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Design of Highly Efficient Energy Absorber in Side Impact Crash

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ABSTRACT

Side impact crashes are one of the most severe accidents and account for roughly 30% of all fatalities in road accidents involving passenger cars and light trucks. For this reason, in many countries legislation has been put into place with minimum requirements for injury parameters in side impact crash tests. The padding is usually applied in the pelvic, the abdomen and the thorax area. The amount of absorption versus push load is important to obtain acceptable levels of the injury parameters as stipulated by legislation. This enables designers of passive safety systems not only to save space, weight and cost but also increase safety ratings. In this paper the foam as a energy absorber having different densities, location in the door panel, foam shapes, will be studied for high energy absorption with on field observations.

Keywords- **Energy absorber , Padding, Passive safety, Side impact crashes.**

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I. INTRODUCTION

Global accident statistics show that side impacts accounts for approximately 30 % of all impacts and 35 % of the total fatalities according to GIDAS, NASS. It is essential for the vehicle manufacturers to provide adequate protection in order to minimize the potential negative effects of such impacts on the Occupants. The art of side impact protection is about ensuring that the intruding velocities are kept to a minimum through a suitable vehicle structure and deploying an appropriate restraint system to dampen the effect of the intruding structure, thus reducing the effect of the impact on the occupants.

Energy absorbing foam padding is widely applied in various areas of modern cars in conjunction with increasing number for the purpose of passive safety systems. High efficient energy absorbing foams which can be used to optimize energy absorption or minimize packaging space are particularly popular. Foam padding is applied in doors for pelvis and thorax protection, behind headliners for head impact protection, in knee bolsters and under steering columns for knee impact protection, in the foot well area for ankle protection and in bumpers to meet competing pedestrian requirements.

The main difficulty in designing for side impact collisions is the limited crumple zone between the impacting vehicle and the impacted occupant. The main objective for introducing the side impact structural system is to maximize energy absorption and minimize injury to the occupant. A proper control of padding stiffness is very important especially for abdomen & Pelvis protection. Many investigations of real world accidents have established that in side crashes of passenger cars, injuries of occupants are mostly caused by impact against the interior side of the vehicle, primarily the door and other intruding side structures. One of the countermeasures that greatly improve the energy dissipation in the car interior is the addition of the energy absorbing padding material in the door area. There is a need to increase performance of existing materials which are in use as passive safety for absorbing shock in side crash for occupant protection. Challenge is to suggest a suitable material which is easily available and can be used easily in serial production. There are various materials can be used for application in side impact but in that polymeric materials such as foam is mostly used. This foam will be located inside the door panel for securing pelvis area of human body as shown in fig 1.

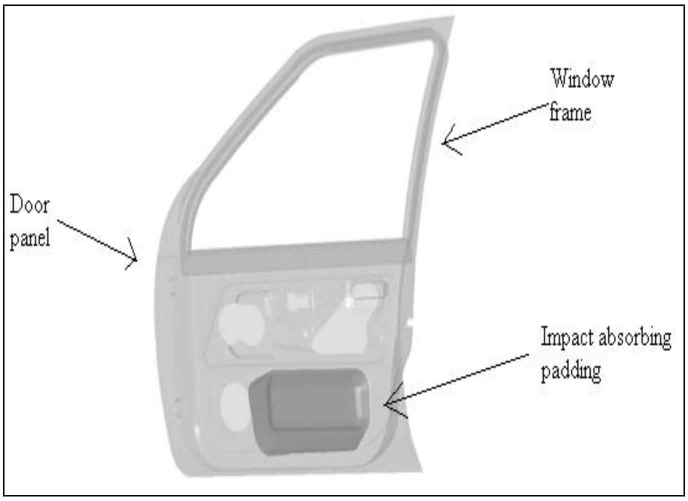

Fig. 1 Inclusion and position of the protection padding

I. LITERATURE SURVEY

Amin in his thesis given focus on mechanical behaviour of cellular structures using finite element study**.** Cellular solids, such as foams are widely used in engineering applications. The strength of foam can be adjusted over a wide range by controlling its relative density.Furthermore, foams can undergo large compressive strains at almost constant stress, so that large amount of energy can be absorbed without generating high stresses. [12]

