass mat thickness is 0.2mm, so 17 layers are required for fabricating composite bumper.

3.4 Force Acting on the Bumper (F)

Force (F) $= m^ * a$

M = mass of the vehicle crashed on the bumper (1554kg)

a = acceleration due to gravity (m/sec^2) =

$a = (u - v) / t$

Where,

v = final velocity after collapsing (m /sec)

u = initial velocity before collapsing (m/sec)

u= km / h * r = 2.22m / s (taken from NHTSA)

t = time taken for collapsing (sec)

$a = (2.22 * 0) / 0.1 = 22.22m / (sec(2))$

Force (F) 1554x22.222-34529.88N

2.4 Model of the Bumper

The load applied on the bumper is not a point load; is it a uniformly distributed load (pressure load). So calculating pressure load is given below: Pressure (P) = F / A

F= force acting on the bumper = 34529.88N

A = font area cross section $= 2055 * 78 = 1602900m * m^2$

P= $34529.88/160290 = 0.13N / m * m^2$

Fig.2. 2: Measurement of E-glass material.

Fabrication of Composite Bumper

In Hand lay-up, liquid resin is applied to the mould and then fiber glass is placed on the top. A roller is used to impregnate the fiber with resin. Another resin and reinforcement layer is applied until a suitable thickness builds up, it is very flexible process that allows the user to optimize the part by placing different types of fabric and mat materials. Because the reinforcement is placed manually, it is also called the hand lay-up process. Though this process requires little capital, it is labor intensive,

Materials Used

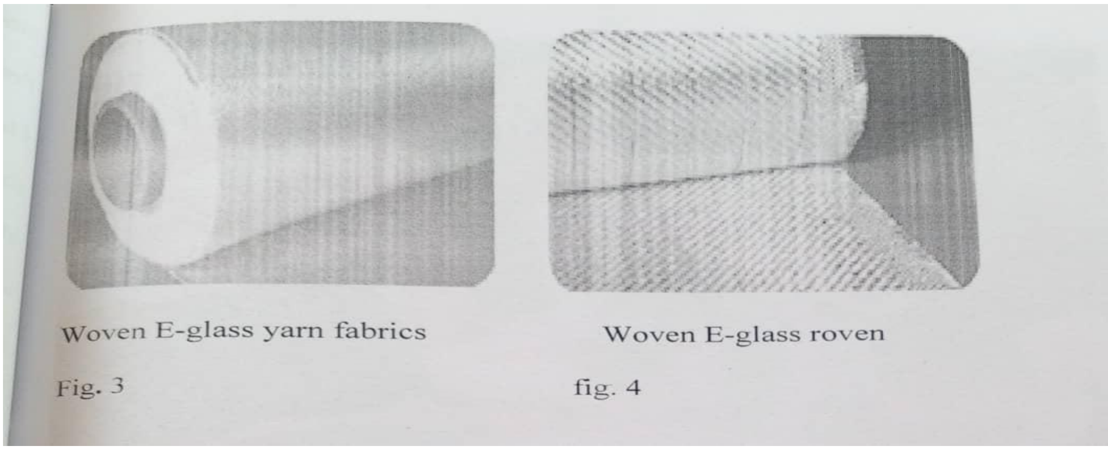
Unsaturated polyester resin

General purpose grade unsaturated orthophathalic polyester resin (RGP 67G), was obtained from Center for Composite Research and Development, JuNeng Nigeria Limited, (Nsukka. Methyl ethyl ketone peroxide (MEKP) and cobalt napthenate of commercial grade were used as the catalyst and accelerator respectively for rein curing. This resin is character- ized by its very low colour, low viscosity, moderate gel time, good adhesion to glass fiber and relatively high reactivity. Composite parts made of this resin and glass fiber reinforcement have very good physical and mechanical properties. It is used for manufacturing of composites such as reservoirs, structural panels, boats, automobile parts and other general-purpose application.

