INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
IJTE

ISSN: 2057-5688

DEVELOPMENT OF CAR BUMPER TECHNOLOGY

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***Abstract**: Automotive design with economy, safety and aesthetics have been a great challenge to design engineers. Augmenting to these factors today environment impact is an upcoming research area. The safety of the passengers during vehicle crashes can be ensured to a certain limit by using good bumpers. At the same time these automotive parts should not be massive in terms of weight contributing to the increase in total the weight of the vehicle. In this work, a bumper used for low passenger vehicle, Ambassador car is modeled by using the software CATIA V5R20. Then this model is imported into FEM impact as well as static analysis. The materials used for these analyses are Steel, Carbon/epoxy , Glass/epoxy shows the lowest deformation and maximum von misses stress value. After the impact analysis, the composite shows the highest stress value, lowest deformation and the lowest strain value on compared with above materials. The analysis under the dynamic loading shows this carbon composite has the maximum stress value and it having the highest strength to weight ratio and producing low deformation. From all these analysis, it can concluded that carbon composite is the best material which can use as the bumper material among all the other materials used here.*

I. INTRODUCTION

Nowadays, in development of technology especially in engineering field make among the engineers more creative and competitive in designing or creating new product. They must be precise and showing careful attentions on what they produce. Here, we concentrate on automotive industry. The greatest demand facing the automotive industry has been to provide safer vehicles with high fuel efficiency at minimum cost. Current automotive vehicle structures have one fundamental handicap, a short crumple zone for crash energy absorption One of the options to reduce energy consumption is weight reduction. However, the designer should be aware that in order to reduce the weight, the safety of the car passenger must not be sacrificed. A new invention in technology material was introduced with polymeric based composite materials, which offer high specific stiffness, low weight, corrosion free, and ability to produce complex shapes, high specific strength, and high impact energy absorption

1.2 Automotive Bumper

The front and rear of the vehicle should be protected in such a manner that low speed collisions will only damage the vehicle slightly, or not at all. For this purpose front and rear bumpers were invented. The uses of bumpers has evolved from being a mechanism placed on the front and rear of the car to protect the body and safety features of a motor vehicle from damage due to a low speed collision to a decorative ornament designed more for the aesthetics of the motor vehicle rather than the actual functionality. The study carried out by Federal Motor Vehicle Safety Standards and Regulations (FMVSS) highlights how the present day bumpers on motor vehicles are connected to the fenders rather than the frame of the motor vehicle where it would be of more use and steady during a low speed collision. The study also shows how some automobile manufacturers have tried to produce shock absorbent bumpers using shock absorbent resilient materials. As highlighted above, the styling of the bumper has become more important than the structural design of the bumper. Nevertheless, the standards and regulations governing the design of the bumper should not be compromised in any circumstances. The same goes for the correct selection of the bumper material. Any attempt to by pass the standards of regulations and material selection would badly affect the structural integrity as it would be next to impossible to provide protection neither to the vehicle body nor the occupant during a crash. In the design of automobile parts and assemblies, components must be positioned within tight tolerances. This tight tolerance is a must to preserve the automotive aerodynamics and functionality of components with respect to each other. Furthermore, the support structures must not deform these components by applying unnecessary stresses. Therefore, the components must be mathematically constrained. Components are often supported on flexures, elastic elements which are relatively stiff in one direction

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and compliant in the other directions. Because these flexures are elastic and typically have negligible damping, vibration of the components relative to the support structure becomes a problem. Therefore, a method of introducing damping into the system must be found. The impact energy absorbed, also known as the bumper energy absorbable (EA) was invented on this basis. Much of the design and development of the modern energy absorbed is dedicated to protecting occupants or reducing vehicle damage during a crash. Although the primary function of the vehicle body structure in this respect is to dissipate the kinetic energy of the vehicle, effective protection depends upon careful management of this energy in order to achieve the optimum collapse mechanism.

Most automotive energy absorbable that are on the market today are designed to meet safety regulations with respect to individual geographic locations. North American markets will require that the design should satisfy FMVSS regulations that require the energy absorbents just to protect the car. The European and Asia-Pacific markets have a different set of requirements that focuses also on the safety of the pedestrian. However, the difficulties of designing a bumper system that is rigid enough to protect the vehicle and, at the same time, compliant enough to protect a pedestrian raise questions as to whether these ideas are compatible.

