ENHANCING THE ENERGY ABSORPTION OF AUTOMOBILE BUMPER

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I. ABSTRACT

Bumpers play an important role in preventing the impact energy from being transferred to the automobile and passengers. Saving the impact energy in the bumper to be released in the environment reduces the damages of the automobile and passengers. The goal of this project is to design a bumper with minimum weight by employing the Glass Material Thermoplastic materials and coil spring & hydraulic cylinder absorb the shock. This bumper either absorbs the impact energy with its deformation or transfers it parallel to the impact direction. To reach this aim, a mechanism is designed to convert about 80% of the kinetic impact energy to the spring and 20% of the hydraulic cylinder. In addition, since the residual kinetic energy will be damped with the infinitesimal elastic deformation of the bumper elements, the passengers will not sense any impact. It should be noted that in this project, modeling, solving and result's analysis are done in CREO and ANSYS.

KEYWORDS:BUMPER,GMT MATERIAL ,SOFTWARE(ANSYS,CREO).

II.INTRODUCTION

MEANING OF BUMPER

A bumper is a shield made of steel, aluminium, 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. Some bumpers use energy absorbers or brackets and others are made with a foam cushioning material.

(a).PURPOSE OF BUMPERS

The car bumper is designed to prevent or reduce physical damage to the front and rear ends of passenger motor vehicles in low-speed collisions. Automobile bumpers are not typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions.

It is not a safety feature intended to prevent or mitigate injury severity to occupants in the passenger cars. Bumpers are designed to protect the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collisions.The main function of a bumper is to protect the car's body in a slight collision, typically at parking speed. The bumper structure on modern automobiles generally consists of a plastic cover over a reinforcement bar made of steel, aluminum, fiber glass composite, or plastic. In most jurisdictions, bumpers are legally required on all vehicles. The height and placement of bumpers may be legally specified as well, to ensure that when vehicles of different heights are in an accident, the smaller vehicle will not slide under the larger vehicle. Although a vehicle's bumper systems should be designed to absorb the energy of low-speed collisions and help protect the car's safety and other expensive components located nearby, most bumpers are designed to meet only the minimum regulatory standards .Bumpers are not capable of reducing injury to vehicle occupants in high-speed impacts, but are increasingly being designed to mitigate injury to pedestrians struck by cars such as through the use of bumper covers made of flexible materials. Automobile industry has been improved significantly since 1953 by emerging the composite materials. Since it is proved that the composite materials can achieve the desirable properties such as low weight, high fatigue strength, easy forming and high strength, they are suitable for material replacing. Although the composites have some undesirable properties such as relatively long time processing, expensive raw materials and low surface finish quality, its light weight is the major reason for the increasing application of the composite materials in the automobile industry. In the mass production of vehicles, the light weight of components results in a significant reduction of the fuel consumption and Consequently the reduction of the CO2 and other emissions . Since the experimental tests, particularly at full-scale, are very costly and require highly specialized test facilities and also the model being evaluated inevitability will suffer extensive damages, utilizing the crash simulation seems to be crucial. Today, numerical models reproduce all details of vehicles, and also include passengers. With such analysis and employing upwards of 1,000,000 elements, it may still take a few days to solve the problem even by the modern multiprocessor computers. Nowadays, with the development of the automobile technology, more and more light weighting materials like the Glass Material Thermoplastic (GMT) are applied to the automobile body. GMT provides a high strength to¬ weight ratio, chemical / corrosion resistance, and excellent impact properties at both low and high temperatures . Compared to metals, GMT offers greater design flexibility, lower tooling costs, and opportunities for part consolidation. Compared with thermo set composites, GMT improves productivity with shorter molding cycle time, greater impact resistance, recyclability (melt reprocess ability), and elimination of controlled-storage requirements . GMT has rate dependant properties, which is due to the visco elastic properties of Polypropylene which is used as matrix in the material. As a result of this visco elastic behavior, the strength (and energy absorption) at practically encountered deformation rates in crash loaded automotive parts is significantly higher than the "quasi static" strength measured at an elongation rate of 0.001 (1/s) . There are three principle types of GMT, including continues glass fiber, chopped glass fiber and unidirectional glass fiber . The use of GMT in high-impact, structural applications in the automotive and transportation industry is well documented .

The bumper system is a structural component, which contributes to the crashworthiness or occupant's protection during a front or rear collision. There is an interest among the researchers to move from conventional materials such as plastic, aluminum, or steel to materials such as polymeric based composites in the bumper system. For instance, a composite material bumper system has been made using sheet molding compound (SMC) with random chopped glass fiber composites . Developed a one piece, injection molded, thermoplastic rear bumper system with pole impact protection . Clark et al. described their extensive work on bumper beams using continuous glass fiber composites to study the stress contour in the component. Developed the composite bumper beam for a passenger car . The material used was glass fiber epoxy composite material, except for the elbow section. And then developed an I-section beam with 40% chopped glass fiber GMT . Over the last few years, some factors have made this application more interesting for GMT, which are as follows .

1. Increasing demands of the vehicle weight reduction: Reduction in fuel consumption and in addition to, since, the bumper is far from the center of gravity of the vehicle so it's weight is also critical to the inertia and as a result to the vehicle handling.

2. Higher required energy absorption: Achieving energy absorption at bumper mounting points to protect the structures behind it in the vehicle, at low speed crash.