In dow automotive Report, focus is given on IMPAXX foam. IMPAXX EA foams are made from a highly engineered, styrene thermoplastic and additive package. The extrusion process was developed and optimized to produce foams having certain anisotropic physical properties which maximize energy absorption. Within LS-DYNA , material type Key word MAT57 (*MAT_LOW_DENSITY_FOAM) was utilized to represent performance of IMPAXX EA foams. This material type was designed for modeling highly compressible low density foams. Its main applications are for seat cushions and padding on Side Impact Dummies (SID). This material model has demonstrated that with appropriate variable settings, it is a robust, appropriate means of representing behavior of IMPAXX EA foams. [2]

Brian et al. have given focus on selecting material models for the simulation of foams in LS-DYNA. For Experimental work, they have studied three foams with an objective to observe a foam behavior. They have used key word MAT_LOW_DENSITY_FOAM (MAT57) material model. In its simple form, the model incorporates only one loading curve, but it can be augmented to handle loading as well as unloading behavior. The EPP foam is neither crushable nor totally recoverable. Neither MAT_CRUSHABLE_FOAM (MAT63) nor MAT57 are logical choices; MAT83 proves to be reasonable choice. Finally in conclusion the MAT 83 Model is best suited in all conditions. [10]

Veronika Effinger et.al nonlinear viscoelastic material model for foams is developed and implemented as a user material subroutine in LS-DYNA. The material response consists of equilibrium and a non-equilibrium part. The first one is modeled with a hyper elastic formulation based on the work of Chang and formerly implemented key word as *MAT_FU_CHANG_FOAM in LS-DYNA (*MAT_083). The second one includes the nonlinear viscoelastic behavior following the multiple integral theory by Green and Rivlin . The polyurethane foam Confor® CF-45 used as part of the leg form impactor in pedestrian safety was chosen for its highly nonlinear viscoelastic properties to test the presented approach. The investigation shows the ability of the method to reliably simulate some important nonlinear viscoelastic phenomena such as saturation. [8]

Milrcdlo Di Leo et al. have shown methods to design and optimized vehicle side structure and padding to improve side impact protection. A good structural behavior is necessary but not sufficient to perform good results in side impact. A proper control of padding stiffness is very important especially for abdomen protection. Author Discussed a method to evaluate the stiffness of padding at thorax level is proposed. A similar method is used to determine failure load of armrest for abdomen protection. An analytical study supported by experimental Evidences and by laboratory tests demonstrated that the main parameters which influence bio-mechanical performance in side-impacts are upper door velocity against thorax. An experiment methodology for characterization of trim stiffness has been proposed by the authors. [13]

Mariana Paulino et al .The author have evaluated efficiency of passive safety mechanism. Crash tests were performed using finite element analysis software LS-Dyna™. Rigid polyurethane foam, IMPAXX™, micro-agglomerated cork and aluminum foam padding’s were tested and their performance. As energy absorbers was confronted with the results with no padding. The results obtained show that the implementation of a foam like material a cellular material as a padding for energy dissipation in lateral doors can, in fact, lead to considerable improvements, mainly in terms of maximum values of deceleration (the direct consequence leading to injury levels) and loads transmitted to the occupants of the vehicle. Furthermore authors have mentioned that, in terms of energy absorbed by the vehicle’s global structure, polyurethane foam was the material exhibiting the best behavior. The inclusion of this padding, as well as micro-agglomerated cork padding, resulted in improvements of approximately 13%. [14]

V.P.W.Shim et al. Made study on characterization and component level correlation of energy absorbing polyurethane foams using LS-Dyna material models. For accurate prediction of the head injury parameters, studies were conducted to establish a reliable LS-DYNA Material model to characterize PU foams. PU foam was characterized using four different material models available in LS-DYNA for simulating foam key word as MAT 57, MAT 63, MAT75, and MAT 83. The Finite Element Analysis results were compared with the physical test results. MAT57 and MAT83 were the two material cards that showed good correlation with physical test values. These are the two cards that are most commonly used in the industry to simulate foams. [3]

Gerhard slik et al. mentioned that energy absorbing foam padding applied as a passive safety system in automotive . For the material model validation they have done a physical test such as drop tower test for defining the material properties. In quasi static stress strain curve the observation was stress ramps up rather fast and remains constant up to