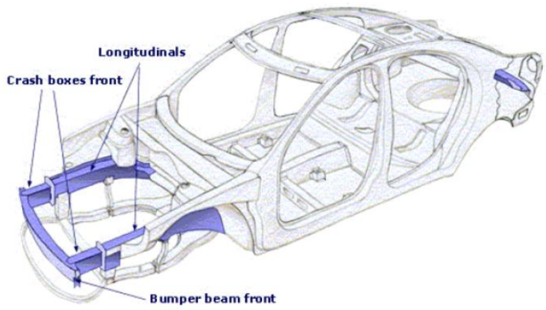

Fig 1.1: Location of bumper in the car

Car Bumper Components

Automobile car bumpers have the important function of lessening low- or high-speed impacts from the front or rear of the vehicle. Numerous designs come equipped on various makes and models with different components and features. Yet they all serve the same function: protecting the occupants of the vehicle from traumatic shock during a collision or lessening body damage to the vehicle by absorbing collision force. Some bumpers have extremely technical features and designs.

INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
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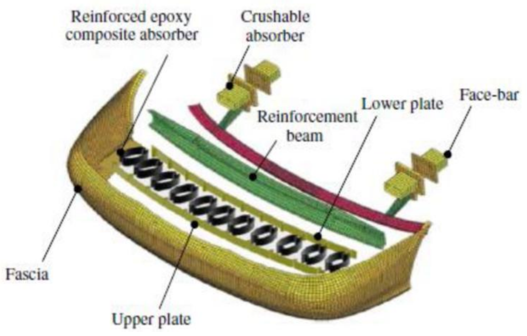

Fig 1.2: Parts of a typical bumper

II REVIEW OF LITERATURE

Extensive investigations of composite materials subjected to impact loads have been undertaken over many years. The objectives vary from examining the behaviour of composite structures under impact caused by various objects such as fragments and low flying objects while in service to designing new components which can efficiently withstand high velocity impact at a substantial weight reduction. The structures of interest in many applications are commonly composed of carbon/graphite, kevlar and glass fibre reinforced polymer matrix composites.

Davoodi M.M[1] proposed conceptual design of fibre reinforced epoxy composite bumper absorbable as a pedestrian energy absorbed. The energy absorption capacity was sufficient for pedestrian impact and it could possible to use as substitute for the existing materials such as EPP foam for low impact collision

Anderson R [2] emphasized that to increase crash performance in automotive vehicles it is necessary to use new techniques and materials. The components that are linked to crash safety should transmit or absorb energy. The energy absorbing capability of a specific component is a combination of geometry and material properties. The chosen material should have high yield strength and relatively high elongation to fracture. These demands lead to increase interest to use of high strength stainless steels.

2.2 Energy absorption of composites.

S. L. Stucki and W. T. Hollowell[3] concluded that the impact force rather than the impact energy governs the initiation of failure for single impact.

C.H Lee [4] investigated the influence of the mass and shape of imp actor, initial velocity and specimen thickness on the impact behavior. A modified damage model was developed and adopted in the user defined martial subroutine of the commercial simulation program LS-DYNE. The dissipated impact energy process was examined through comparisons of the predicted data with the experimental results. They have concluded that the specimen thickness is the most important parameter that should be considered in the design of components for the aspect of impact behavior.

Lee [4] performed tensile and compressive tests on glass-epoxy composites with different strain rates, which are typical strain rate range during automobile crash accidents in order to measure the strength variation with respect to strain rate. The impact energy absorption characteristics of glass fibre reinforced composites were estimated using a newly proposed progressive impact fracture model.

K. S. Cheon [5], studied the effects of impact energy, imp actor mass and impact velocity on the maximum contact force, maximum deflection, contact time, absorbed energy, and overall damage area of glass/epoxy laminated composites, experimentally and numerically. They have concluded that the decontamination area in the sample subjected to a lower imp actor mass with higher velocity is lower than the denominational area in the sample subjected to a higher imp actor mass with lower velocity for the same impact energy..