3. Controllable fracture behavior: Part integrity and stabilization function at very high speed crashes. At these rates primarily the deformation behavior is important. In this research, a typical new front bumper beam on a passenger cars have been designed with GMT composite materials. This bumper absorbs impact energy with its deformation or transfers it perpendicular to the impact direction with the aid of a spring mechanism that is able to convert about 80% of the kinetic energy to the spring potential energy in low speed impacts according to American standard. The main design concepts of this bumper are based on aerodynamic forms and frontal configuration of passenger cars. The design of spring system has done with the aid of ANSYS. The PRO/E data of the bumper structure have imported to Ansys and analyses have done with nonlinear explicit impact modeling elements. Modeling, solving and analysis were carried out with respect to the design standard (Bumper Standard) and a bumper was designed with 7.6 kg weight which has half weight compared with a similar steel bumper (with equal strength).

(b)PROBLEM IDENTIFICATION AND SPECIFICATION

FIG 1

(c) PROBLEM

1. Existing bumper Weight is high and also rigid on impact loading time.
2. Impact energy with its deformation or transfers it perpendicular.
3. Passengers will be sense the impact load
4. Also affect the engine parts and in it front side major engine accessory

(d)SPECIFICATION OF BUMPER

5. Toyota innova model	
6. Toyota Innova Length in mm	4585 mm
7. Toyota Innova Width in mm	1765mm
8. Toyota Innova Height in mm	1760 mm

III.BUMPER MODEL DESIGN&TYPES OFCOMMON BUMPERS

There are several models and systems for bumpers of passenger cars . Traditional models have corrugated open section areas for installing some car elements and increasing bending strength of the bumper. Main parts of the conventional bumper systems are depicted in Fig.2

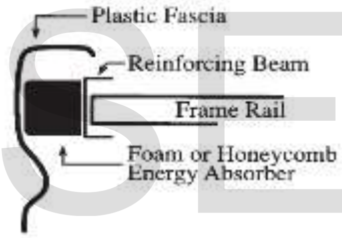


Fig 2 Configuration of common bumper type

1.Fascia: bumper fascia must be aerodynamic, light weight and aesthetically pleasing to the consumer. Usually fascia are made of polypropylene, polyurethane or polycarbonate.

2. Energy absorbers: energy absorbers are designed to absorb a portion of the kinetic energy from vehicle collision. Its types include foam, honeycomb and mechanical ones. However mechanical absorbers have several times the weight of foam and honey comb absorber, they receive limited usage.

3. Reinforcing beam: this part is a key component of the bumper and helps absorb the kinetic energy and provide protection to the rest of the vehicle. The designed bumper in

this research is a combination of these elements. In other words, in low-speed contacts, the kinetic energy of impactor is absorbed by changing the impact force direction by the spring system (as mechanical energy absorbers) and in high speed contacts it is absorbed by deformation of conic composite cells of the bumper (as reinforcing beam). The main elements of this bumper are as follows (see Fig.2):

1. Front rubber tape: that is composed of polypropylene (PEP) for damping of poor contacts.
2. Fascia: it indicates the aerodynamic form of the bumper and is used as a bearing for spring system retainer.
3. Spring system: it contains 26 vertical springs for converting the kinetic energy to the spring potential energy, In addition to 4 horizontal springs for connecting the fascia to base plate.
4. Conics and base plate: they are main elements of the bumper for energy absorbing in high speed contacts (i.e. reinforcing beam).

5. Connecting plastic parts: two propylene (PEP) parts that connect the bumper base plate to the car.

FIG 3

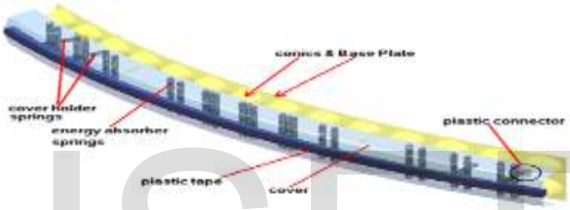


FIG 4 Schematic configuration of the desired bumper

In the low speed impacts, the cover moves toward the conics to reaches its top surface and make the spring system to stretch in vertical direction as a result of cover edges sliding on the conics. The initial dimensions are calculated and selected proportionally then as a result the spring system stretches a totally 6 cm perpendicular to the impact direction. So, it absorbs kinetic energy in the form of spring potential energy. Also, two small areas between the cover edge and the middle part of the cover have designed with thinner thicknesses (i.e. there are two lateral notch at the top and bottom corners of the cover), which guarantee easier deformation rather than the other parts of the cover, so, the cover edges movements mechanism is completely predicted and in control. For high speed contacts, the cover reaches the conics and they deforms as a composed part. There is a concavity in the cover where the plastic tape seats on and increases the bending strength of the bumper.

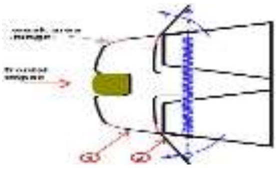


FIG 5

section view of bumper – cover and spring movement during Frontal impact

IV.STEP TO DESIGN OF BUMPER AND STEPS TO ANALYSIS OF GMT

Following table pars are designed using the creo software . the parts are plotted with step by step .

