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Application of Glass Fibre Reinforced Composite in the Production of Light Weight Car Bumper (A Case Study of the Mechanical Properties)

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***Abstract*: Composites consist of two or more phases that are usually processed separately and then bonded, resulting in properties that are different from those of either of the component materials. Polymer composites matrix generally combines high-strength, high-stiffness fibres with low-density matrix materials to produce strong and stiff materials that are lightweight. These properties coupled with easier mouldability, good strength to weight ratio and corrosion resistance gives reinforced composites an edge over steel in car bumper. Coupled with the fact that fuel efficiency of passenger cars is an important issue these days, the best way to increase the fuel efficiency without sacrificing safety is to employ fibre reinforced composite materials in car bumper manufacturing. In this paper the existing steel bumper was replaced with glass fibre reinforced composite bumper, the fabrication of glass fibre reinforced composite bumper is carried out by hand lay-up process using E-Glass bi-directional laminates and epoxy resin. The results of the test show a satisfactory flexural strength at a load of over 0.5KN at a span of 80mm, tensile strength of 3.9MJ and impact strength of 100KJ/m^2 with a 60% reduction in weight compare to the steel car bumper.**

Keywords: Glass Fibre; Car Bumper; Tensile Strength; Impact Strength; Weight, Safety

1. INTRODUCTION

A composite material is composed of reinforcements (fibres, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics) [1]. The matrix holds the reinforcements to form the desired shape while the reinforcements improve the overall mechanical properties of the matrix. When designed properly, the resulting material exhibit better strength than the constituent materials [1, 2]. Composite is a heterogeneous substance consisting of two or more materials which does not lose the characteristics of each component but brings about new desirable properties, naturally occurring composites are tendon, bone, bamboo, rock, and many other biological and geological materials [2]. Composite materials play an important role in modern industry through the design and manufacture of advanced materials capable of attaining higher stiffness/density and strength/density ratios. These ratios allow composite materials to be used in various applications where the weight and strength of the structure are highly significant design parameters (e.g. aircraft, cars, aerospace shuttle industries, etc.). Composite materials dramatically enhance the performance and increase the efficiency of such structures [3]. In order to insure structural integrity and safe performance, thorough understanding of the behavior of these materials under arising loads must be established. Of particular importance is the problem of damage initiation and evolution in composites [4].

Impact resistance in composites is the study of the effect of damage induced by striking a foreign body on a material and the factors affecting it, which are generally recognized as the most severe threat to composite structures [5]. This includes the study of the failure modes, initiation development and extent of impact damage. Impact damage is normally initiated in laminated composites as a transverse matrix cracking, followed by delamination, fibre/matrix debonding and fibre fracture. Damage due to impact substantially reduces the residual strength after impact of a composite structure, even when damage cannot be visually observed [6, 7].

Any material that is to be used for car bumper must be able to absorb more energy on collision, it should have good rust resistance, it should have high strength, light in weight, easy to manufacture in large quantity and should be of low cost [8]. Composite materials have found more application in this area due to high reduction in weight, absorption of more collusion energy than steel, ease of manufacturing, good corrosion resistance, rapid response to induced or release stress, high impact strength etc [9-13].

The major objective of this research work is to produce a glass fibre reinforced composite car bumper and to under study the mechanically properties in terms of performance, high corrosion resistance, low tendency to creep under load, high stiffness strength and improved strength to weight ratio. Standard passenger car bumper specifications were considered during the design and analysis stage of this project work. The selected materials were compared to each other for the design parameters like shape, material and impact condition.

