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Automobile Bumper Beam Analysis to Improve Energy Absorption

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Abstract --- Automotive Bumper is one of the main parts which is used as protection for passengers from front and rear collision. Bumpers beam play an important role in preventing the impact load from being transferred to the automobile and passengers. So it becomes an important part of a vehicle as a safety and performance point of view. The basic use of bumper is to absorb energy in case of a collision. The main purpose of this paper is to design a bumper beam which is to improve crashworthiness of the bumper and analyzes the impact behavior of a composite car bumper beam made from s-glass fiber reinforced epoxy composite materials with a volume fraction 60% fiber and 40% matrix. Crashworthiness is the ability of the bumper beam to prevent occupant injuries in the event of an accident and this is achieved by minimizing the impact force during the collision. The existing Lifan 520 model bumper beam is replaced with composite bumper. The internal energy which is absorbed by steel material is 1200.9 J where the composite material is 1980 J which is 39 % higher than that of steel. The study is performed using ANSYS software for the design of the new car bumper made from s-glass fiber reinforced epoxy composite materials and the internal energy absorbed by the materials, total deformation as well is evaluated by use of finite element method.

Keywords: s glass fiber, epoxy, impact load, total deformation, internal energy.

1 INTRODUCTION

A bumper is a car shield made of steel, aluminum, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. An automotive bumper is the rear most or front most part of the vehicle which is used to protect the passengers inside from the impact during a collision. [1]

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One possible application area that allows material replacement to achieve vehicle light weighting is the bumper subsystem. Optimization of the car bumper subsystem, particularly the bumper beam can improve not only weight reduction but also structural energy absorption.

The bumper beam plays an important role in the energy absorption during a collision. The materials selected for automotive bumper has been recently a concern. The main governing criteria for material selection are stiffness and strength properties that will determine the overall performance

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of vehicle during static and dynamic loading conditions.

Fiber reinforced composite materials have been widely used in various transportation vehicle structures because of their high specific strength, modulus and high damping capability. If composite materials are applied to vehicles, it is expected that not only the weight of the vehicle is decreased but also that noise and vibration are reduced. In addition to that, composites have a very high resistance to fatigue and corrosion. Traditionally, the materials used in the construction of vehicle bodies are mainly various grades of steel. Although aluminumintensive body concepts were used starting from executive class cars, and then later on applied to other car classes. This study focuses in the application of s glass fiber reinforced epoxy resin composite materials in a car bumper beam for optimizing energy absorption. [2]

Steel bumper beam have many advantages such as good load carrying capacity. In spite of its advantages, it stays back in low strength to weight ratio. It is reported that weight reduction with adequate improvement of mechanical properties has made composites as a viable replacement material for conventional steel. In the present work, the steel bumper used in passenger vehicles is replaced with a very good composite polymeric based bumper. Nowadays, the composites are used mainly to make cars more energy efficient by reducing weight, together with providing durability, corrosion resistance, toughness, design flexibility, resiliency and high performance at low cost. The study is performed using ANSYS software for the design of the new car bumper made from s glass fiber reinforced epoxy resin and the stress concentration distribution is evaluated by use of FEM to determine the impact cases.

As shown in Fig.1. A conventional bumper system comprises a bumper cover 1 defining an outer appearance of the bumper system,

an energy absorber 2 formed of an elastic material such a polypropylene foam body or a urethane foam body to absorb energy, an impact beam 3 for supporting the energy absorber 2, and a stay 4 for connecting the impact beam 3 to a vehicle body. [3, 4]

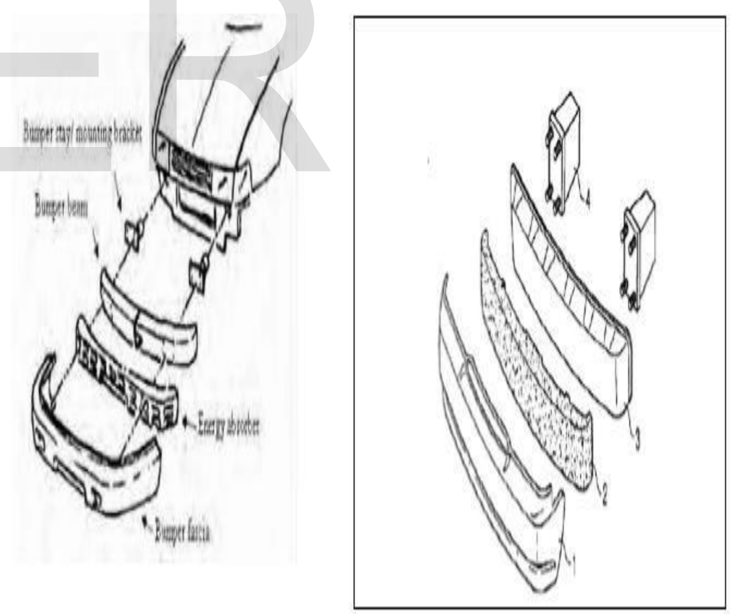


Figure 1: Conventional vehicle bumper system.

