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Design and Analysis of Advanced Side Impact Protection System for T-Knock Collision

Suvodip Das

***Abstract*— The survey of the road accidents depicts that around 30-40% of the deaths during crash occurs in case of T-Knock collisions. The number of crumple zones in the side panels of the car is comparatively lower than that of front of the vehicle. In case of side impact collision there is no such facility to absorb the shock hence the probability of transmission of the impact in the passenger compartment is higher. Hence introduction of a Visco-Elastic solid material called Sorbothane is fabricated with the side door panel to enhance the safety of the occupants during collision. Evaluation of the effectiveness of the system is carried out using analytic solution and FEA simulation. Results obtained by both of the methods are studied and compared in the existing and proposed method.**

***Index Terms*- T-Knock collisions, Visco-Elastic solid, FEA**

I. INTRODUCTION

A car crash can led into the fatal injuries or even death to the occupants. A vehicle crash in traffics can be classified into two types:

A. *HEAD-ON COLLISION*

In Head-on collision, the vehicle hits the incoming vehicle so that the front end of both the vehicle undergoes the crash. In such cases the impact of the crash is absorbed by the crumple zones present on the front of the struck vehicle. The vehicle will come to rest after loosing its momentum in form of impact. These crumple zones includes airbags, collapsible steering e.t.c. which tends to absorb the impact and restrict it to reach the occupant cell. Fig (a)

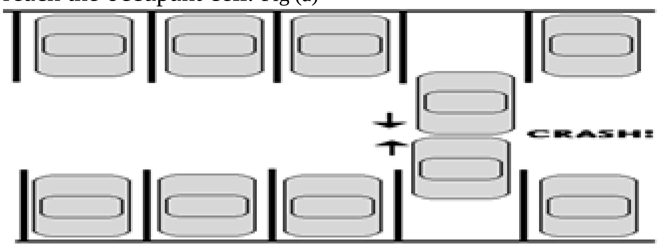
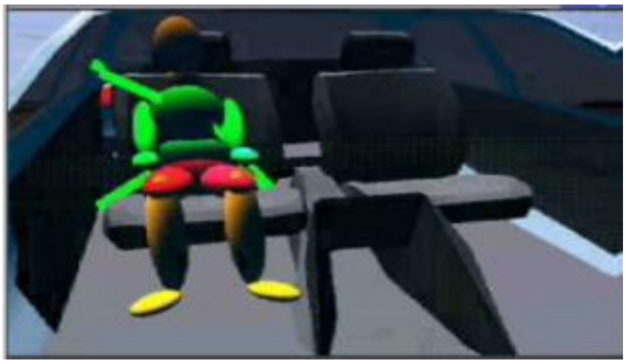


Fig (a)

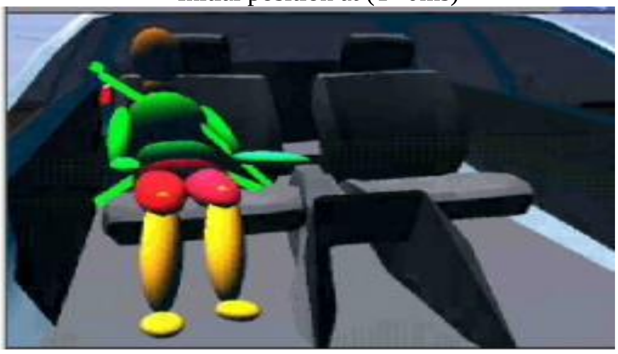
B. *SIDE CRASH or T-KNOCK CRASH*

In this type of collision, a vehicle is struck by another vehicle perpendicularly or at an offset angle to the side door panels. This type of road accidents where there is multiple divisions of roads, hit stationary objects like poles, tress e.t.c. In this case the strike vehicle contributes a greater momentum on the struck vehicle. Since the impact space in the side is considerably less than compared to the front and hence it may cause fatal injuries such as head trauma, brain hemorrhage as well as even it may lead to death.