E-Glass fibre

Emulsion coated chopped strand mat e-glass fibre applicable to hand lay-up moulding process as used in this work was obtained from Center for Composite Research and Development, JuNeng Nigeria Limited, Nsukka

Preparation of composite test specimens and auto-body bumpers Chopped strand fibre-polyester composites containing e-glass emulsion coated chopped strand mat fibre and natural (coir and raffia) were prepared in a ratio of 10:90; 30:70 & 50:50 by hand lay-up method using a mild steel mould. Prior to the composite preparation, the mould surface was polished well and a mould-releasing agent (waxpol) was applied on the surface of the mould. Unsaturated polyester resin (UPR) was mixed well with 1% by wt. Cobalt naphtbenate accelerator and 1% by wt. MEKP catalyst. The fibre mat was placed in the mould and the resin mixture was poured evenly on it. Using a metallic roller, the air bubbles were carefully removed and the mat was allowed to wet completely. The mould was closed and the excess resin was allowed to flow out as 'flash' by stabbing with hand brushes. The pressure was held constant during the curing process at room temperature for 24 hours. The composite sheet was post cured at 80°C for 4 hours. Test specimens, according to ASTM standards, were cut from the sheet. This same process was used in the fabrication of the auto-body bumper according to the size and shapes the mould



Woven E-glass yarn fabrics

Fig. 3

Woven E-glass roven

fig. 4

Tools Required

The mould design for the hand lay-up process is very simple as compared to other manufacturing process because the process requires room temperature to cure with low pressures. In this project existing bumper is used as mould.

Fabrication of Bumper

In the hand lay-up process the thickness of the composite part is built up by applying a serious of fiber glass layers and liquid resin layers. A roller is used to squeeze out the excess resin and create uniform distribution of the resin throughout the surfaces. By the squeezing action of the roller, homogenous fibre wetting is obtained, the part is then cured at room temperature for about one week and once solidified it is removed from mould.

Fig. 2.4 Fabrication of glass fibre reinforced bumper.

Description for Steel and Composite Bumper

DESCRIPTION	STEEL	COMPOSITE
Element type	Solid 186	Solid 191
Pressure Load (N/mm2)	0.13	0.13
Young's modulus (N/mm2)	2*105	78*103
Poison ratio	0.3	0.27

Boundary Condition

Two ends of the bumper are fixed for supporting purpose. It is common for both steel and composite bumper. Bumper is arrested at 547.88mm from center to both the ends.

Mechanical Property Measurements

The standard mechanical properties are determined by the procedures found in ASTM standards for plastics. The mechanical properties studied are tensile strength, Young's modulus, elongation strength, flexural modulus and impact strength. at break (EB) %, flexural

Tensile Properties

The tensile properties were tested at the Civil Engineering Laboratory, university of Nigeria, Nsukka (UNN).using a Hounsfield Monsanto Universal Tensometer Machine at a constant rate of traverse of the moving grip of 5mm min.- for randomly oriented fibre composites and 20 mm min^{-1} for oriented fibre composites. The test specimens were rectangular in shape with dimensions 160 x 19 x 3 mm^3 for randomly oriented fibre composites.

The sides of test specimens were polished using emery paper prior to testing. One grip is attached to a fixed and the other to a movable (power-driven) member so that they will move freely into alignment as soon as any load is applied. The test specimen was held tight by the two grips, the lower grip being fixed. Load is applied by gradually increasing the distance between the clamps until failure occurs. The force is then recorded and the area of the cross-section's test piece the tensile strength is calculated.

The output data in the form of stress-strain graph and elongation, modulus and energy absorbed at various stages of the test calculated.

