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A Review on 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. By considering this reason, in many countries legislation has been put into place with minimum requirements for injury parameters in side impact crash tests. Various structures have been used for the purpose of achieving safety such as side bars, crumple zones, crash cones and energy absorbing padding's. The padding is usually applied and located in vehicle door for securing the pelvic, the abdomen and the thorax area. The amount of absorption of occurred impact 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 review paper , we will study the approach from the latest trends in the vehicle and occupant safety by the application of energy absorber in side impact crash .

Keywords—side impact crash, legislations, crumple zones, paddings , passive safety

I. INTRODUCTION

The use of cellular materials such as polymeric foams has been increasing significantly for the last few decades. These materials are used in automotive applications for many different purposes, among which are, sound and thermal insulation, vibration damping, fire protection and the most important is of crashworthiness and energy absorption. Thus, crashworthiness, safety and protection parameters are strongly influenced by the materials used and, as a consequence, polymeric foams play a major role in the vehicle's crashworthiness levels and occupant safety. The energy absorption capability of this class of materials can lead to significant improvements on the vehicle's passive safety, better protecting the passengers from aggressive impacts, by absorbing impact energy. In addition, design limitations due to environmental constraints are also increasing as far as safety is concern .Therefore, the combination of properties such as low density, low cost and design flexibility with a great energy absorption capability, is what makes cellular materials such as foams an attractive option for automotive industry.

Vehicle side impacts and vehicle rollover are presently among the most common types of car accidents and collisions observed around the world. Additionally, these are also frequently the most serious accidents in terms of occupant injuries. So due to these the car manufacturers are more concerned with the protection of the occupants in side impacts. Field accident analysis dealing with automotive side collisions suggests that the pelvis is very vulnerable, but there is a lack of knowledge of the behavior of the pelvic bony structure and of its biomechanical tolerance. This knowledge however is essential in order to optimize protection devices and car structures with regard to the security of the occupants.

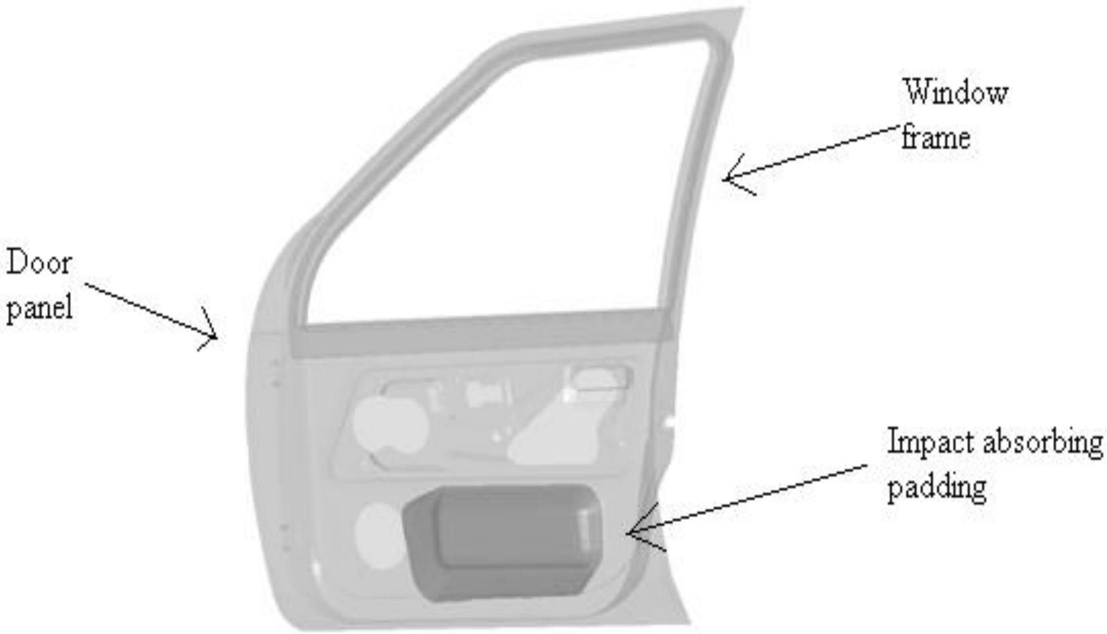

Figure 1: Inclusion and position of the protection padding [16]