W. Abramowicz [6] conducted high velocity impact tests on E-glass fibre/polyester resin matrix composite plates of different orientation and thicknesses. It is found that the cross-ply unidirectional with plain weave composite plates showed relatively higher ballistic limit velocity towards very sharp nose conical head projectile impact as compared with other type of reinforcement used. It is also found that the specific energy absorption per weight per unit area for the composite plates revealed increase in values with
increase in thickness.

The Bumper

A bumper of an automobile is designed to absorb shock loads at low speeds in order to mitigate the effects of the impact. The bumper is meant to reduce damage to the vehicle at low speeds. The bumpers of vehicles are required to pass an impact test at 2.5 mph (4 km/h) with no visible damage to the body. Bumpers keep safety-related equipment such as headlights and taillights, hoods, fenders, exhaust and cooling systems, away from damage. When bumpers are poorly designed, these car body parts sustain damage even in parking-lot collisions and other low-speed impacts. Replacement costs of such components are very high. It is therefore essential to equip passenger

ISSN: 2057-5688

vehicles with bumpers that effectively reduce damage in low speed collisions.

Baker [7] studied the mismatches in bumper heights.Passenger vehicles are designed to absorb crash energy in frontal crashes through deformation of energy-absorbing structures forward of the occupant compartment. This is basically the bumper. In collisions between cars and light trucks, however, possible mismatches in height can cause the capacity of energy-absorption structures not be fully utilized. There are benefits from enhancing the compatibility between cars and light trucks in serious front-to-front crashes.

O'Neill and Kyrychenko [8] proposed that if the bumpers of different vehicles are made compatible, fatality risks for car occupants in front-to-front crashes with light trucks could be reduced by about 8 percent for lighter SUVs and pickups weighing between 2400 and 2500 pounds, and by about 28 percent for car occupants in front-to-front crashes with heavier trucks weighing 4,000 lbs or higher.

Park Dong-Kyou [9]studied trends in the design is to make pedestrian-friendly bumpers. Two general approaches to reducing the severity of pedestrian lower limb impacts can be identified. They are the provision of cushioning and support of the lower limb in the bumper and a new lower stiffener; as well as the integration of impact sensors and exterior airbags. The main method proposed for cushioning the lower limb in an impact uses an energy absorbed in front of a semi-rigid beam. Energy absorbents proposed include plastic foams (single or multi-density), molded plastic 'egg-crates', 'spring-steel', composite steel-foam, and crush-can energy absorbents. The most common beams used in the proposed pedestrian-friendly bumper designs are rolled steel or extruded aluminum. Other designs propose the use of molded plastic beams or plastic-steel composite structures. There are also designs that involve deploying bumpers that either move or change stiffness in response to the impact. The typical design proposed for supporting the lower limb in an impact is with a secondary lower beam, also called a 'stiffer' or 'spoiler'. Plastic plates or metal beams appear to be the most recommended types of lower stiffeners. Exposed steel bumpers that involve frontal airbags design are also alternative design concepts that appear to be adaptable to meet the pedestrian's safety requirements but these may be

ISSN: 2057-5688

costly and require advanced sensors to function efficiently.

According to (NHTSA) [10], for passenger cars in USA, the law specifies 10 bumper tests, including pendulum tests and crashes into a fixed flat barrier. This is in line with the bumper standards that stipulates the impact resistance of vehicles in low speed front and rear collisions. The purpose of this standard is to reduce physical damage to the front and rear ends of a passenger motor vehicle from low speed collisions. Bumpers are tested using pendulum and fixed barrier tests. Apart from pendulum tests at 2.4 km/h (1.5 mph), bumpers must pass the fixed barrier tests. The fronts and rears of the vehicles crash into a flat barrier at 4 km/h (2.5 mph). To pass these barrier and pendulum tests, unlimited damage is allowed to the bumper, but none is allowed to other parts of the vehicle.Hood and trunk doors, propulsion, suspension, steering, and braking systems must all operate normally after the test. There should be no broken headlights or fuel, cooling, or exhaust leaks or constrictions after the tests. The bumper should be within the test zone of 40.64 to 50.8 cm (16-20 inches) from the ground. SUV's and vans are excluded from such bumper standards. Even though most pickups and SUV's do have bumpers, their heights often vary from the USA federally specified test zone for cars. The Insurance Institute for Highway Safety (IIHS) in USA uses a series of four tests to better reflect real vehicle-to-vehicle collisions and the kinds and amounts of damage they cause. Instead of a flat barrier, it uses a test barrier shaped like a bumper of a vehicle with a deform-able surface.