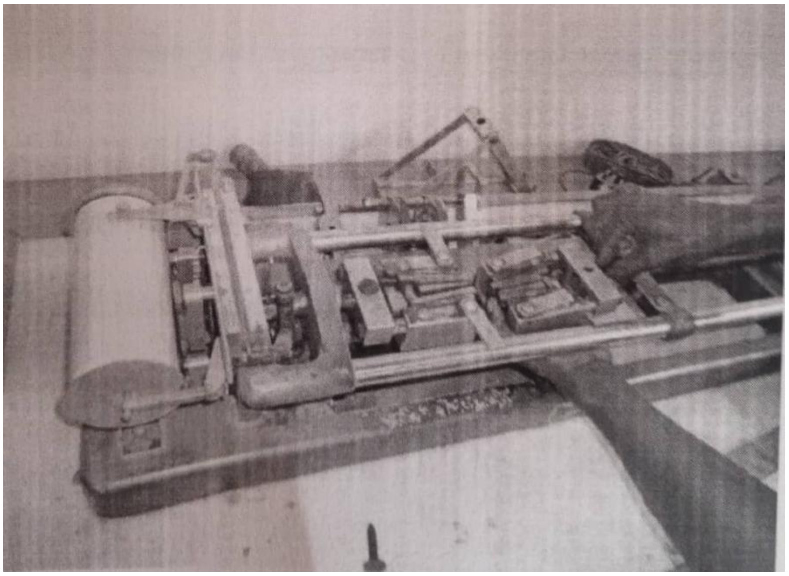


Fig. 2.5 Hounsfield Monsanto Universal Tensometer Machine

Flexural Properties

The flexural properties were tested at the Civil Engineering Laboratory, university of Nigeria, Nsukka(UNN), on a Hounsfield Monsanto Universal Tensometer Machine (ASTM D 790-99) at a constant rate of traverse of the moving grip of 5mm min. for randomly oriented fibre composites and 2mm min. for oriented fibre composites. The test specimens were rectangular in shape with dimensions 100 x 19 x 3 mm^3 for randomly oriented fibre composites. The specimens were polished using emery paper prior to testing. The depth and width of the specimen was measured nearest to 0.01 mm. The support span was 16 times the depth of the specimen. The specimen was centred on the supports with the long axis of the specimen perpendicular to the loading nose and supports. The load was applied to the specimen and flexural strength and modulus were recorded. The load-deflection curve was also obtained. It is calculated at any point on the stress strain curve by the following equation S = (3PL)/(2b * d ^ 2)...........1

where S-stress in the outer fibres at midpoint (MPa), P = I at any point on the load-elongation curve (N), L = support span (mm), width of specimen tested (mm), d = depth of specimen (mm).

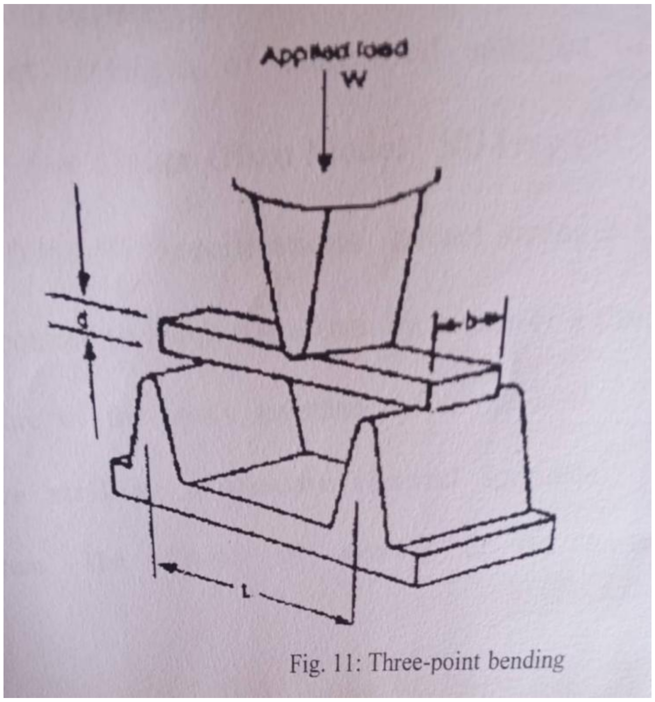


Fig. 2.6 Determination of flexural properties

Flexural modulus is the ratio of stress to corresponding strain and is expressed in MPa. It is calculated by drawing a tangent to the steepest initial straight-line portion of the load-deflection curve and using the equation

$$E_{R} = (L^3 * m)/4 * m/(d * D^3)$$

Where E * 8 = modulus of elasticity in bending (MPa), L support span (mm), b = width of specimen tested (mm), d = depth of specimen (mm), m = slope of the tangent to the initial straight line portion of the load-deflection curve (N mm .l of deflection).