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2.0 MATERIAL AND METHOD

2.1 Materials

For designing the composite bumper, an already existing steel bumper was used as mould and the 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 = 7800 kg/m^3

The following materials were also used during the course of this research work:

- E-Glass Fibred
- Unsaturated polyester resin
- Cobalt Naphthenate accelerator and catalyst
- Methyl ethyl ketone peroxide (MEKP)
- Wax

2.2 Methods

The reinforced composite bumper was fabricated using the hand lay-up method. Prior to the composite preparation, the mould (steel bumper) surface was well polished and a mould-releasing agent (waxpol) was applied on the surface of the mould. Unsaturated polyester resin (UPR) was thoroughly mixed with 1 % by wt. Cobalt naphtbenate accelerator and 1% by wt. MEKP catalyst. On adding the catalyst or hardener the resin began to become more viscous until it reaches a state when it is no longer a liquid and has lost its ability to flow, this is the 'gel point'. The resin continued to harden after it has gelled until it has fully hardened. This reaction itself is accompanied by the generation of exothermic heat, which, in turn, speeds the rate of reaction; this is known as the curing of the resin [8, 14]. 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 were cut from the sheet. This same process was used in the fabrication of the auto-body bumper according to the size and shapes of the mould. The produced glass reinforced composite is shown in Figure 1.

Tensile Test

The tensile test were performed according to the ASTM D3039 standard, the specimen with recommended dimensions are created and tested by a calibrated AUTOGRAPH-AGS-2003 testing machine with speed 5 mm/min.

Impact Test

Izod impact test methods were conducted according to the ASTMD256-04 standard [15]. The samples with specified dimensions and defined notches were prepared and the results were obtained.

Flexural Strength Test

The specimens were tested by a calibrated AUTOGRAPH-AGS-2003 testing machine. The flexural strength was conducted according to the ASTM D790 (3 point bending) standard [16]. The specimens with desired dimensions and velocity of 5 mm/min were tested. The testing was conducted for various span lengths like 100 mm, 80 mm and 60 mm.

3.0 RESULTS AND DISCUSSION

3.1 Results

The fabricated glass reinforced composite car bumper was subjected to standard mechanical properties according to the lay down procedures of ASTM standards for plastics. The mechanical properties studied are tensile strength, Young's modulus, elongation at break (EB), flexural strength, flexural modulus and impact strength. The obtained results are as stated below:

Figure 1: Fabricated Glass Fibre Reinforced Composite Car Bumper

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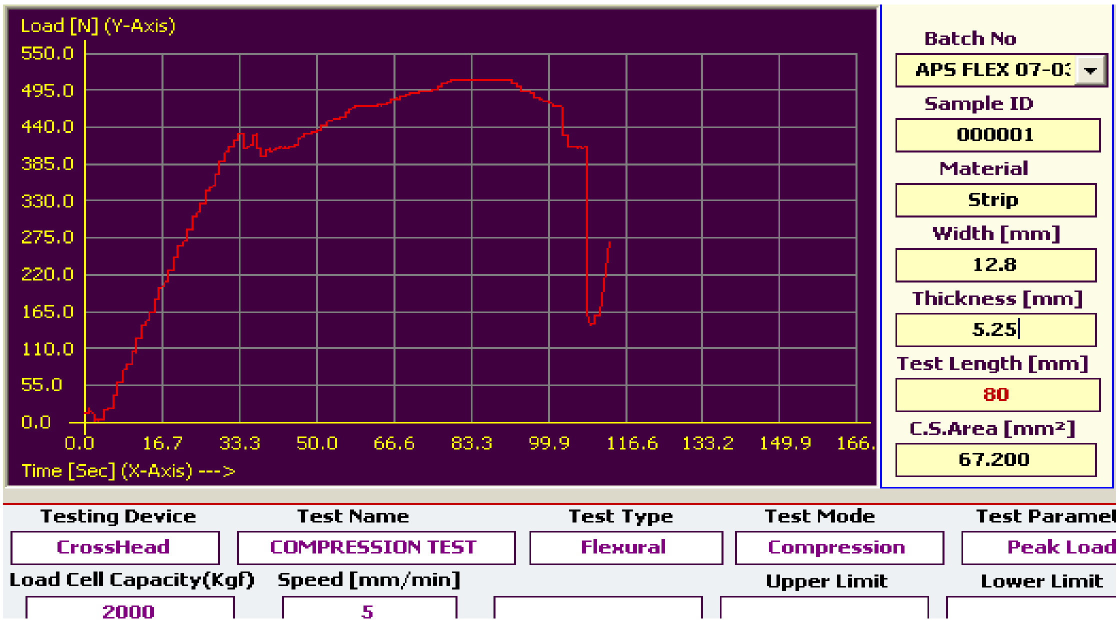