70-80% Compression. From then on the material densifies and the stress increases rapidly. Due to these behavior the material can be categorized as high efficient energy absorbing since the stress strain curve is nearly a block curve and an ideal absorber would show a square wave response. In their research they have conducted four basic tests such as Quasi static compression test, Drop tower test , impact test with pelvic shape impactor , and free motion head form test. In LS DYNA material model type 57& 63 was selected.After different simulation and testing results the stress strain curved was determine. These were further used as input for LS Dyna material models 57&63. Finally for both the material model types same results can be achieved with same level of accuracy .Both model showed good correlation with pelvic shaped impactor test. [15]

Vivek Srivastava et al**.** Automobile OEMs have found a very attractive replacement of metal in Expanded Polypropylene (EPP). EPP is now being extensively used in bumpers and passenger safety application where material is expected to experience large multi-axial deformation at high strain rates. [1]

II. METHDOLOGY IMPLEMENTED

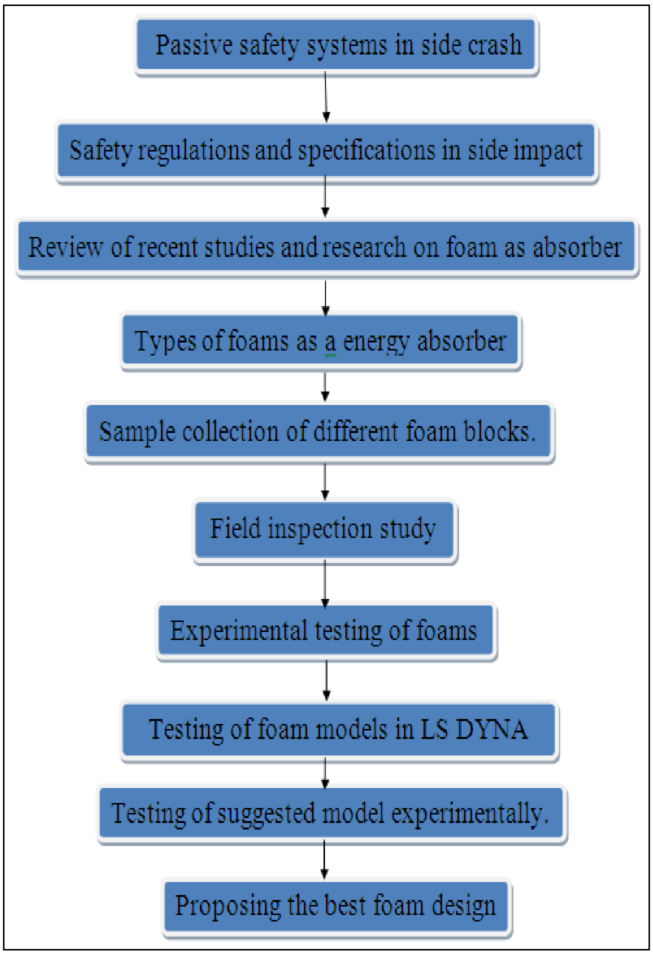

Fig. 2 flow chart for work

A) Passive safety systems in side crash .

Foams , crumple zone and crash cones are generally used as a passive safety devices in side impact crash. Foams are preferred as it easy to cut and can be located according to OEM shape and size.

B) Safety Regulations

There are several regulation applied by the different countries for occupant protection and safety in side impact crash. Following are some of the main regulations:

1. National highway traffic safety administration.

It's a executive branch of the U.S. government, part of the Department of Transportation. It describes its mission as "Save lives, prevent injuries, reduce vehicle-related crashes. It enforce federal motor vehicle safety standards 214 and licenses vehicle OEM's and importers. It also involves in development of the anthropomorphic dummies used in safety testing. NHTSA provides consumer information on vehicle performance in side impacts. The information is collected as part of NHTSA's New Car Assessment Program (NCAP).