Sno	Part name	Material	Qty
1	Front bumper	Gmt	1
2	Back plate	Steel	1
3	Middle plate	Gmt	1
4	Helical spring	Spring material	7
5	Hy.damper	Std	2

V.STEPS OF ANALYSIS&ANALYSIS OF GMT BUMPER

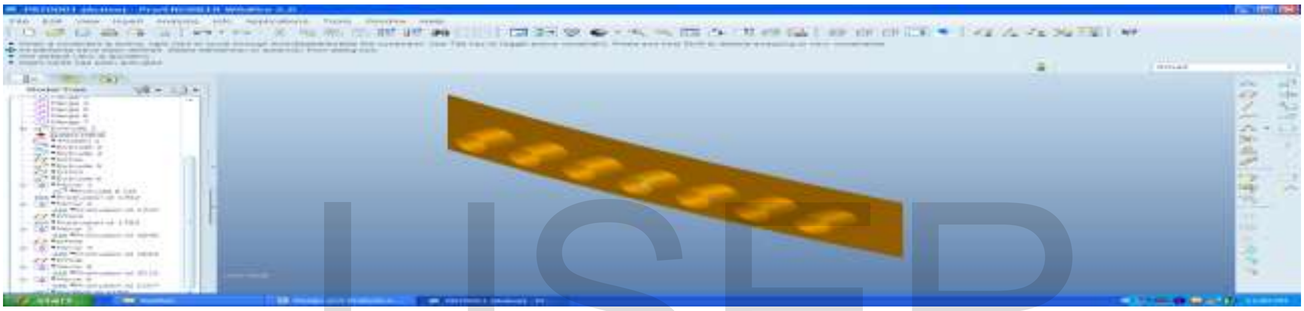