Impact strength

Izod impact strength of unnotched samples of the composite was measured on a Tinius Olsen Model 503 Impact Tester, according to ASTM 0256-97 specifications. Impact strength is a measure of the energy required to break a specimen by means of a sharp impact and is also a measure of the shock resistance of a material. The impact tests involve striking a standard shaped specimen with a swinging pendulum. The distance of upswing of the break pendulum after breaking the specimen is compared to the distance travelled when no specimen is present. This gives a measure of the energy required to break the specimen.

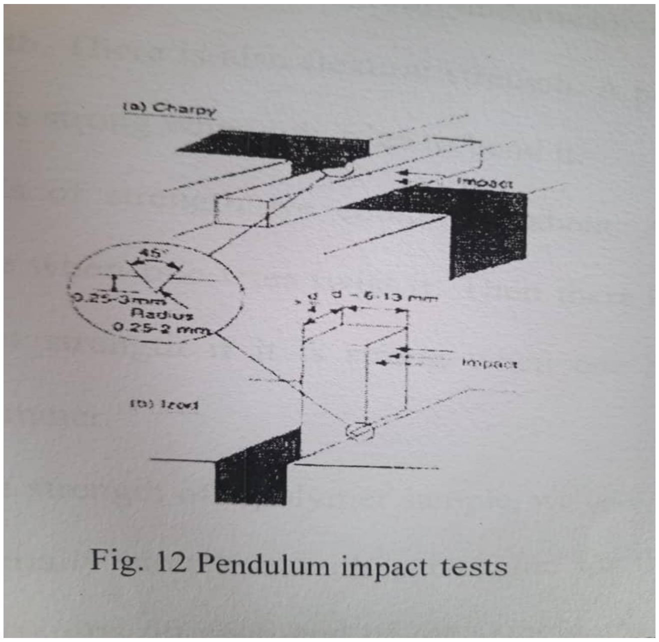


Fig. 2.7 Determination of mechanical properties

Mechanical Properties Measurements

Also the following mechanical properties were measured :

i. STRENGTH
ii. Elongation
iii. Modulus
iv. Modulus of Elasticity
v. Toughness

Results

Theory of Impact Test

The impact behavior of composite materials has been studied with different scientific approaches and on different material. Good design can only be achieved by using appropriate design procedures, and these must be establishes by understanding the impact phenomena and the roles of various parameters on impact damage/ the parameters are the impact velocity, the specimen stacking sequences, the impactor mass, the specimen geometry, the impactor size and the impact energy.

In each test, a specimen was clamp on a rigid support of size 100mm x 100mm. Although it was not checked whether clamping was maintained constant for both small of large plates, the different was considered too small to have any influence over their structural response when very few frictional sliding scratches on specimen surfaces were observed in the clamping regions of both plates after impact. In this test, we found that the impact energy from the drop weight is too high so we suggest that the equipment is just to determine the maximum impact energy of the specimen.