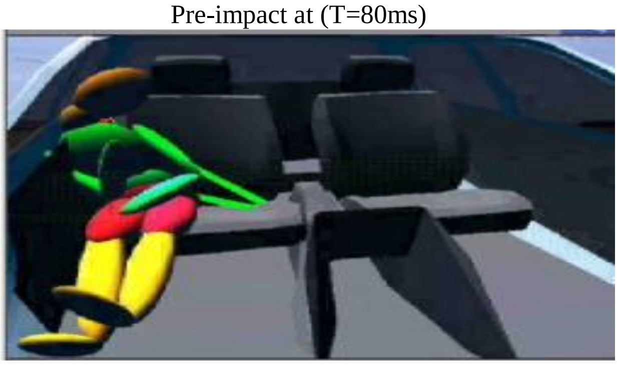
The following figures depict the movement of a driver during a T-Knock collision. Fig (b)



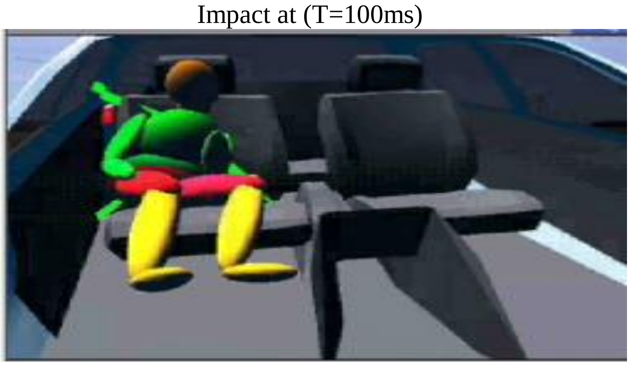
Initial position at (T=0ms)



Pre-impact at (T=80ms)



Impact at (T=100ms)



Post-Impact at (T=120 ms)

LITERATURE SURVEY

Indian survey of accidents depicts that around 30-40%of the vehicle accidents deaths occurs as T-Knock collisions. The survey depicts that around 65% of the occupants in the sample were killed in near side impact compared to 35% killed in far side impact. Fig (c)

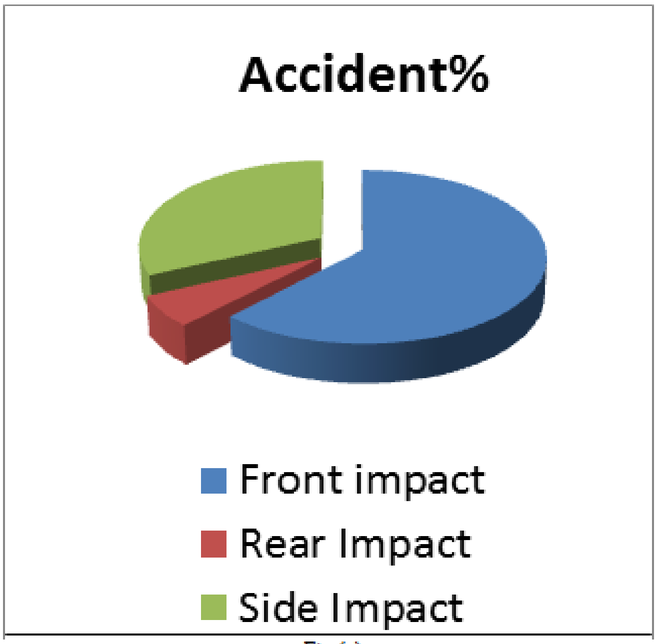


Fig (c)

Fig (d) shows the distribution of the impacting object directional angle α with the side of the impacting car. Most of the cases were classified as pure side impacts where the directional impact angle was around 90 deg.