Fig 6 of bumper back plate

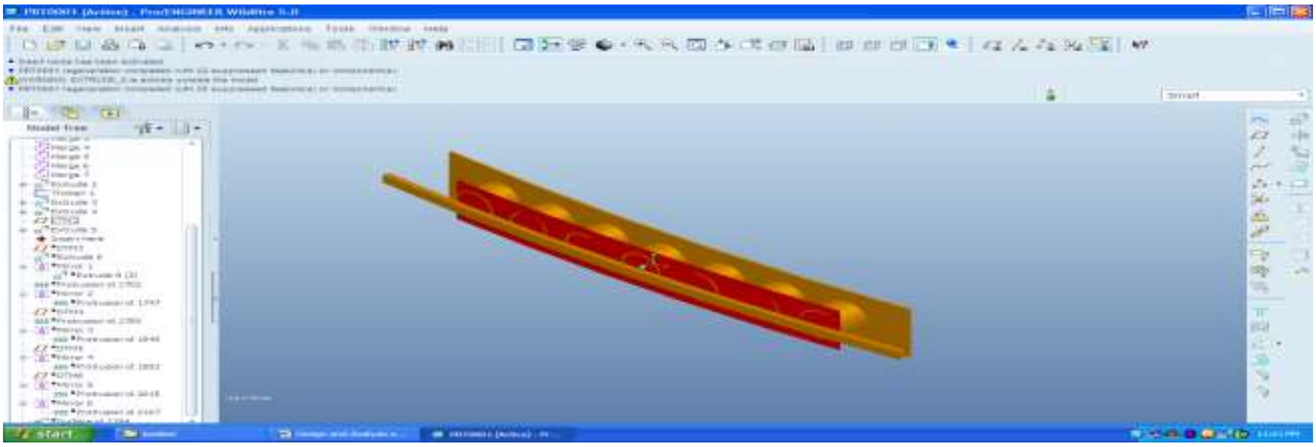


Fig 7 of bumper front plate

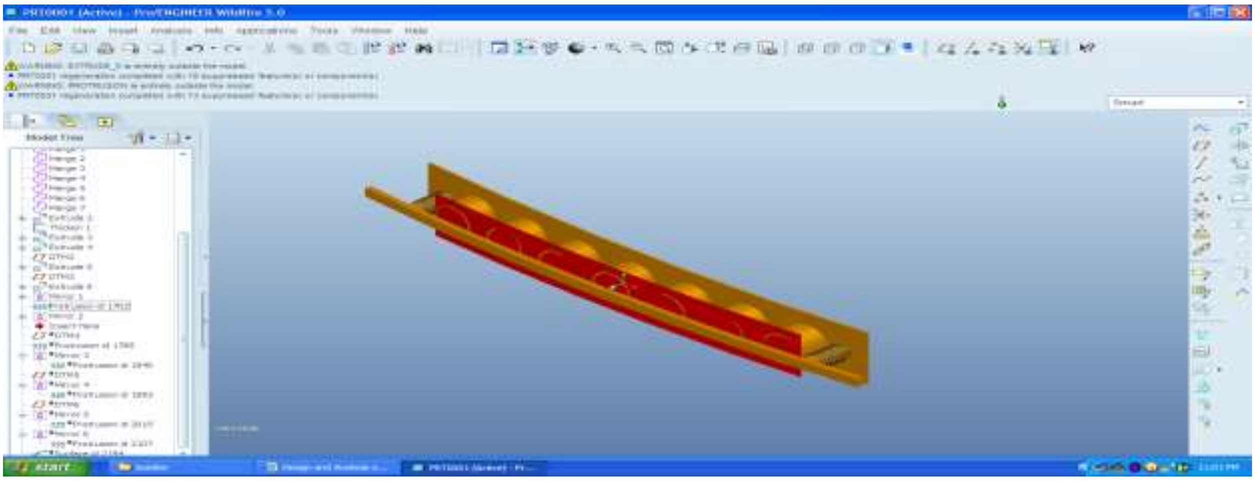


Fig 8 of bumper with energy spring horizontal 8 no

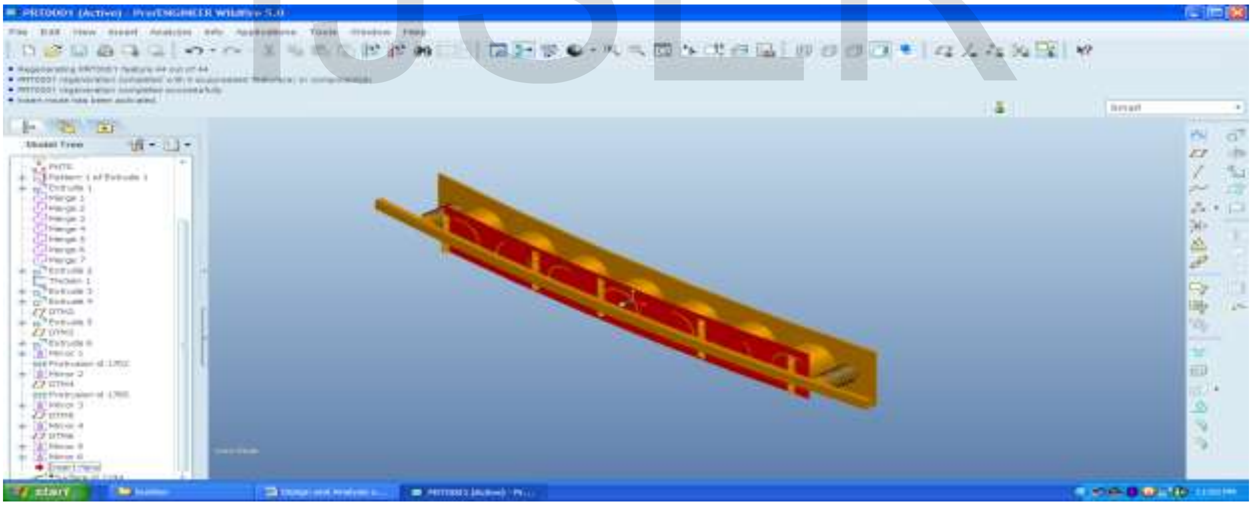