Figure 2: Flexural Strength of the Reinforced Composite Bumper

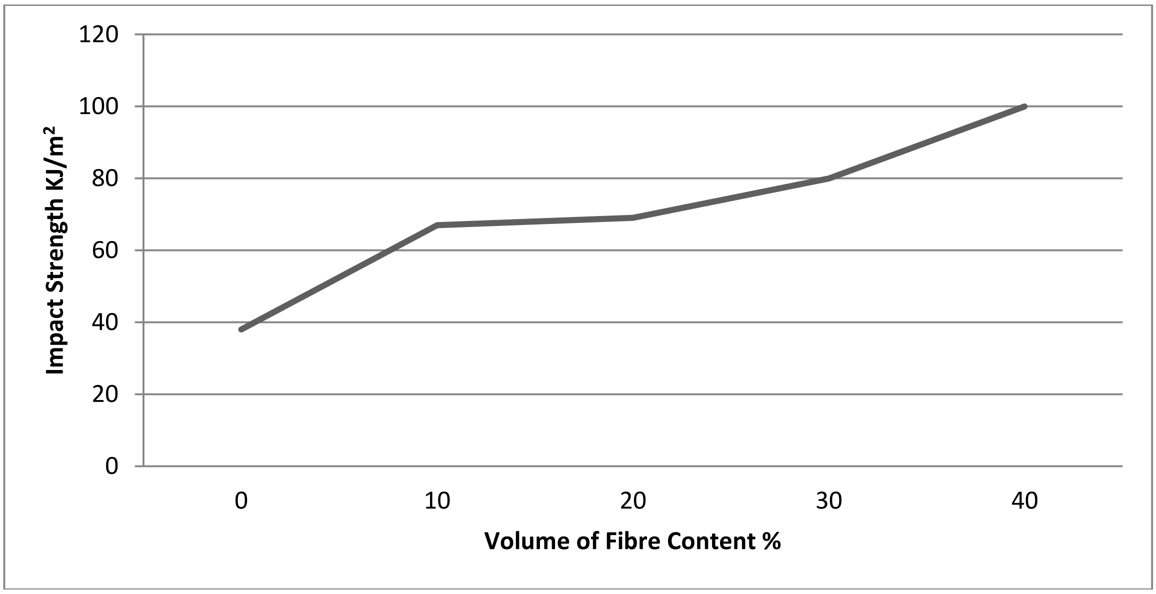

Figure 3: Impact Strength of the Reinforced Composite Bumper

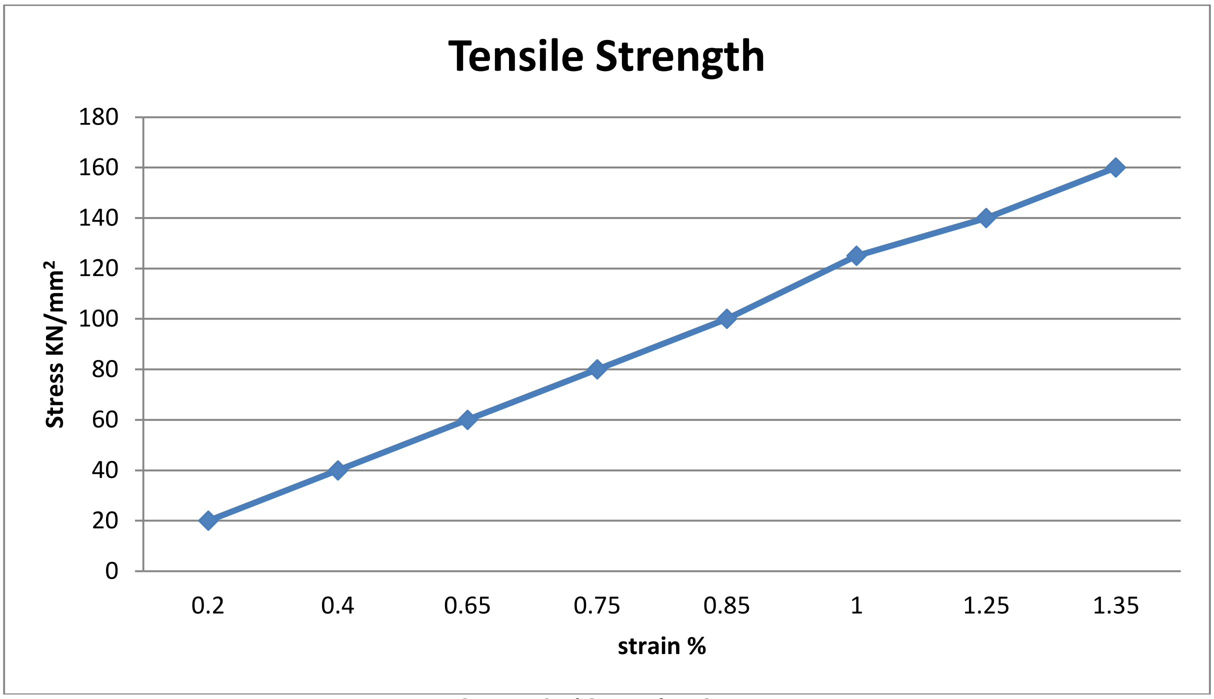

Figure 4: Tensile Strength of the Reinforced Composite Bumper

3.2 DISCUSSION

From the results shown above, it was observed that the flexural strength (Fig. 2) of the glass fibre reinforced composite car bumper at a force of over 0.5KN and time of 83.3 sec with a loading capacity of 2000Kgf was found to be satisfactory at a span of 80mm, this shows high resistance to creeping under loading. The impact test as shown in Fig. 3 shows that the maximum impact strength was obtained at 40% fibre content by volume is 100KJ/M^2. The specimen size for the tensile strength was 260x24x5mm and the result is shown in the Stress–strain curve (Fig. 4). The results from Fig. 4 show that there was a linear response (elongation) from the glass fibre reinforced composite car bumper as the applied loading increases which can be seen as the reason for the high impact rate of the material. It was observed from the stress-strain curve that the glass reinforced composite car bumper is a brittle material which implies a good performance in service. The weight of the fabricated glass fibre reinforced composite car bumper was measured as 2.06Kg which represent 60% reduction in weight compare to the steel car bumper.

4.0 CONCLUSION

A glass fibre reinforced composite bumper was designed and fabricated. It mechanical behaviour was also investigated. Tensile strength, impact strength, flexural strength etc test was carried out on the glass fibre reinforced composite bumper. The results of the test show a satisfactory flexural strength at a load of over 0.5KN at a span of 80mm, tensile strength of 3852.8KJ (3.9MJ) and impact strength of 100KJ/m^2 with a 60% reduction in weight compare to the steel car bumper, The tensile strength and the Young's modulus of the specimens were higher than common bumper beam materials such as low fibre reinforced composites (LFRT) [6]. The typical yield strength and Young's modulus of the LFRT is 101.3MPa and 5.5GPa, respectively [6]. From the obtained results it can be concluded that the glass fibre reinforced composite can be successfully used as a replacement for steel in car bumper for a safer, light weight, non corroded, high performance and fuel efficiency car bumper.

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