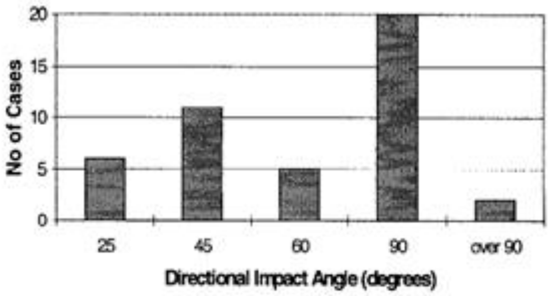


Fig (d)

Fig (e) shows the cumulative distribution of the maximum cabin intrusion for all cases in the far side injury sample. It is being seen that intrusion exceeds 400 mm in around half of the cases. In around 20 % of the case, the maximum intrusion exceeds 625 mm which is equivalent to half of the cabin width of a typically small car.

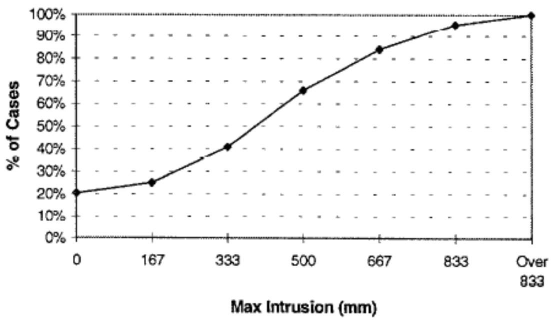


Fig (e)

II. MATERIALS & METHODOLOGY

MATERIALS

Car body panels are made up of pressed sheet metal. The existing material as per the survey doesn't provide sufficient intrusion resistance upon impact.

PROPOSED METHOD

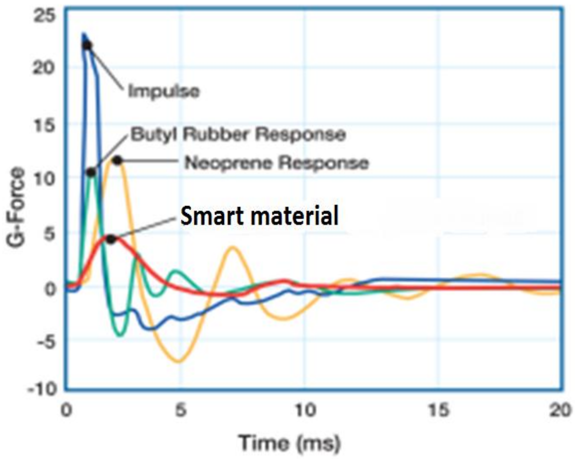
Introducing a smart material between the door panels that will tend to absorb the shocks imparted by the strike vehicle to the struck vehicle on its door panels during a T-Knock collision

Smart Material Name-Sorbothane
Composition-Polyol & Isocyanite
Load rating-18000 kg/pad
Tear Strength-29.

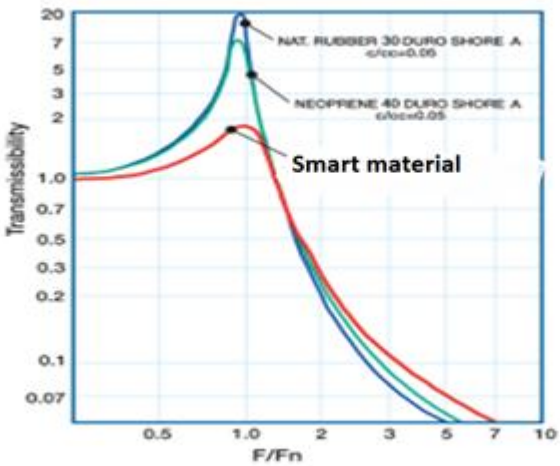
CHARACTERISTICS OF SORBOTHANE

- It's a Non-Newtonian material and mechanical energy is 'lost' by conversion to heat. The response to a load is highly dependent on the rate of force application.
- The most effective static deflection with a shape factor between 0.3 and 1 is in the range of 10-20%
- It has a superior damping coefficient with an efficient shock absorbing characteristics over millions of cycles.