The high speed impact test is used to determine toughness, load- deflection curves and total energy absorption of impact events. Since speed can be varied, it can simulate actual impact values a high speeds. This sophisticated impact test provides full forces and energy curves during the milliseconds of the impact, using, using a "tup" which incorporates an impact head and a load cell. Calculation formula of impact test:

i) Impact energy

Kinetic energy = (1/2) * m * v ^ 2 Potential Energy mgh,

Divided both side by m V ^ 2 V = 2gh = sqrt(2gh)

Impact Energy, J = (1/2) * m * v ^ 2

Where:

m = Mass

V = Velocity

G = Acceleration of gravity (9.81m /sec^ 2)

H = Drop Height

ii) Percentage of impact energy, % = Blow Impact Energy*100

Max. Impact Energy

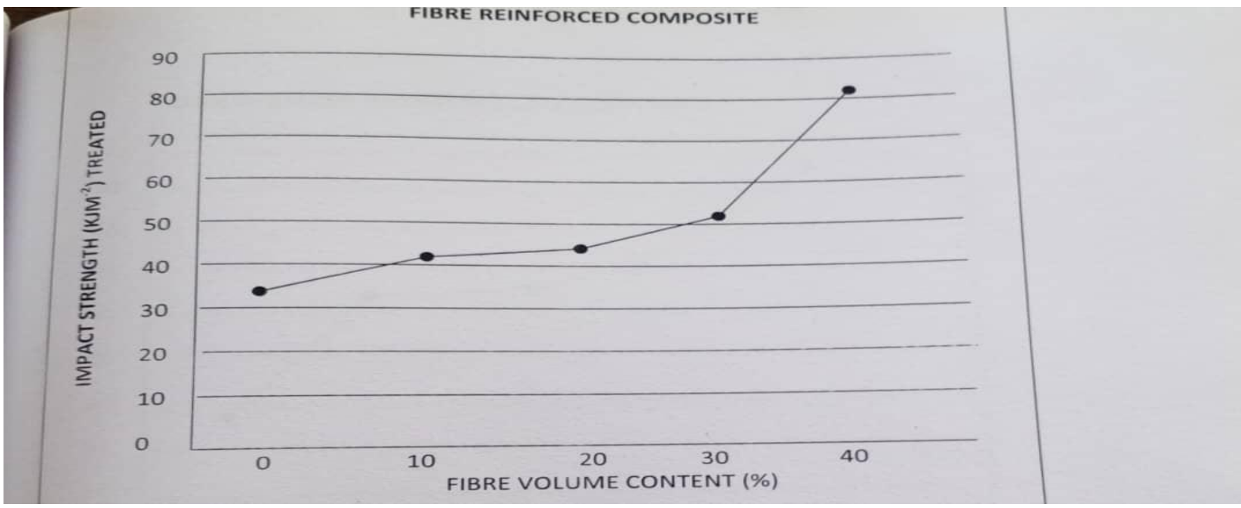


Fig. 3.1: Graph of Impact Strength against Fibre volume content for a treat fibre reinforced compo