Fig 9 of bumper with 2 hydraulic cylinders

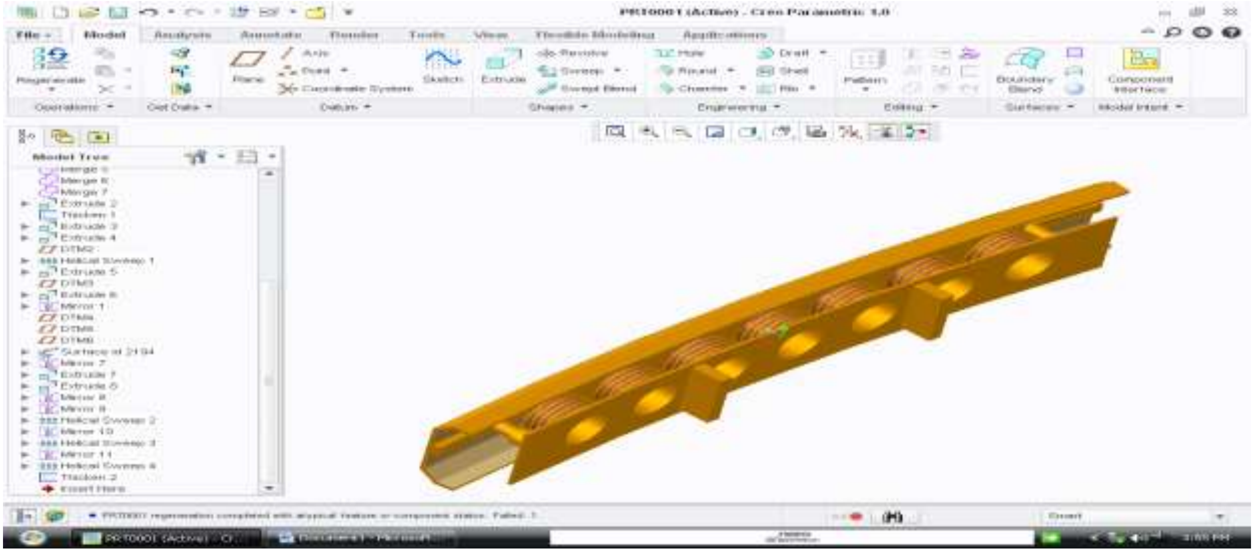


Fig 10 of bumper with front channel

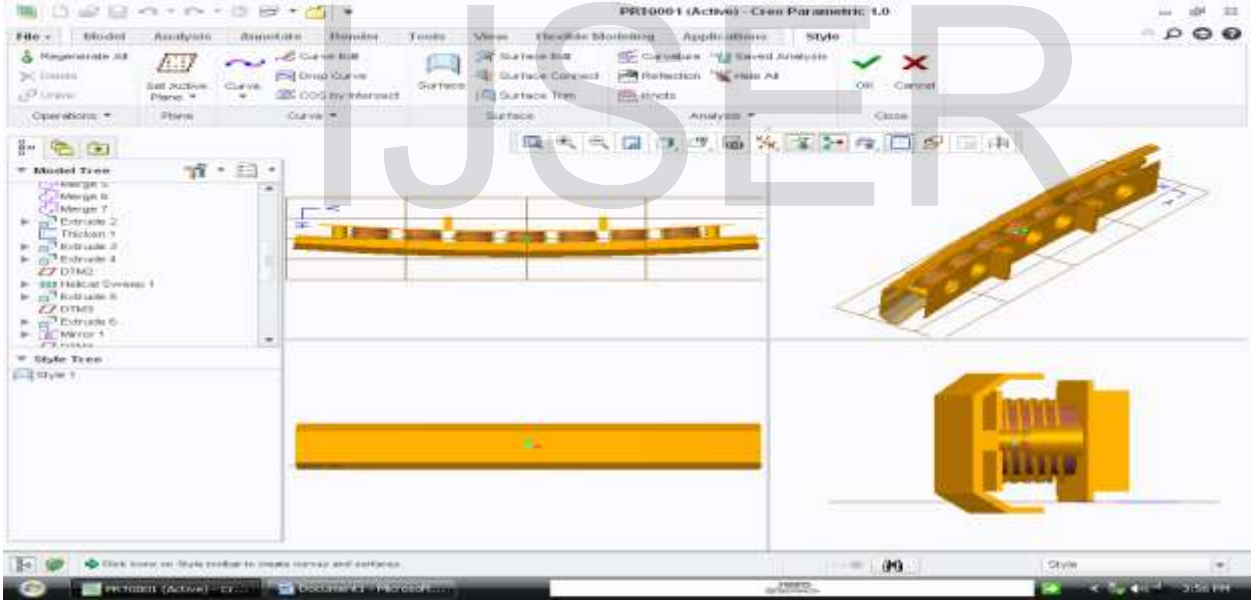
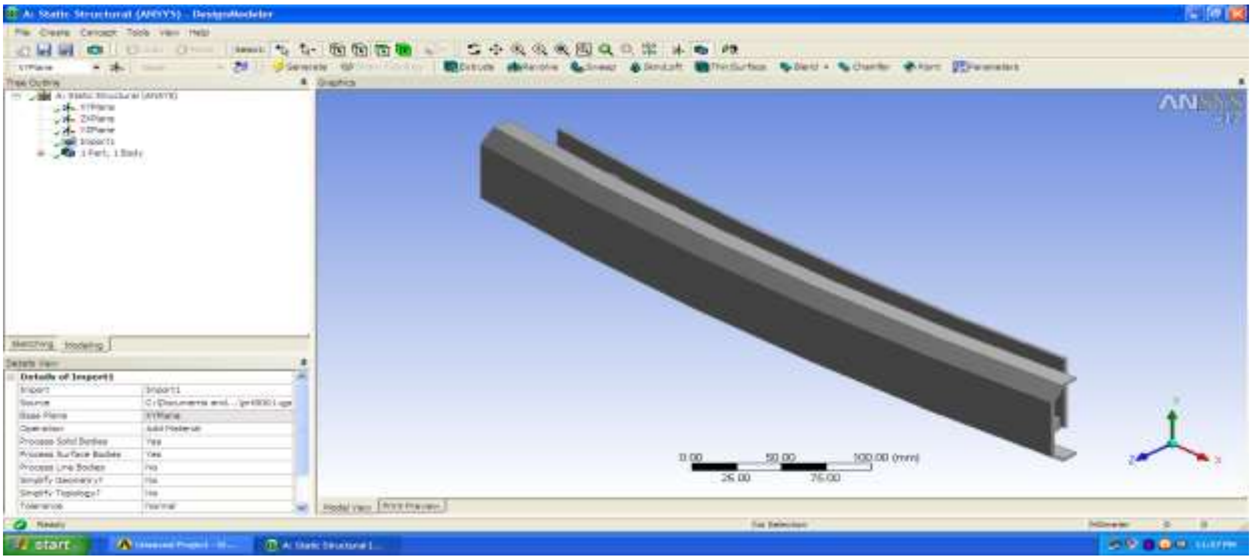
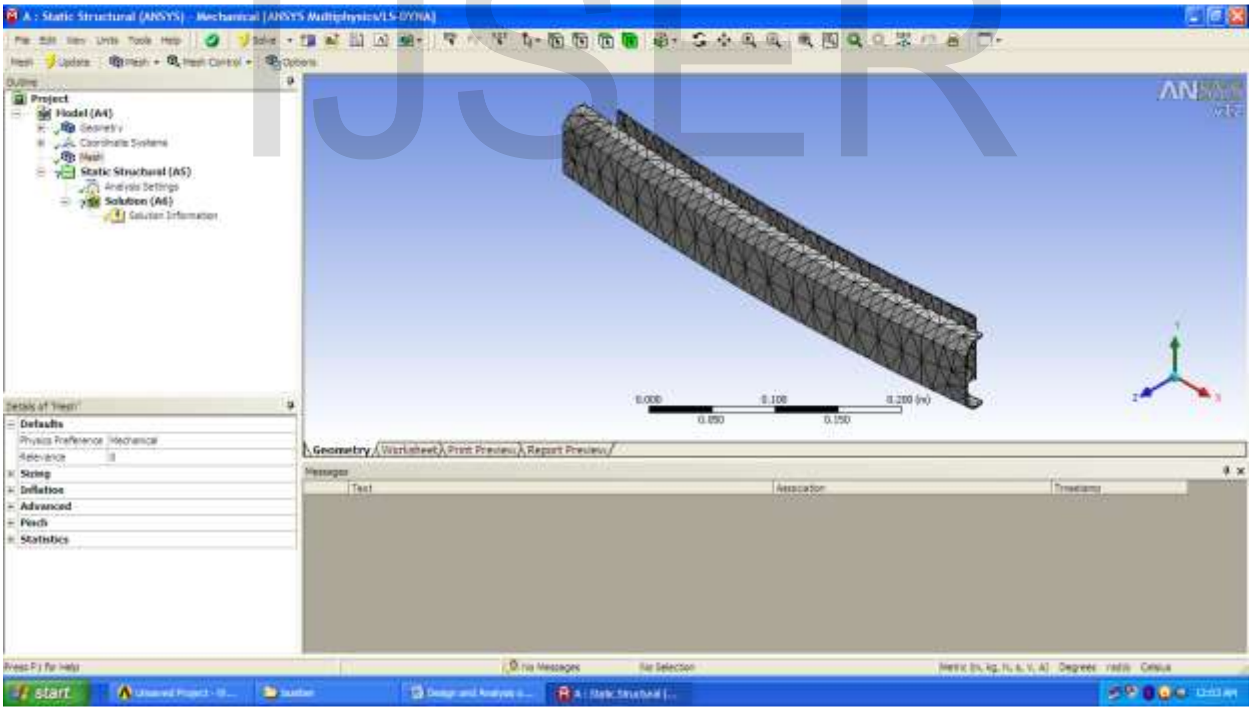