CHARACTERISTICS CURVE OF SORBOTHANE



Time Delay Effect of Impulse (Shock) Response of Selected Materials



Transmissibility range of Sorbothane

MATERIAL TESTING

A car door sample has been bought from which the car door sample has been taken out from the maximum cross-section area. Fig (f) & Fig (g)

Fig (f)

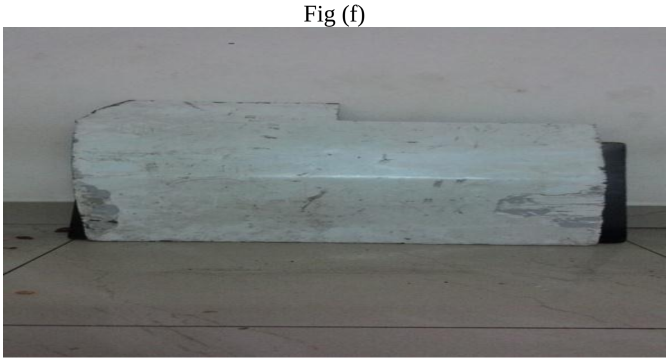


Fig (g)

The car door sample has been tested with the existing and the proposed method and the comparison is concluded below:

PROPERTY	EXISTING	PROPOSED
Density	9.1 g/cc	1.311 g/cc
Tensile Strength	253.52 N/mm^2	285.36 N/mm^2
Bend test	No Crack found	Crack found after 5 mins
Elongation	20.34 %	220%
Impact Test	8.1 J	9.3 J
Crushing test	38 kgf	58 kgf

The above analytic comparison shows how much improved crashworthiness is providing with the proposed method than with the existing method:

THEORITICAL CALCULATION:

- **Force Imparted by the strike vehicle on the struck vehicle.**

T_f=Traction at Front wheels
T_r=Traction at Rear wheels
Ra=Aerodynamic Resistance
R_r=Rolling Resistance
T_f=(Te*ηt*G)/r
Radius of tire=r=0.1905m
Engine Torque=Te=127 N-m
Transmission efficiency=ηt=95%=0.95
Overall gear ratio at 2^{nd} gear=G=8.02
Tf = (127*0.95*8.0255)/0.1905=**5079.3333 N**
Aerodynamic Resistance
Ra=(1/2)ϱ*A*(V^2)*Cd*Density of Air =1.225 kg/m^3
Coefficient of Drag* Area (C_d*A)=0.682 m^2
Velocity of Vehicle (V)=13.889 m/sec^2
Aerodynamic Resistance
Ra=(1/2)*1.225*0.682*(13.889^2) =**80.58.09 N**

Rolling resistance=R_r=ɰ*W [ɰ=rolling coefficient]
=0.015*1190
=**175.1085 N**
Grade resistance=Rg=0(slope =0)
Force Imparted
T_f-(R_a+R_r)= 5079.3333-(80.5809+175.1085)
= **4818.6419 N**

SPEED (kmph)	50	60	70	90
TRACTIVE FORCE (N)	4819	4819	4819	4819
AERODYNAMIC RESISTANCE (N)	80.58	116	158	261
ROLLING RESISTANCE (N)	175.1	175.1	175.1	175.1
FORCE IMPARTED (N)	4723	4759	4801	4904

- **DEFLECTION PRODUCED FOR THE GIVEN LOAD**

The door is a **Fixed** beam since its constrained on all the four side during impact
Deflection of the Fixed beam upon Point Load (Y_{max}) = (WL^3/192EI)
Load (W) = 4818.6419 N
Length of the beam (L) =1.11125 m
Elasticity (E) =2*(10^5) N/mm^2
Moment of Inertia (I) = [bh^3/3]+ [bh^3/12] =205.438(mm^4)
Using Deflection Formulae = Y_{max} = 4818.6419*(1111.25^3)/192*2*10^5*205.438
= 853.15 mm

METHODOLOGY

In this work modeling and analysis has been carried out on two different methods i.e. the existing method and proposed method.

Dimension and specification of the Car door:

Dimensions are as per the specification of the given Honda city 3rd Gen model.