Taylor ben [11] studied the three major components of good bumper design that are lacking on many current passenger vehicles are compatible geometry, stability during impacts, and effective energy absorption. Compatible geometry implies bumpers must be located and sized so they engage the bumper systems on other vehicles with sufficient overlap to account for variations in ride height due to occupant and cargo loading and braking. The stability requirement expects that once engaged, bumper systems offer a stable interface and remain engaged throughout the impact. Apart from meeting the geometry and stability requirements, bumpers still must have sufficient energy absorption capabilities to limit damage to the bumper system itself. Bumper stability is mainly influenced by bumper cover

INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
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ISSN: 2057-5688

geometry, bumper reinforcement bar shape and strength, and energy absorbed design

III COMPOSITES

A composite material (also called a composition material or shortened to composite) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

Typical engineered composite materials include:

- Composite building materials, such as cements, concrete
- Reinforced plastics, such as fibre-reinforced polymer
- Metal composites
- Ceramic composites (composite ceramic and metal matrices)

Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marblesinks and countertops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environments.

Fibre-reinforced polymers or FRPs include carbon-fibre-reinforced polymer or CFRP, and glass-reinforced plastic or GRP. If classified by matrix then there are thermoplastic composites, short fibre thermoplastics, long fibre thermoplastics or long fibre-reinforced thermoplastics. There are numerous thermoset composites, but advanced systems usually incorporate aramidfibre and carbon fibre in an epoxy resin matrix.

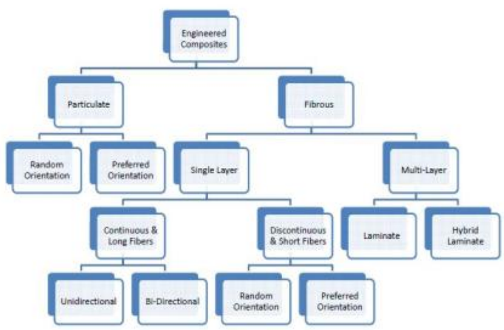


Fig 3.1: Classification of composites

Fiber-reinforced composite materials have gained popularity (despite their generally high cost) in high-performance products

ISSN: 2057-5688

that need to be lightweight, yet strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, bicycle frames and racing car bodies. Other uses include fishing rods, storage tanks, swimming pool panels, and baseball bats. The new Boeing 787 structure including the wings and fuselage is composed largely of composites. Composite materials are also becoming more common in the realm of orthopedic surgery.

Carbon composite is a key material in today's launch vehicles and heat shields for the re-entry phase of spacecraft. It is widely used in solar panel substrates, antenna reflectors and yokes of spacecraft. It is also used in payload adapters, inter-stage structures and heat shields of launch vehicles. Furthermore disk brake systems of airplanes and racing cars are using carbon/carbon material, and the composite material with carbon fibres and silicon carbide matrix has been introduced in luxury vehicles and sports cars.

In 2007, an all-composite military Humvee was introduced by TPI Composites Inc. and Armour Holdings Inc., the first all-composite military vehicle. By using composites the vehicle is lighter, allowing higher payloads. In 2008, carbon fibre and DuPont Kevlar (five times stronger than steel) were combined with enhanced thermoses resins to make military transit cases by ECS Composites creating 30-percent lighter cases with high strength

Composites are made up of individual materials referred to as constituent materials. There are two main categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. A synergism produces material properties unavailable from the individual constituent materials, while the wide variety of matrix and strengthening materials allows the designer of the product or structure to choose an optimum combination.