Fig 11 full model of bumper



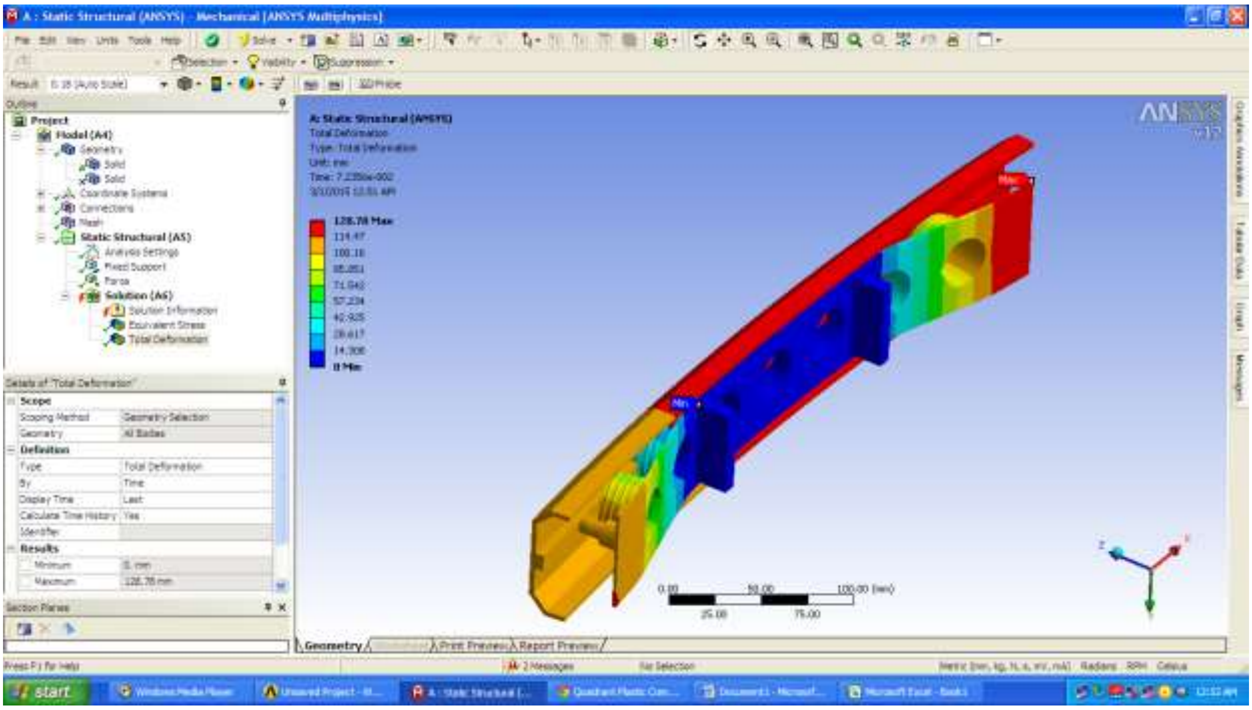
Details of Import1	
Import	Import1
Source	C:\Documents and...\[illegible]
Base Plane	XYPlane
Operation	Add Material
Process Solid Bodies	Yes
Process Surface Bodies	Yes
Process Line Bodies	No
Simplify Geometry?	No
Simplify Topology?	No
Tolerance	Normal

Fig 12 of igs file imported



Details of "Mesh"	
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Inflation	
Advanced	
Pinch	
Statistics	