Material Property

For proposed method:
Elastic Modulus=1399633.20 N/m^2
Poison ratio=0.5
Shear Modulus=473462.13 N/m^2
Density=1.311 g/cc
Tensile Strength=860000 N/m^2
Thermal Conductivity=0.380 W/(m-k)
Damping ratio= 0.344@2.34 Hz

Modeling of Car door and Car bumper

A car door and bumper is designed using Solidworks as per the dimension specifications and analyzed by ANSYS ver. 14
In this, the door will be subjected to various bumper load to optimum stresses and to get the best results among the two methods The solid model of car door and car bumper is shown below. Fig (h) &Fig (i)

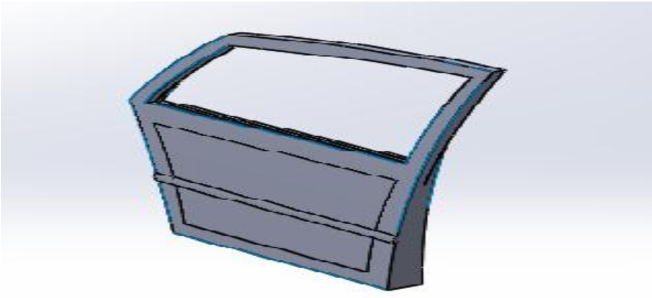


Fig-(h)

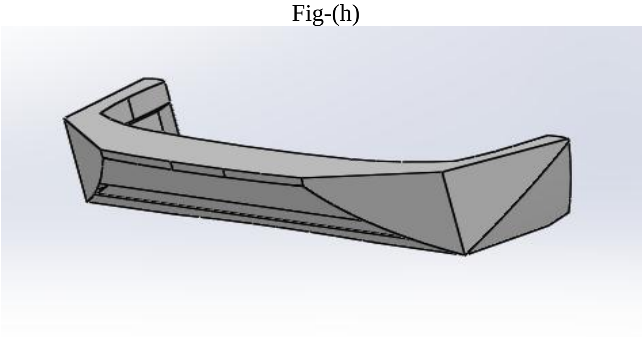


Fig-(i)

Analysis of the Assembled Car door and bumper

An assembled model of the car door and the bumper is being created using Solidworks software. Then the assembled model is imported to ANSYS workbench using IGES format. Fig (j)

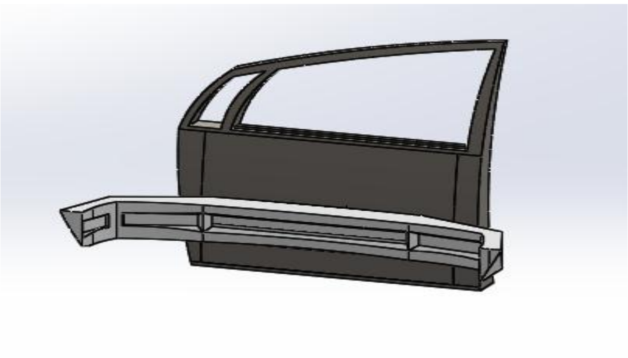


Fig-(j)

The mesh is generated to contain the material and structural properties which defines how the structure will react to certain loading conditions Fig (k). Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. The model includes the static analysis with two different methods to obtain the best results.

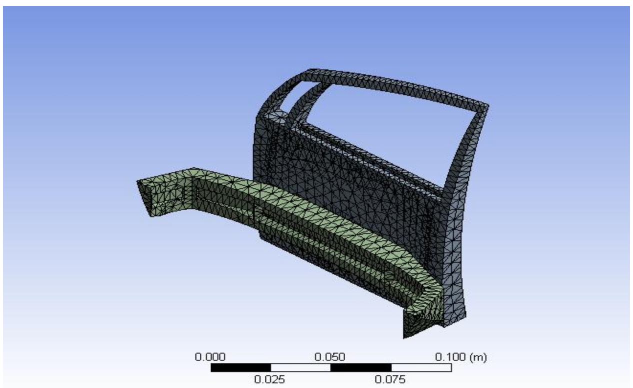
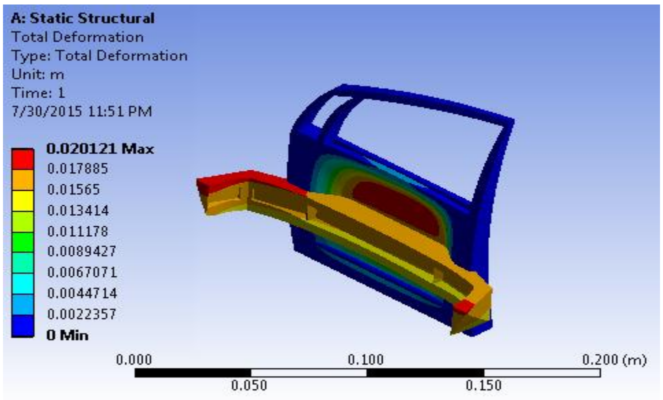