2 ANALYTICAL METHODS AND MATERIALS

2.1 **Material**

Determining the right material during the selection process is very important. The material selected should meet the expectation of the engineer. The material should prove mechanically feasible and should be economical. Apart from this the selected material must convincingly prove better than the currently used material. The proposed material properties may help the material engineers to perform the right material selection during the selection stage. [5]

2.1.1. **Glass Fibers**

GLASS FIBERS are among the most versatile industrial materials known today. They are readily produced from raw materials, which are available in virtually unlimited supply. Glass fiber is made by blending raw materials, melting them in a three-stage furnace, extruding the molten glass through bushings in the bottom of the fore hearth, cooling the filaments with water, and then applying a chemical size. The filaments then are gathered and wound into a package. All glass fibers described in this article are derived from compositions containing silica. They exhibit useful bulk properties such as hardness, transparency, resistance to chemical attack, stability, and inertness, as well as desirable fiber properties such as strength, flexibility, and stiffness. Glass fibers are used in the manufacture of structural composites, printed circuit boards and a wide range of special purpose products. Over 95% of the fibers used in reinforced plastics are glass fibers, as they are inexpensive, easy to manufacture and possess high strength and stiffness with respect to the plastics with which they are reinforced. Their low density, resistance to chemicals, insulation capacity are other bonus characteristics, although the one major disadvantage in glass is that it is prone to break when subjected to high tensile stress for a long time. [6]

Fiber Forming Processes Glass melts are made by fusing (co-melting) silica with minerals, which contain the oxides needed to form a given composition. The molten mass is rapidly cooled to prevent crystallization and formed into glass fibers by a process also known as fiberization. Nearly all continuous glass fibers are made by a direct draw process and formed by extruding molten glass through a platinum alloy bushing that may contain up to several thousand individual orifices, each being 0.793 to 3.175 mm (0.0312 to 0.125 in.) in diameter. While still highly viscous, the resulting fibers are rap- idly drawn to a fine diameter and solidify. Typical fiber diameters range from 3 to 20) lm (118 to 787) Lin.). Individual filaments are combined into multifilament strands, which are pulled by mechanical winders at velocities of up to 61 rn/s (200 ft/s) and wound onto tubes or forming packages. This is the only process that is described in detail subsequently in the present article. The marble melt process can be used to form special-purpose, for example, high-strength fibers. In this process, the raw materials are melted, and solid glass marbles, usually 2 to 3 em (0.8 to 1.2 in.) in diameter, are formed from the melt. The marbles are remelted (at the same or at a different location) a nd formed into glass fibers. [7]

Sizes and Binders. Glass filaments are highly abrasive to each other. "Size" coatings or binders are therefore applied before the strand is gathered to minimize degradation of filament strength that would otherwise be caused by filament -to-filament abrasion. Binders provide lubrication, protection, and/or coupling. The size maybe temporary, as in the form of a starch-oil emulsion that is subsequently removed by heating and replaced with a glass -toresin coupling agent known as a finish. On the other hand, the size may be a compatible treatment that performs several necessary functions during the subsequent forming operation and wh ich, during impregnation, acts as a coupling agent to the resin being reinforced. [8]