TABLE I
NHTSA SPECIFICATINS

Parameter	Specification
Target speed	33.5 km/hr
Occupants	2 Occupants belted
Barrier type	Crabbed deformable mobile (27^{O})

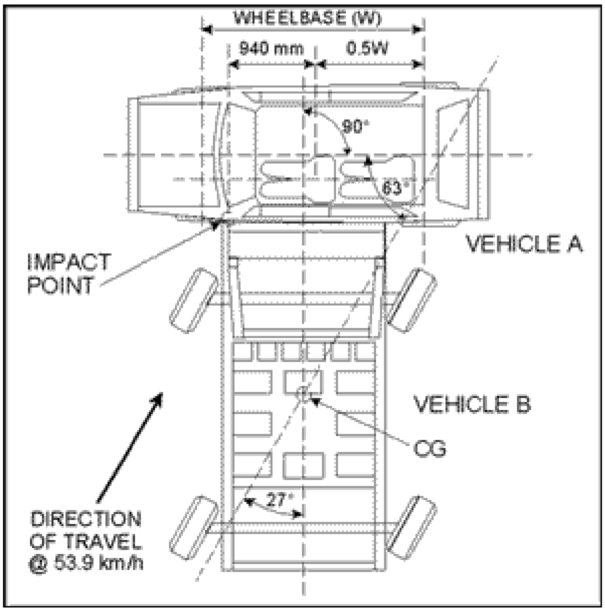

Fig.3 Test setup of NHTSA for side impact testing

2) European regulations and NCAP

The European New Car Assessment Programmed (Euro NCAP) is a European car safety performance assessment programmed based in Brussels (Belgium) and founded in 1997 by the Transport Research Laboratory for the UK Department for Transport and backed by several European governments, as well as by the European Union. The European Union approved a side impact safety regulation, EU Directive 96/27/EC, in October 1996.

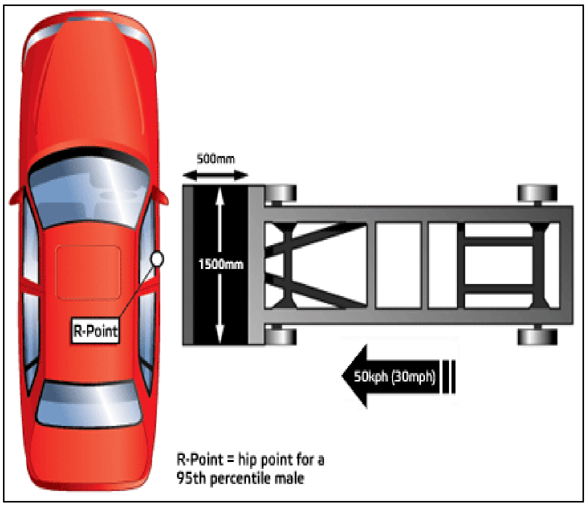

Fig.4 Test Setup of EURO NCAP for Side Impact Testing

TABLE II
EURO NCAP SPECIFICATIONS

Parameter	Specification
Target Speed	31 mph (50 Km/hr)
Occupants	1 Euro SID-1seated at the driver place
Barrier Type	Crabbed Deformable Mobile (90 ^{o})

3. Insurance institute for highway safety

IIHS is a U.S. organization funded in 1959. The MDB weighs 3,300 pounds (300 pounds more than FMVSS 214). Its front end simulates the height and other characteristics of a pickup truck or SUV. IIHS rates vehicles good, acceptable, marginal or poor .It carries out research and produces ratings for popular passenger vehicles as well as for certain consumer products such as child car booster seats.