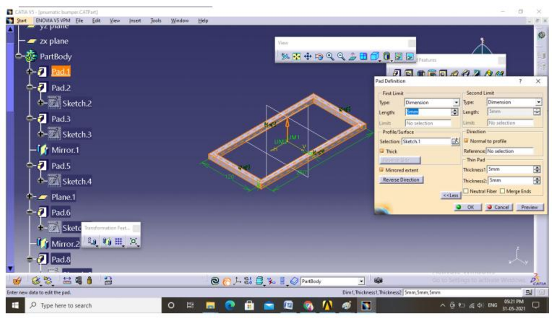
Engineered composite materials must be formed to shape. The matrix material can be introduced to the reinforcement before or after the reinforcement material is placed into the mould cavity or onto the mould surface. The matrix material experiences a melding event, after which the part shape is essentially set. Depending upon the nature of the matrix material, this melding event can occur in various ways such as chemical polymerization or solidification from the melted state.

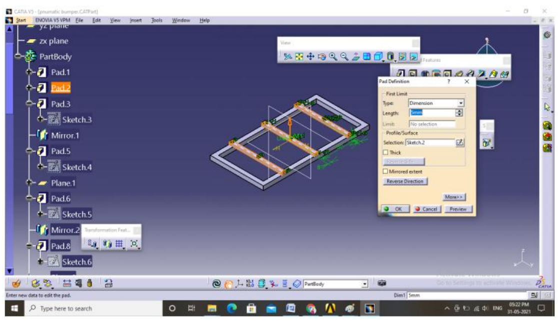
A variety of moulding methods can be used according to the end-item design requirements. The principal factors impacting the methodology are the natures of the chosen matrix and reinforcement materials. Another important factor is the gross quantity of material to be produced. Large quantities can be used to justify high capital expenditures for rapid and automated manufacturing technology. Small production quantities are accommodated with lower capital expenditures but higher labour and tooling costs at a correspondingly slower rate.

Many commercially produced composites use a polymer matrix material often called a resin solution. There are many different polymers available depending upon the starting raw ingredients. There are several broad categories, each with numerous variations. The most common are known as polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, PEEK, and others. The reinforcement materials are often fibers but also commonly ground minerals. The various methods described below have been developed to reduce the resin content of the final product, or the fibre content is increased. As a rule of thumb, lay up results in a product containing 60% resin and 40% fibre, whereas vacuum infusion gives a final product with 40% resin and 60% fibre content. The strength of the product is greatly dependent on this ratio.

IV GEOMETRIC MODELLING

Modelling Of Pneumatic Bumper





Design

The design of the bumper used in this project is of the ford festiva (1992-2000) model. The original bumper is simplified, and the bumper beam is only taken into consideration in this project. The simplified design of the bumper beam is shown in the fig

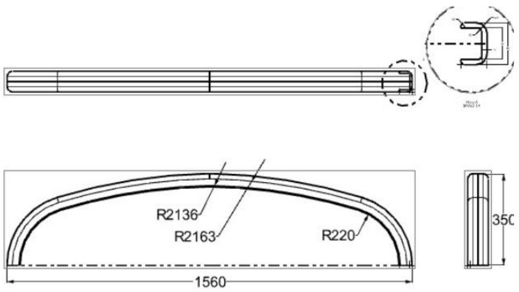


Fig 4.1: Draft sketch of bumper

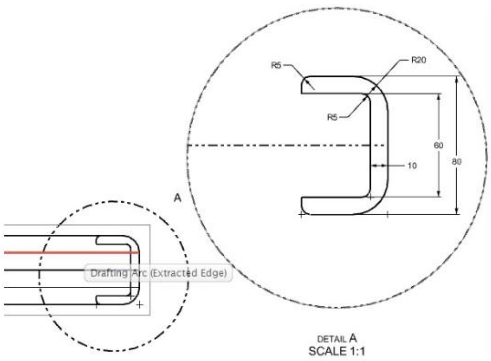


Fig 4.2: Cross section of the bumper

V ANALYSIS OF THE BUMPER BEAM

Strategic parameters

The need for computer crash simulations with high degrees of fidelity and robustness is becoming increasingly important for use in parametric studies and early design analysis. The numerical simulations also enable new design concepts to be evaluated where there is a need to establish an optimum design with interaction between materials and structural forms. The main objective of this chapter is to investigate the ability of the nonlinear FE code Ansys Autonomy to predict the response of the bumper beam system. The main focus is placed on accurate prediction of the observed system behaviour with respect to force-deformation characteristics.