Glass Fibre Reinforced Composite

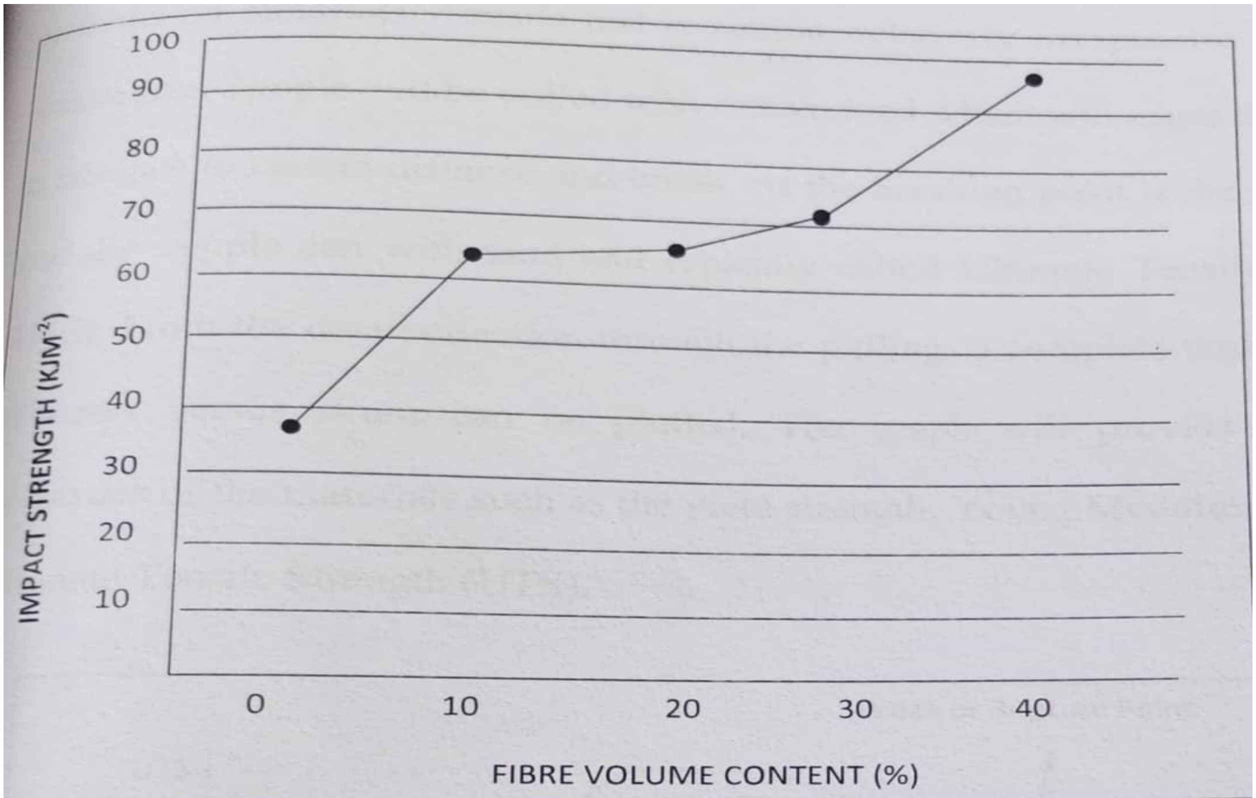


Fig. 3.2: Graph of Impact Strength against Fibre volume content for a Glass fibre reinforced composite

Impact Testing

The impact properties of the material are directly related to the overall toughness which is defined as the ability to absorb applied energy. Area under the stress-strain curve is proportional to the toughness of a material. Nevertheless, impact strength is a measure of toughness.

Theory of Tensile Test

Tensile test is the most fundamental type of mechanical test that can be performs on materials. Tensile test is simple, relatively inexpensive and fully standardize. Simple will be pulled with certain load which will cause the sample to elongate to certain distance and break. At the breaking point is the maximum load the sample can withstand and typically called Ultimate Tensile Strength (UTS). From the data collection through the pulling, a complete tensile profile of stress versus strain can be plotted. The graph will provide important properties of the materials such as the yield strength, Young Modulus, E and the Ultimate Tensile Strength (UTS).