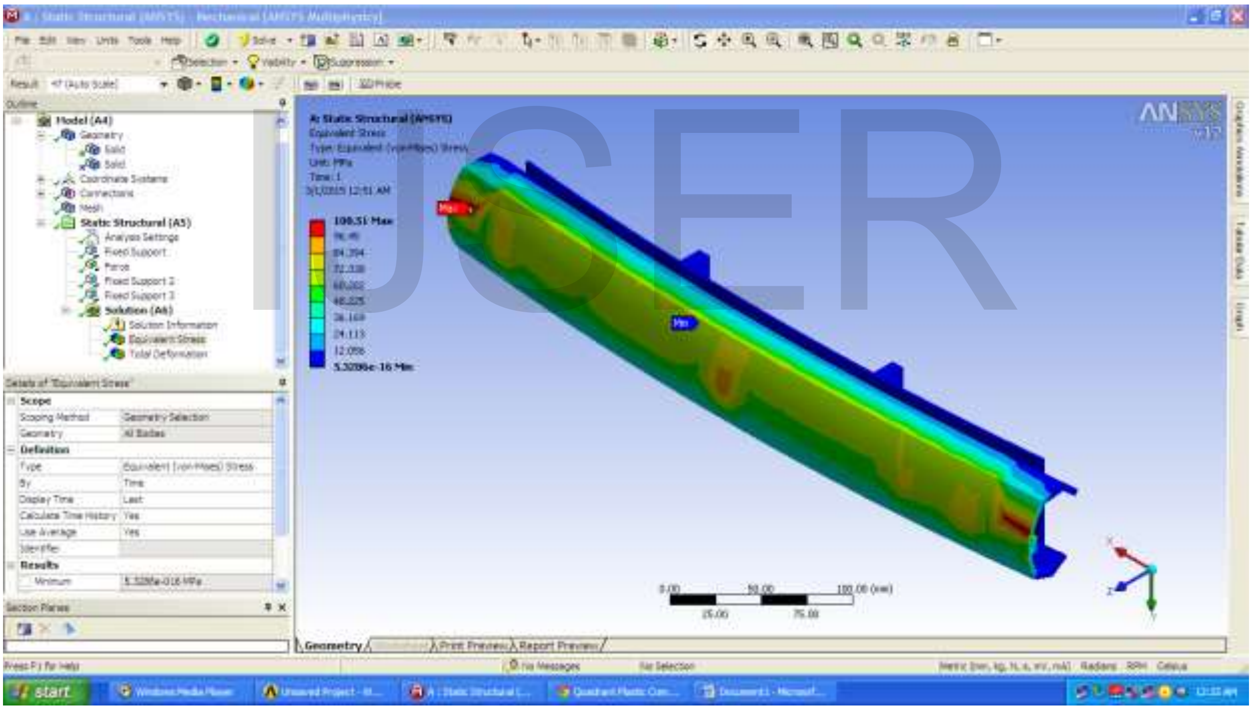
Fig 13 of mesh model (FEA)



Details of "Total Deformation"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Results	
Minimum	0. mm
Maximum	128.78 mm

Fig 14 of deformation on impact load



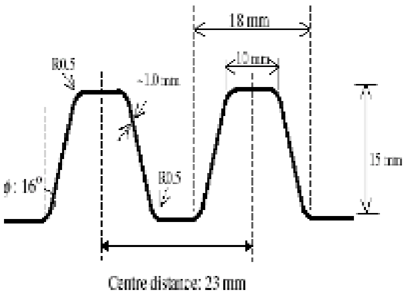
Details of "Equivalent Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) Stress
By	Time
Display Time	Last
Calculate Time History	Yes
Use Average	Yes
Identifier	
Results	
Minimum	5.3208e-016 MPa

Fig 15 of stress value with in yield stress limit

VI.DESIGN ANALYSIS

The results of some investigations identified that the grid-domed cellular structure possesses the highest specific energy absorbing capacity among so many cell configurations (including circular and square tubular knitted, multi-layer 3D woven, non-woven spun spooned and grid-domed cells) under both quasi-static compression and impact conditions. In addition, other geometrical factors on these flat-tapped cellular composites that govern the energy absorbing capacity, including cell height, diameter ratio of cell-top to cell-bottom, projected wall area, cell density and component content have also been optimized Fig. 5 shows a cross section of this cellular structure.



In this research an impact test has simulated so, the GMT with 30% V.F. with similar dimensions as usual car dampers has used for the first try of design and analysis. In accordance with the standard of straight frontal impact test, the mass of imp actor must be equal to net car mass. So, initial kinetic energy of the imp actor (as a result of its initial velocity) could be derived as in eq(1):

$$\mathrm{KE} = \frac{1}{2} MV^2 = \frac{1}{2} \times 850 \times \left(\frac{4}{3.6}\right)^2 = 524.69J \qquad (1)$$

The objective of the spring design is to completely absorb the above (1) kinetic energy as the cover reaches the conics and its edges are opened and the springs are in maximum extension length. In other words, the total impact energy should be used for cover change from stage 1 to stage 2 which also cause the springs to extend simultaneously.

VII.SPRING DEFLECTION

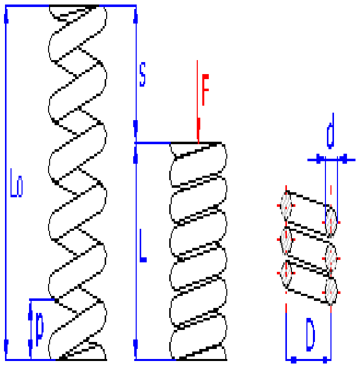


FIG 16

$S= (8.F.n.D^3)/ (G.d^4)$

$S=(8*59027*40^3)/(15200*10^4)$

S=198mm

c ... spring index (c=D/d; c=D/b) [-]

b ... wire width [mm, in]

d ... wire diameter [mm, in]

D ... mean spring diameter [mm, in]

F ... loading of spring [N, lb]

G ... modulus of elasticity in shear [Mpa, psi]

h ... wire height [mm, in]

k ... spring constant [N/mm, lb/in]