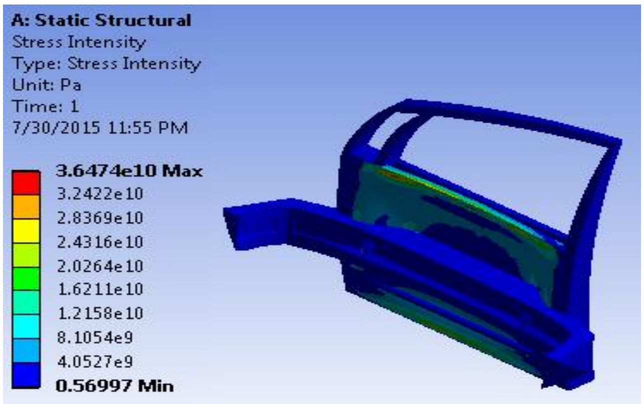
Fig-(j)

The static analysis is carried out on onto two different methods and loading boundary conditions as mentioned. The total deformation, Stress Intensity, Elastic Strain Intensity, Strain Energy and Damage.

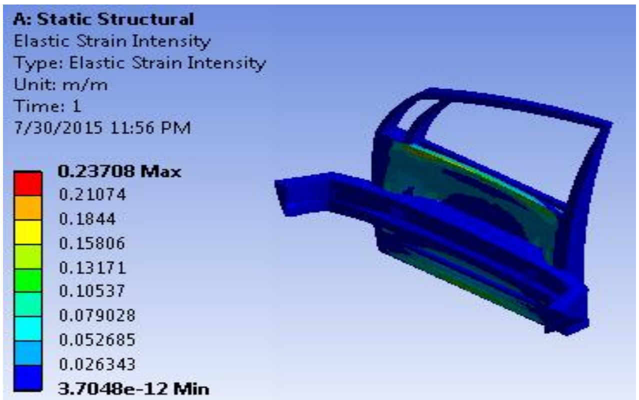
III. ANALYSIS OF EXISTING MODEL



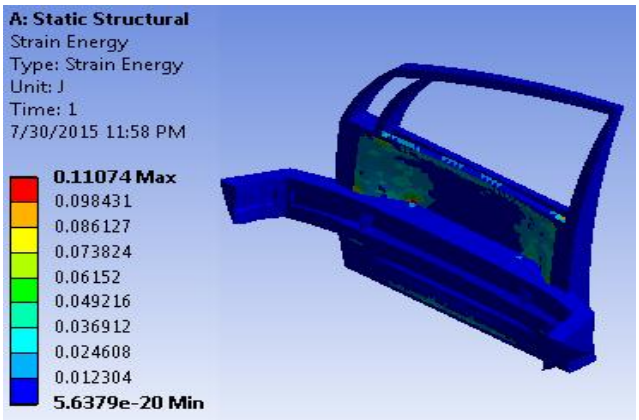
TOTAL DEFORMATION