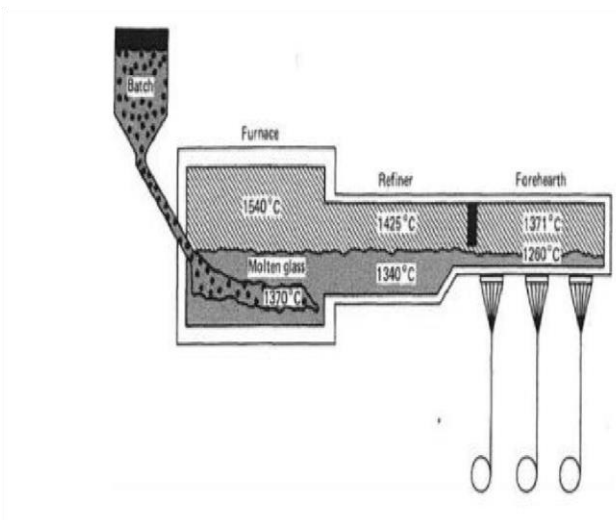


Figure 2: Furnace for Glass Melting

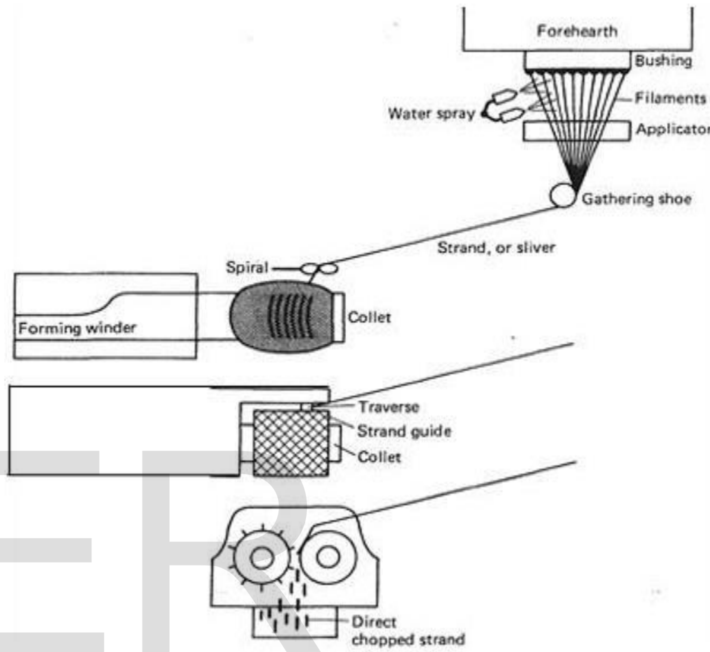
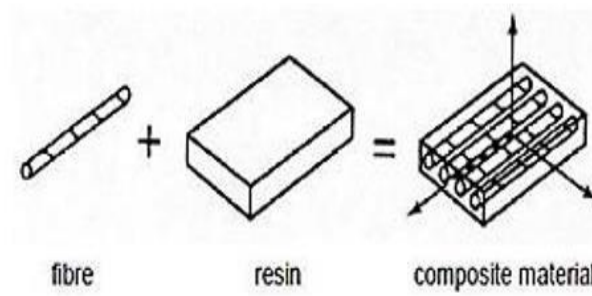


Figure 3 Fiber Glass forming process

Fiber-reinforced polymer (FRP) is composed of two material phases: fiber and polymer matrix. Fibers are impregnated into the polymer matrix to form a macroscopically orthotropic layer of material with distinctly higher mechanical properties along the fiber direction compared to the transverse directions. The advantages of using FRP are the high strength and stiffnessto-weight ratio along the fiber direction, ease of application in construction due to its light weight, corrosion resistance, electromagnetic inertness, and design versatility in which high strength and stiffness (fibers) may be oriented where needed in design. Continuous fibers become extremely strong and stiff as fiber diameter becomes smaller due to the reduction and sometimes elimination of defects in the microstructure. On the other hand, small-diameter fibers are not capable of carrying axial compression or shear stresses due to the lack of shear transfer medium between them. [8] Thus, the fibers are embedded into a polymeric matrix that binds them together and allows load transfer by shear among the fibers. Additional specifics about fibers and matrix are described in the following sections.

2.1.2. Epoxy Resin

The epoxide functional group is enclosed in the epoxy that is a preserved thermoset resin. Before use, the hardener (which cures epoxy resin) and epoxy resin are usually blended together. Many industries observe the use of Epoxy, e.g., structural adhesives electronic and electrical components, metal coatings, fiber-reinforced plastic materials and high tension electrical insulators. Epoxy resin is the prevalent polymer used with advanced composites. Epoxy resins are the prevalent polymer used with advanced composites. Their extensive use is primarily due to their superior mechanical properties, excellent adhesion, good possibility utilizing additiontype reactions, low cure shrinkage and low cost.