There were four main strategic parameters being studied during the test modelling. In the first step for metallic material it was necessary to know the type of material can affect the impact specifications and what kind of materials could be used as replacement in order to lower part weights. The effect of module of elasticity and yield strength on impact behaviour of bumper was under investigation in this section. Secondly, the thickness, i.e., how the bumper beams thickness could affect the impact specifications. Thirdly, the shape, i.e., how could small changes and modifications result in easier manufacturing processes and lessening material volume without lowering the impact strength. Finally, the impact condition, i.e., how the test

INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
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ISSN: 2057-5688

conditions other than the previously mentioned parameters could affect the impact behaviour.

Mechanical properties of materials

Mechanical properties for the bumper materials are given below in the table

Material	Density kg/m^3	Poisson ratio	Young's modulus Mpa	Ultimate strength Gpa
Steel	7850	0.3	20000	460
Carbon/epoxy	1420	0.41	61340	805
E glass/epoxy	2000	0.4	45000	415

Table 5.1: Properties of the bumper material

Carbon/epoxy taken above is 'Carbon/epoxy woven 230Mpa generic' (as specified in mat web, a product of good fellow composites) with 56% fibre.

E glass/epoxy taken above is ' E glass/epoxy woven generic' with 50% fibre.

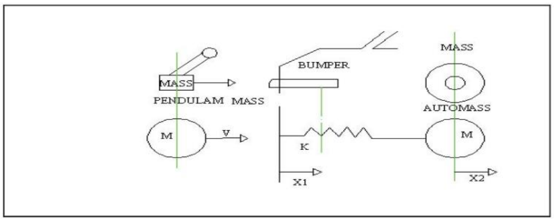

Fig 5.2: Equivalent spring mass system for bumper and impactor

The validation of the FEA analysis of the bumper testing is essential ,it is necessary to redefine and check the values before the prototype of the bumper design.To optimist the FEA results this numerical modelling was developed and to help to compare the values. The impact behavior in vehicle collision is assumed as shown in Figure this type of vehicle collision is named as elastomer-plastic impact (Nimmar et al 1987). During low speed impact, the collision involves transient and non-linear analysis. To assess this issue some simple spring-mass model was employed. Here the pendulum is modeled simply as a rigid solid of mass M with an initial velocity of V. Similarly, the car is modeled as a rigid solid of equivalent mass M. Since the mass of the bumper is small with respect to the car, it is neglected in this analysis. However, the stiffness of the bumper is included in the model as a spring of stiffness KB. This stiffness can be quantified either experimentally or analytically by considering the displacement 'y' of a

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ISSN: 2057-5688

bumper beam under a load F from a pendulum. Then the stiffness KB simply becomes

$$K_B = \frac{Load}{Deflection} = \frac{F}{y}$$

The governing differential equations for the dynamic system
described in Figure are

$$M\ddot{x}_1 + K_B(x_1 - x_2) = 0$$

$$M\ddot{x}_2 + K_B(x_1 - x_2) = 0$$

and the initial conditions are

$$x_1(0) = 0$$

$$\dot{x}_1(0) = V$$

$$x_2(0) = 0$$

$$\dot{x}_2(0) = 0$$

Solution of this set of simultaneous linear equations leads to

$$x_1 = \frac{V}{2}t + \frac{V}{2\sqrt{2}\omega}\sin\sqrt{2}\omega t$$

$$x_2 = \frac{V}{2}t + \frac{V}{2\sqrt{2}\omega}\sin\sqrt{2}\omega t$$

where t and stands for time and angular velocity respectively,

$$\omega = \sqrt{\frac{K_B}{M}}$$

A number of very important conclusions can be drawn from above Equations . An expression for the total force exerted by the pendulum on the bumper for Equations can be derived as

$$t \le \frac{\pi}{\sqrt{2}\omega}$$

$$F = K_B(x_1 - x_2)$$

$$F = V\sqrt{\frac{K_B M}{2}}\sin\sqrt{2}\omega t$$

$$F_{\max} = V\sqrt{\frac{K_B M}{2}}$$

In addition, the impact event terminates when the force goes to zero and that “Total impact duration, ” can be expressed from Equation

After all the output parameters are assigned the problem is then solved. Ansys uses autonomy solver for solving the model.