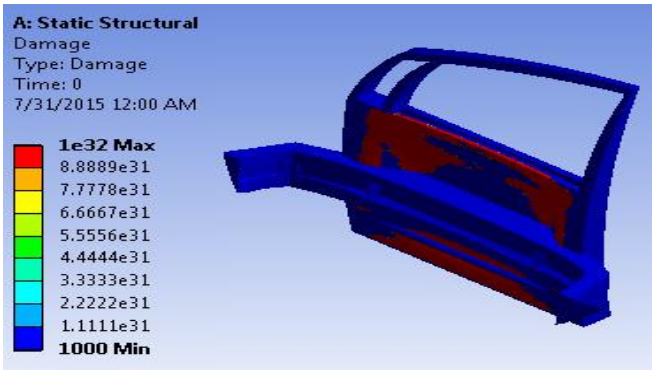
STRESS INTENSITY



ELASTIC STRAIN INTENSITY



STRAIN ENERGY

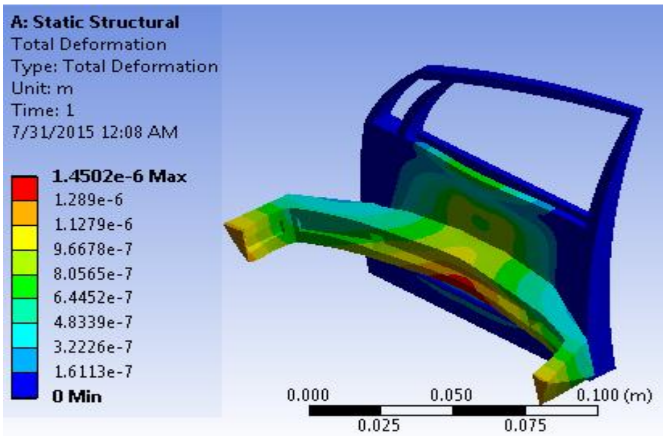


DAMAGE

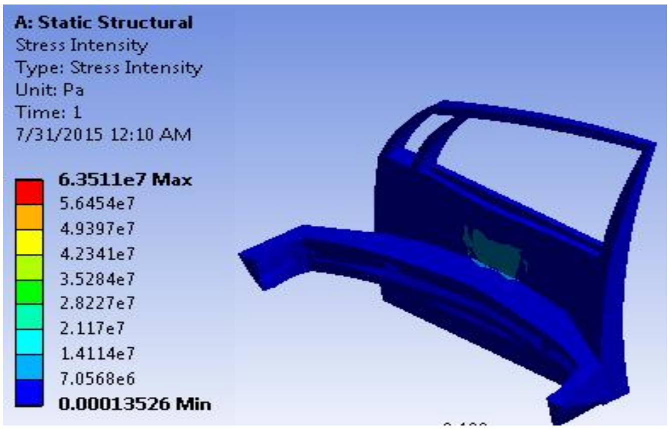
Now the proposed method is analyzed using ANSYS and the test results are being compared between the two methods :

In this proposed method a smart material of negligible thickness is inserted between the door panels.