2.1.3. Properties of Common Glass Fibers

Properties of Common Glass Fibers

	Glass Type		
Property	E	C	S
Diameter (μm)	8–14	—	10
Density (kg/m³)	2540	2490	2490
Tensile modulus (GPa)	72.4	68.9	85.5
Tensile strength (MPa)	3450	3160	4590
Elongation (%)	1.8–3.2	4.8	5.7
Coeff. of thermal expansion ($\times 10^{-6}$/°C)	5.0	7.2	5.6
Thermal conductivity (W/m/°C)	1.3	—	—
Specific heat (J/kg/°K)	840	780	940

Source: Courtesy of Hyer (1998).

3 Methodology

3.1. solid works model

The automobile selected for the purpose is Lifan 520 model released in 2015. The bumper of the existing model had steel bumper.

A solid works Model of bumper beam of Lifan 520 Model:

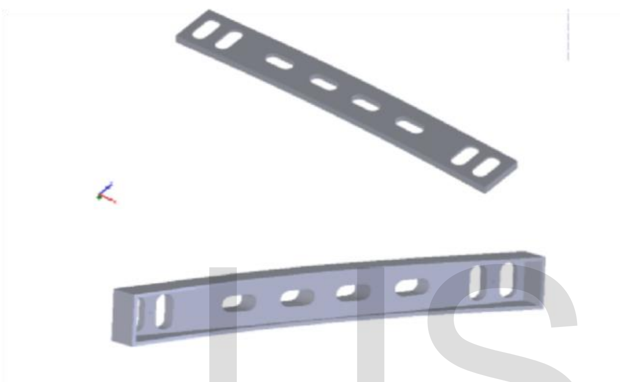
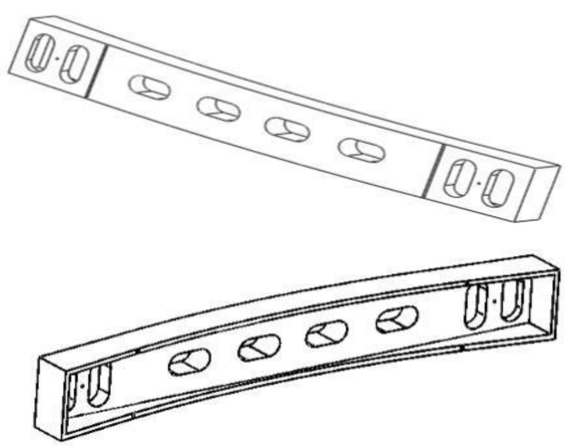


Figure 4: Existing Lifan 520 Model Steel Bumper Beam



3.2. Load Determination

Estimation of Impact force for a collision

Energy Transferred, (kE) = ½*[{(m1*m2)/(m1+m2)} * (u2-u1)2]

Where, m1 and m2 are the two colliding masses with velocities u2 and u1 respectively. Since both m1 and m2 are two vehicles with similar masses and the vehicle (m2) is at rest, m1=m2& u2=0

=>kE = 1/4 *m1*{u1}2

Now, Force = kE/t, Where‘t’ is impact time.

=>F = ¼ * m1*{u1}2/t

Mass of the vehicle = 1250 Kg

Maximum Speed of Vehicle, u1 = 48km/hr. = 13.3 m/s (moderate vehicle speed) This speed is according to regulations of Federal Motor Vehicle Safety Standards, FMVSS 208- Occupant Crash Protection whereby the purpose and scope of this standard specifies requirements to afford impact protection for passengers. [9, 10]

In most crash time t is of the order of 0.1s.

=>F = ¼ * 1250*{13.3}2/0.1= 312KN.

The Design Factor of Safety, FSd was taken as 1.5. This relatively high value is taken to account for the uncertainty in the nature of forces.

=> F = 1.5 * 312= 468KN.

Hence for design purposes force is taken to be 468 KN.

For the easiness of calculation this force is converted into a pressure which is acted on the front surface of the modelled bumper.

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Area of the front face of bumper beam =l*b =0.11184 m2

l= length of front face in mm, b = breadth of front face in mm

Pressure acted on the bumper = F/A =468000/0.18130187 = 2581330N/m2= 2.5 MPa

F= Force acted during collision in Newton's, A = Area of the front face of bumper in m2.