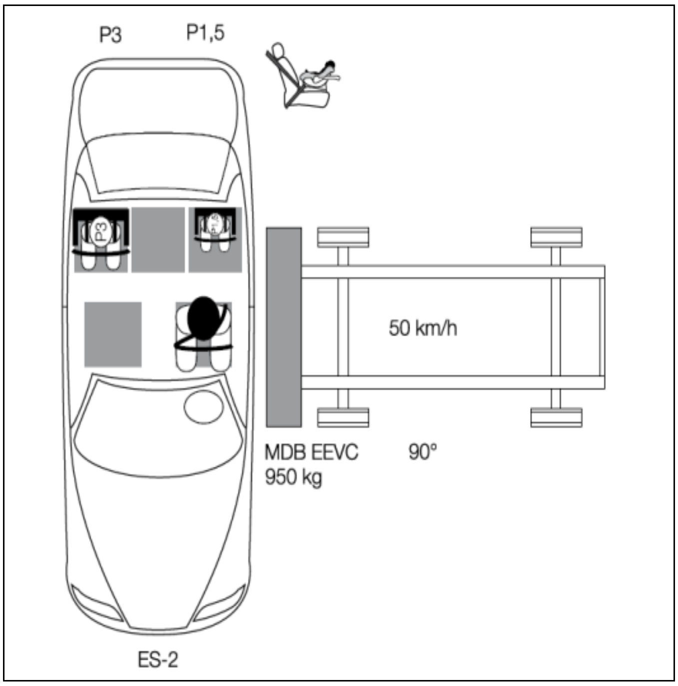

Fig.5 Test Setup of IIHS for Side Impact Testing

TABLE III
SPECIFICATIONS OF IIHS

Parameter	Specification
Target Speed	31 mph (50 Km/hr)
Occupants	1 Euro SID-1 at the driver place
Barrier Type	Crabbed Deformable Mobile (90 ^{o}) 300mm high 920-950 kg

C) Foams as a energy absorbers

Foam is defined as a substance that is formed by trapping many gas bubbles in a liquid or solid. Foams are created with two important variables the matrix material and the morphology of the gaseous phase. There are two generic morphologies open cell and closed cell. Foams are often characterized based on the percentage of open cell fraction or the closed cell fraction. Following are the different types of foams which can be used as a energy absorbers.

1. Polyurethane foam
2. Polyethylene foam
3. Expanded polystyrene foam
4. Polypropylene foam

III. EXPERIMENTAL TESTING OF FOAM

For understanding the foam material behavior it has to be tested under different conditions of loading and velocity. Following are the different test by which foam can be Characterize and its performance parameters can be found out.

A) Quasi static compression test

The simplest way to get first impression of the material behavior is by quasi-static compression. Quasi static test is used to study compression behavior at low strain rates. In these test the block samples will be compressed at constant, low velocity. The impact velocity is kept 2 to 4m/s. In these test set up foam is located between flat impactor and rigid base. From these stress strain curves for foam samples can be determined.

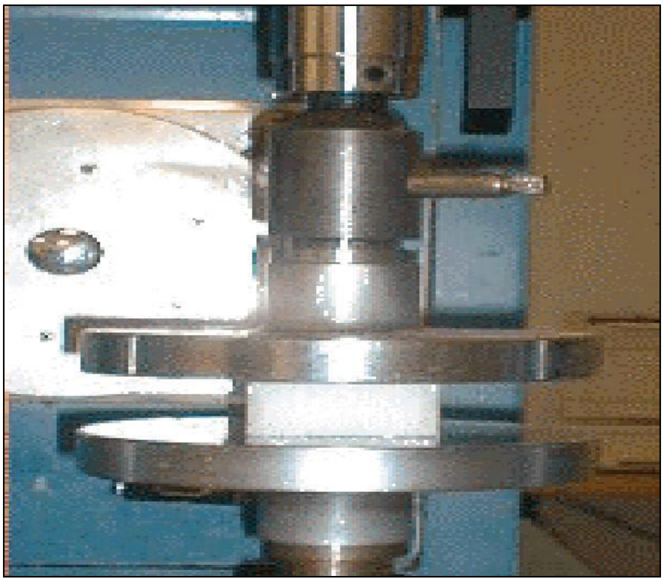

Fig. 6 Foam testing under quasi static compression testing

B) Dynamic compression testing

In these method material behavior of foam at high velocity (high strain rates) will be obtained from drop tower tests. Foam block samples will located in between impactor and rigid base .Impact mass, as well as the impactor drop height, were varied resulting in various impact velocities and impact energies. For these tests, flat impactors (discs) will be used. The velocity of impact will be kept up to 5 to 9 m/s.

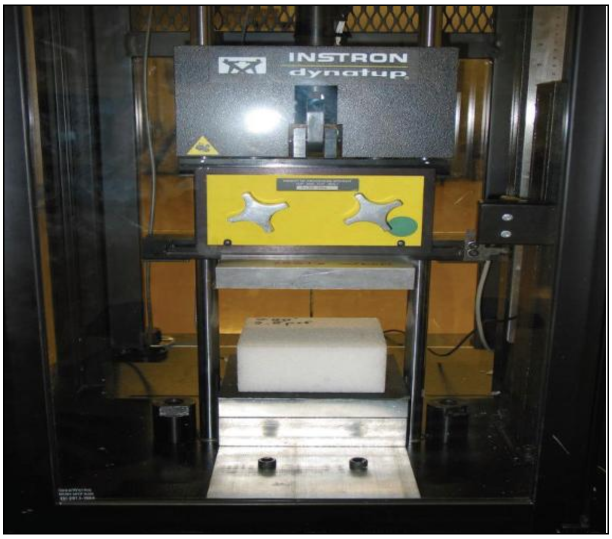

Fig. 7 Dynamic compression testing

C) Test model shapes

Following are the different test models can be used for testing purpose. But in most of the vehicles Rectangular shape blocks is used as it is easy to design and manufacture .Also material wastage is less in rectangular blocks as foam is produced in long sheets .