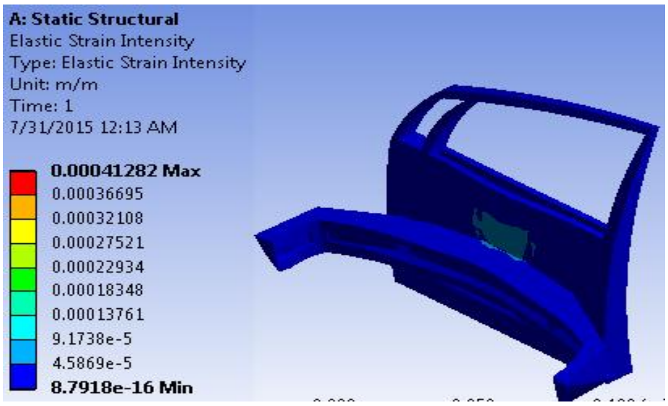
ANALYSIS OF PROPOSED MODEL



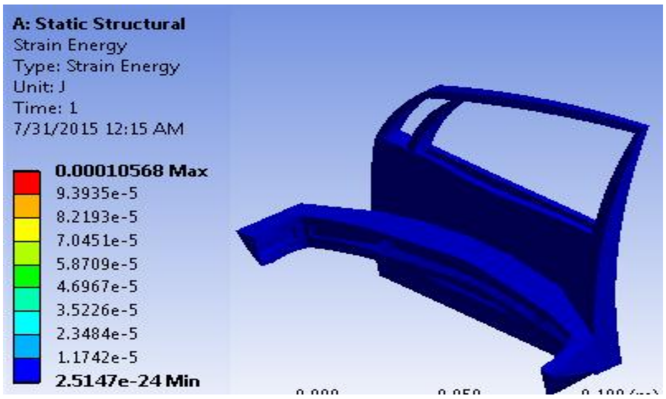
TOTAL DEFORMATION



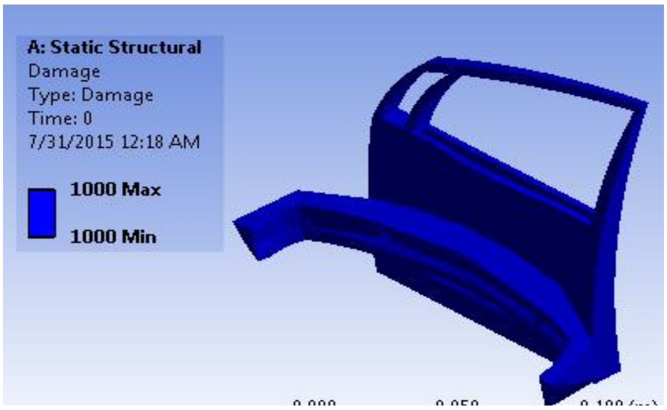
STRESS INTENSITY



ELASTIC STRAIN INTENSITY



STRAIN ENERGY



DAMAGE

IV. RESULTS AND DISCUSSION

The static analysis of Car door and bumper is carried out in ANSYS with two different methods i.e. Existing method and Proposed method. Hence the results analyzed are Total deformation presented in Table 3, Stress intensity, Elastic Strain Intensity, Strain Energy are shown in respectable table 4, 5 and 6.

	PROPOSED METHOD	EXISTING METHOD
TOTAL	1.15E-06 m	0.0159 m
DEFORMATION	1.27E-07 m	0.0017 m

TABLE 3

	PROPOSED METHOD	EXISTING METHOD
STRESS	5.04E+07 Pa	2.89E+10 Pa
INTENSITY	0.0001 Pa	0.4508 Pa

TABLE 4

	PROPOSED METHOD	EXISTING
ELASTIC STRAIN INTENSITY	0.0003	0.18819
	6.66E-16	0.0209

TABLE 5

	PROPOSED METHOD	EXISTING
STRAIN	6.65E-05 J	0.0698 J
ENERGY	1.42E-24 J	3.9 E-20 J

Maximum Value   Minimum Value

To improve the crashworthiness we need to reduce the intrusion level to a maximum extent and from the above tabular column the max. Total deformation caused with the smart material is much lower than compared to the minimum value in existing method. So this proves that our project is successful. The simulation was carried out for two methods in ANSYS and compared in which our proposed method shows reduced stress strain value.

V. CONCLUSION

The present work of optimum design and analysis of a car door and bumper for motor vehicle subjected to static analysis of car door panels. The analysis shows the stress and strain response of car door panel when subjected to a a given load and it also enhances the crashworthiness against T-knock collision of vehicles. The following observations are drawn from the analysis results:-

i) The maximum intrusion induced for a given load
   Existing Method= 0.0159 m
   Proposed Method=1.15E-06 m
ii) The stress intensity induced for a given load
   Existing Method=2.89E+10 Pa
   Proposed Method=5.04E+07 Pa
iii) The Elastic Strain Intensity induced for a given load
   Existing Method=0.18819
   Proposed Method=0.0003
iv) The Strain Energy induced for a given load
   Existing Method= 0.0698 J
   Proposed Method= 6.65E-05 J

Based on the modeling and analysis, we can conclude that our proposed method provides better against T-knock collision than compared to Existing method which are used in motor vehicles.

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