4. Result

4.1. Existing AISI 1006 Steel Bumper

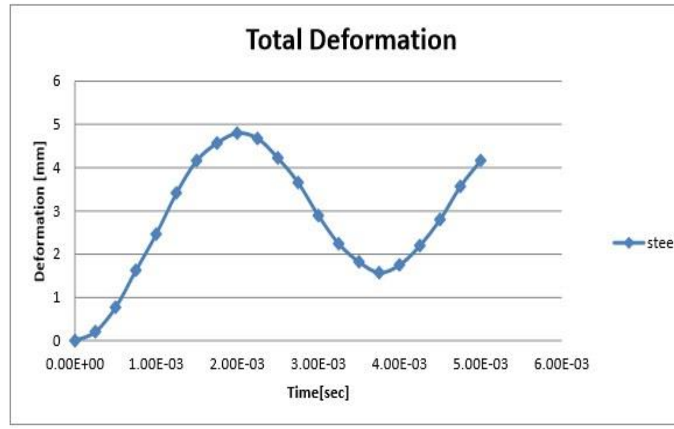
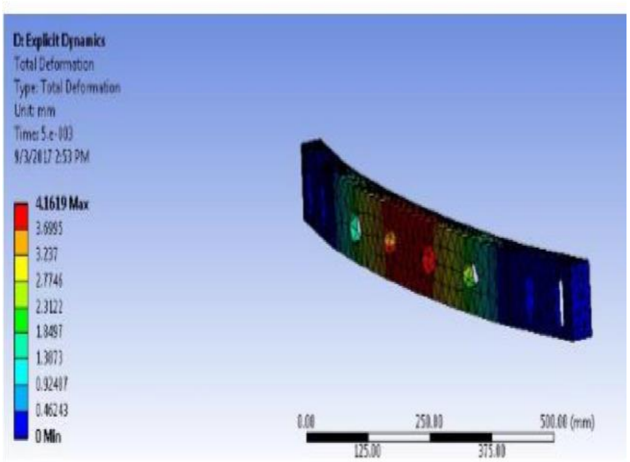


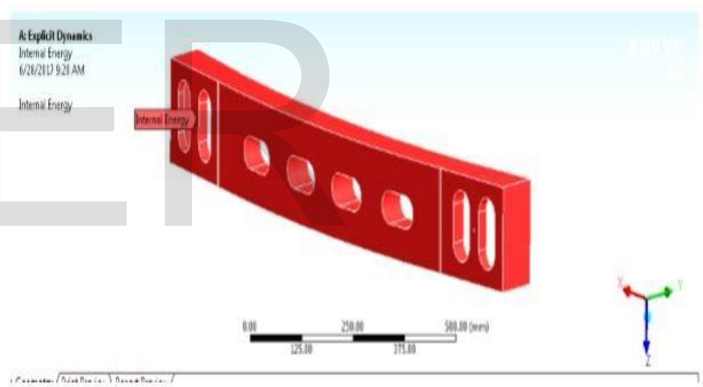
Figure 5. Total Deformation of Steel Bumper Beam

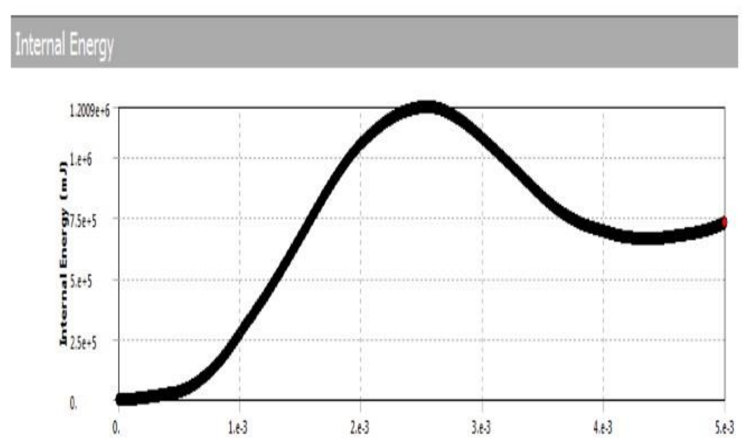
Beam Results

4.1.1. Total Deformation

Due to the applied pressure load maximum deformation length is 4.8 mm as shown in the graph. But 4.1619 mm is total deformation.







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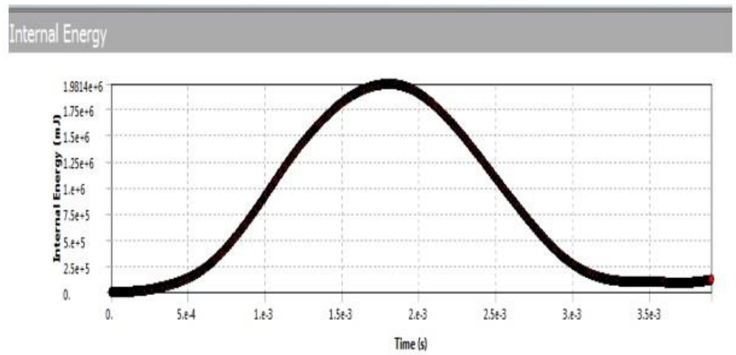
4.1.2. **Internal Energy**