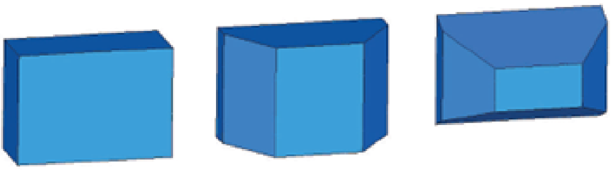

Fig.8 Different shapes of foam blocks

V. CAE TEST SET UP

Following is the block diagram of CAE test set up. As shown in figure foam will be placed on flat rigid base. Rigid impactor with the specific mass will be impacted with initial velocity to achieve the desired energy. From these deformation pattern of foam will be studied.

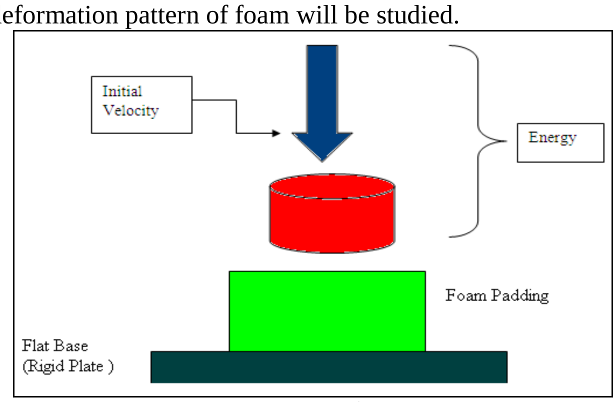

Fig. 9 Block diagram of CAE test set up

VI) FIELD INSPECTION STUDY& OBSERVATIONS

For the purpose of finding the exact position & space availability of foam in door panel field visit was done. The visited location was hyundai and toyota service centres. Through these visits lots of information was gathered such as inside structures which will be remain in contact with foam, mounting position of foam and shapes which can be probably fitted inside door panels. Fig 10,11, & 12 shows actual door panel view of different OEM vehicles .

Fig. 10 Hyundai verna door panel

Fig.11 Toyota etios side impact

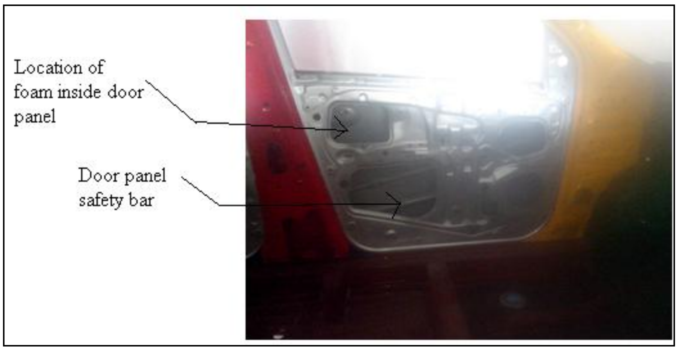

Fig.12 Inside door panel view of training vehicle for crash

Fig .13 Collected PU foam sample (30 g/l)

Fig.14 Collected PU foam sample (40 g/l)

Above Fig 13 & 14 shows the collected polyurethane foam samples having different densities from the foam manufacturer for testing purpose.

CONCLUSION

As per field inspection study and observation made from it , foam location in door panel vary according to each manufacturer and its own specifications. The dimensions, and its geometric shape also seen different according to the vehicle applications. But through observations mostly rectangular geometry of foams is preferred for the location in most of the OEM'S. Further study will be made on best possible foam design in side impact crash considering material and its specifications, cost of material, availability of material, manufacturing requirement for shape design etc. Another important point will be studied related to foam density and its effect on energy absorption. The suggested foam model will be checked experimentally and results will be compared with the help of LS DYNA material models for the further validation.

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