K_s ... curvature correction factor [-]

L_0 ... free spring length [mm, in]

L_S ... solid length [mm, in]

n ... number of active coils [-]

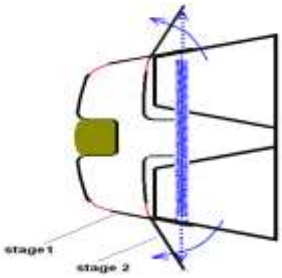
p ... pitch between coils [mm, in]

s ... spring deflection [mm, in]

NOTE: MEAN DIA =40 mm

PITCH =10 mm FREE LENGTH = 200 mm

FIG 17



In the case which there are no springs, thus there isn't any resistance forces on the cover edges, the simulation shows that in changing from stage 1 to stage 2, the vertical displacement of the cover edges are more than 6 cm. in this case, stresses are negligible, except in a small area between the cover edge and the middle part of the cover (i.e. elastic hinges) and all deformations are completely elastic, so absorbed energy is negligible too.Related to the stages 1 & 2 and numbers of conics, prescribed parameters are: δ (springs displacement) and ns (number of springs in the system) which are held between conics. That when impactor reaches the conics, displacement in X direction increases with a low rate i.e. the bumper reaches its maximum deformation. Since all deformations are in elastic range, the bumper parts back to the initial states, gradually. In order to observe the stress wave distribution in the bumper, two paths were defined in the vertical and horizontal directions on the cover as shown in Fig.17

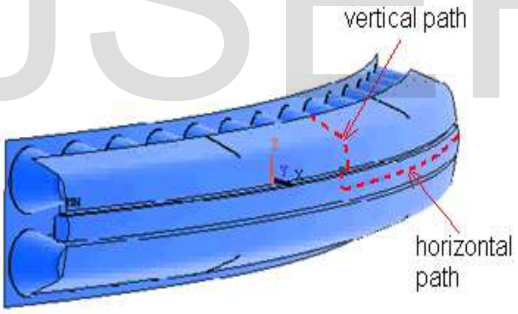
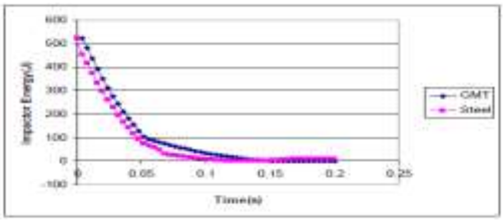


FIG 18 Paths on the cover, vertical and horizontal

The maximum stress distribution occurs at t=0.052 s which correspond with the time that cover reaches to the conics. On vertical path, the stresses are a combination of compression in longitudinal & lateral directions and tension in lateral direction. Maximum Von Mises stress occurs at location 4 since the elements are under compression on the contacting surface with the imp actor and under tension on the lateral direction. The next extremes are for points 2 and 6 because of stress concentration due to relative sharp corner and implemented notch (hinge) respectively. Points 7, 8 & 9 are those on the cover edge after the hinge and hence yielding Von Mises stresses of nearly zero. In horizontal path, stresses are more tension than compression and also stress wave fluctuate and decreases along the path from the center of the bumper to each side. Safety factor can be derived with the aid of maximum Von Mises stress and GMT yield strength. By utilizing this concept, the safety factor in vertical path has shown in Fig.. Minimum value occurs at point 4 and is about 1.5 that is generally satisfactory.If this bumper was made by steal instead of GMT with yield strength of 230 Mpa, then to achieve the same safety factor (i.e. to have the same strength for the bumper structure), generally all the thicknesses should be decreased by a reduction factor of 0.34 (The inverse of yield strength of steel divided by GMT). Fig. 18 shows that for equal safety factor steel bumper has a bit better energy absorption capacity rather than GMT, although by comparing steel & GMT density and implementing thicknesses a weight reduction of about ½ is achieved that is satisfactory for using GMT instead of steel.



FABRICATION MODEL

FIG 19 hydraulic cylinder

FIG 20 back plate and spring

FIG 21 FULL MODEL BUMPER

The innovative Toyota front coil bumper is fabricated with estimated cost. The full model of coil bumper is checked with parts wise. And the working action is tested using hand action.

VIII.CONCLUSION

There are many effective factors in selection of a bumper system. The most important one is its ability to absorb impact energy especially in high speed crashes according to legal standards. Weight, manufacturability and price have secondary importance. Although the bumpers are designed for low speed impacts, in high speed crashes, bumper is the first part for energy absorption and also replacement. The GMT offers more suitable material at lower cost and easier Production process in comparison with conventional metals. Also, it can form large and complex parts with appropriate dimensional stability in a short shaping cycling. A commercial short-fiber composite bumper made of GMT material with a mechanical spring mechanism (as energy absorber mechanism) is designed under frontal impact test according to American bumper standard. It is revealed that by utilizing this mechanical energy absorber the bumper is able to convert about 80% of the kinetic impact energy to spring potential energy and release it to the environment in the low impact velocity. The residual kinetic energy will be damped with infinitesimal elastic deformation of bumper elements. So, the passengers will not sense any impact. Finally, steel bumper (as a conventional material) was compared with the GMT and the results showed inappropriate weight increase of about two times of the GMT bumper with the same safety factors. However in high speed crashes, GMT conical part of the bumper was desired to absorb the kinetic energy of the impact or as much as possible, the authors believe more practical tests and simulations should be carried out to verify the advantages and stability of the proposed structure.

IX.REFERENCE

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