Which is the energy absorbed by the 1006 steel beam material

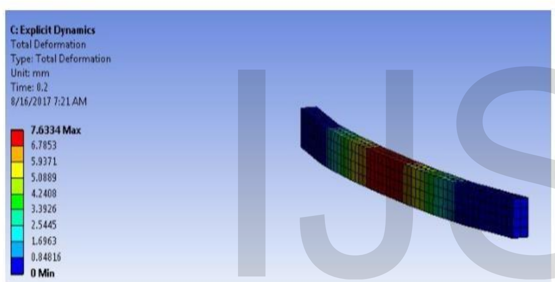
Figure 6. Internal Energy



4.2. **Optimized s glass fiber reinforced epoxy composite bumper beam**

4.2.1. Total Deformation

Due to the applied pressure load elastic deformation length is 1.84 mm as shown in the graph. But 7.6334 mm as a total deformation at t=0.2 sec.



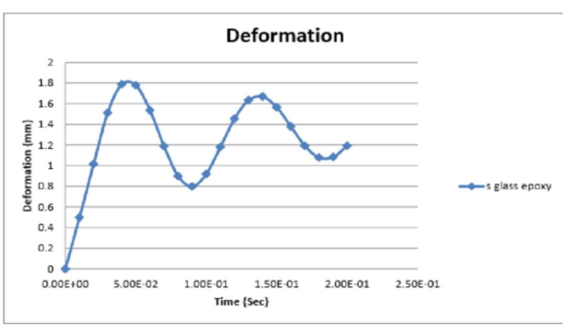


Figure 7.Total Deformation of S Glass Fiber Reinforced Epoxy Beam Material

4.3. **Internal Energy**

Which is the energy absorbed by the s glass fiber reinforced epoxy material

4.4 Total Deformation

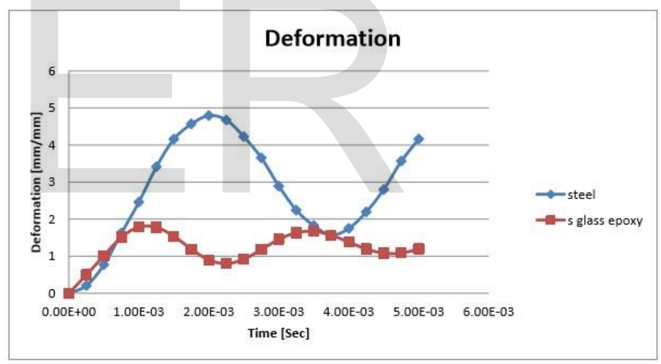


Figure 8. Total Deformation of both materials

4.4.1. Equivalent Elastic Strain

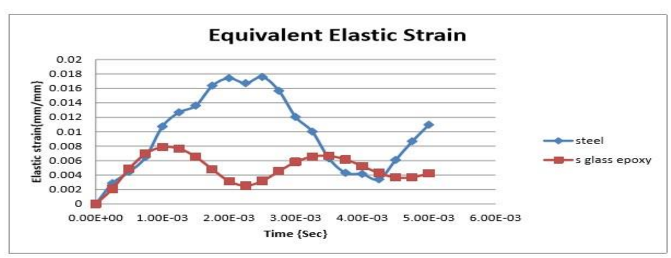


Figure 9. Equivalent elastic strain of both materials

5. **Conclusion**

Bumper beam is an important member of an automobile from the safety point of view. Thus the analysis of bumper will help to increase the safety of passengers and new size, shape and material may also be considered to replace the existing one. Design of composite bumper (using s glass fiber material) is completed and also composite bumper is analyzed and compared with steel bumper.

- The steel bumper has a deformation of 4.8 mm where the composite bumper beam has a deformation of 1.84 mm which is 61.6% high strength than steel bumper.
- The internal energy which is absorbed by steel material is 1200.9 J where the composite material is 1980 J which is 39 % higher than that of steel.
- The existing and composite bumper is analyzed in ANSYS16.0 and the Maximum stress induced in the composite bumper is 213.76 Mpa where steel is 2300.3 Mpa.

From the study, it is concluded that s glass fiber reinforced epoxy composite has better energy absorption capacity than steel material and fiber reinforced plastic material is a suitable material for manufacturing the bumper.

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