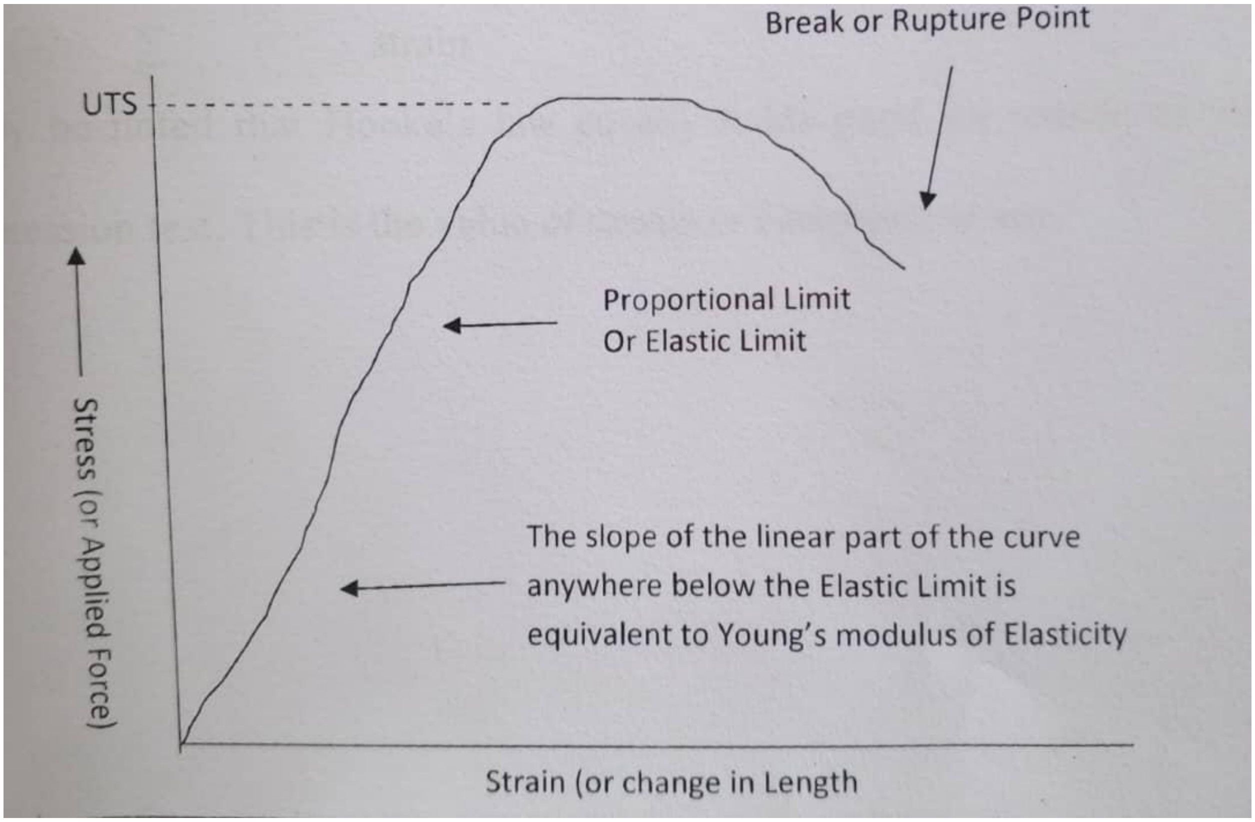


Fig. 3.3: Graph of Impact Strength against Fibre volume content for a Glass fibre reinforced composite

Referring to the above figure, the straight line of initial portion of the test shows that the relationship between the applied load and the elongation of the specimen is linear. In this region, it is said that the line obeys the Hooke's Law where the ration of stress to strain is constant by the equation:

Mathematically

$\sigma x E =$ $E*EE$ $\underline{\sigma} =$ constantΣ

Where E = young modulus or modulus of elasticity.

σ = stress

Σ = strain

It may be noted that Hooke's law equally holds good for tensile as well as compression test. This is the value of tensile or compressive test.

Table 3.1: The value of EC modulus of Elasticity in Everyday use are

S/No	Material	Modulus of elasticity (E)
1	Steel	200 to 220
2	Wrpught iron	190 to 200
3	Cast iron	100 to 160
4	Copper	90 to 110
5	Brass	80 to 90
6	Aluminum	60 to 80
7	Timber	10

Conclusion

Design, fabrication and testing of steel and composite bumper (using glass fibre material) are completed and also composite bumper is analyzed and companied with steel bumper. In terms of weight, the composite bumper is lesser than steel bumper. It is prove that fuel economy of the vehicle is also improved as the composite bumper weights less when compared with steel bumper cost of composite (fibre reinforced plastic) is less than steel bumper.

Impact strength of fibre reinforced bumper measured in source/mm² is higher than that of steel bumper. The existing bumper and composite bumper are analyzed and maximum stress induced is lesser compared to steel bumper. From the project factor of safety for composite bumper is higher it is conclude that fibre reinforced plastic materials is a material for manufacturing the bumper.

This means that in the near future, fibre reinforced plastic composites will even be preferred to steel castings in terms of important engineering applications such as automobile, boat and air craft constructions.

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