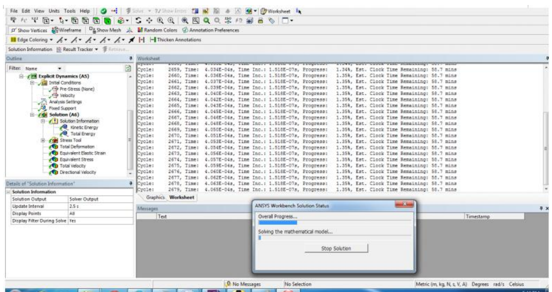

Fig 5.20: Solution status

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VI RESULTS AND DISCUSSIONS

The three bumpers are made to impact the barrier at velocity of 2.2 m/s and the deformation graphs are plotted with respect to time. The graph shows the comparative deformation graph between the three bumpers. While the e glass/epoxy bumper has shown maximum deformation, steel and carbon/epoxy bumpers have shown equal amount of deformation. By the time the simulation has terminated all the three bumpers have shown gradual drop in deformation. This shows that the deformation is elastic and is regaining its initial state. The graph shows the stresses developed in the bumper during the impact. The stress values are equal in the three bumpers. The graph shows the strain in the bumpers with respect to time. Carbon has minimum strain values whereas e glass has maximum strain values. The table shows the maximum deformation and stresses in each bumper.

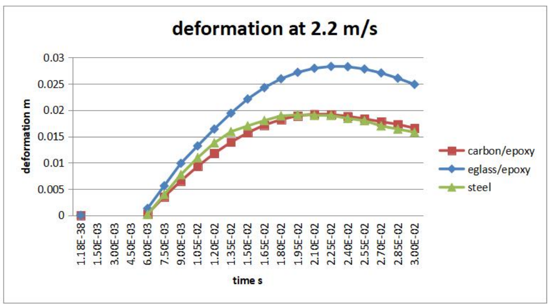

Fig 6.1: deformation of the bumper at 2.2 m/s velocity

Material	Stress (Pa)	Deformation (m)
Steel	501170000	0.0666
Carbon/epoxy	636580000	0.0700
E glass/epoxy	357040000	0.0951

Graphs showing total energy change in the bumpers:

The graphs show the energy change in bumpers at the impact velocity of 5 m/s. In these graphs the carbon/epoxy bumper has shown relatively slow increase in energy than in the steel and e glass/epoxy bumpers.

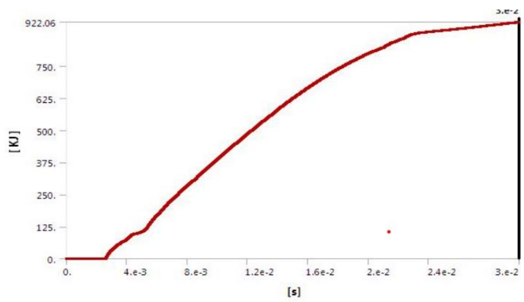

Fig 6.13: Total Energy change in steel bumper at 5 m/s

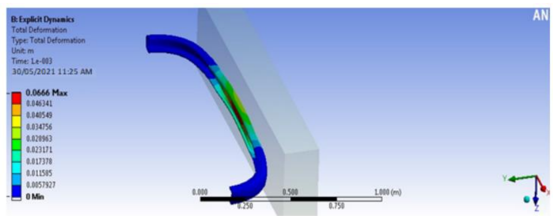

Fig 6.16:Deformation of steel

VII CONCLUSION

Determining the best bumper is a typical task. A good bumper should have the following characteristics

A bumper should be able to absorb the energy during impact by allowing itself to deform.

A good bumper should deform elastically during collision and should regain its original shape after the impact. Practically this is possible only at low speeds.

The deformation should be limited to certain amount. If a bumper is allowed to take maximum deformation, it damages the parts of the automobile.

The above characteristics were all shown by all the three bumpers at 2m/s velocity. But the carbon epoxy bumper has shown less plastic deformation and more elastic deformation. Moreover the carbon epoxy bumper is having less weight making it the best material for bumper.

At increased speeds has shown less deformation than the other two bumper. Though the e glass/epoxy bumper has absorbed more energy it has shown maximum deformation which more than the clearance between the bumper and engine parts.

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