The amount of absorption versus push load is important to obtain acceptable levels of the injury parameters as stipulated by legislation FMVSS 214 and consumer tests NCAP and IIHS. Practice shows many types of foam padding designs which fulfill the requirements, often in combination with side airbags. This enables designers of passive safety systems not only to save space, weight and cost but also increase safety ratings by having a better defined and more easily tune-able loading system on the dummy during side impact crashes. Pelvic fractures account for about 12% of injuries suffered in a side impact compared to patients in MVAs without pelvic injury, those with pelvic fracture have more severe injuries and higher mortality rates. A collapsible console and a seat track which allows lateral displacement of the seat may help to reduce pelvic injury in side impact crashes. 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.

There are various safety systems that are used in side impact for energy absorption and crash protection of occupants in automotives. Passive safety system is mostly used in automotives for shock absorption and occupant protection. 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. In this paper the the literature has been studied related to the latest research in concern for energy absorbing foam materials in side impact crash .

II. LITERATURE REVIEW

M. Avalle et al. [1] Studied on mechanical properties and impact behavior of a microcellular structural foam. Density is the primary parameter affecting foams behavior. The author has performed different test such as tensile tests at three loading speed and compression tests which are quasi static in nature. Addition with these an impact test was performed. Tension tests were conducted at various speeds to study the effect of strain-rate on the mechanical behavior. The impact tests will be used to verify models and simulations of this material, and in particular to check how the influence of the loading speed is modeled. Compression tests were performed along different loading directions and anisotropy was shown from these results. The author also reported an in-depth analysis of the way density influences foam mechanical properties, and how to deal with the effect of density.

Michele Colloca et al. [2] Studied mechanical properties and failure mechanisms of closed-cell PVC Foams. The study of closed-cell polyvinyl chloride (PVC) foams with varying densities is conducted under tension, compression, and impact loading. In conclusion author have mentioned that four types of high performance closed-cell PVC foams with different densities and microstructures are tested under tension, compression, and impact loading. The elastic moduli and strengths show increasing values with increasing foam density. Strength and energy absorption exhibit a strong dependence on the density and microstructure of the PVC foams. PVC foams are found to absorb up to about 5 times more energy under compressive loading than under tensile loading.

Brian et al. [3] [15] 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.

Isaac et al. [4] given focused on strain rate dependent behavior of polymeric foams. The material studied was closed cell PVC foam, an orthotropic/transversely isotropic material, exhibiting strain-rate-dependent elastic or viscoplastic behavior. The material was characterized at three strain rates, quasi-static, intermediate and high. Quasi-static and intermediate strain rate tests were conducted in a servo-hydraulic testing machine. Finally as concluding point it was observed that the stiffness, based on the initial slope of the stress-strain curves, did not change with strain rate. However, the characteristic peak stress, the “critical stress,” following the proportional limit and the plateau stress, marking the onset of strain hardening, increased linearly with the logarithm of strain rate. The peak stress is the “critical point” corresponding to collapse initiation of the cells in the foam.

C. Fremgen et al. [5] given focused on modeling and testing of energy absorbing lightweight materials and structures for automotive applications. In this paper they have done shear and compression test on absorbing material which was foam and studied its behavior. Also model is prepared in pam crash as a simulation. The design of the structural parts of the inner trim and roof often involves energy-absorbing polymeric foams and their reinforced versions. The mentioned foams have proved to be the best for this purpose and are widely used in automotive industry to prevent injuries to the occupants in the event of front or side collisions. The use of foamed materials results in a significant improvement of the passive safety of the vehicle, owing to their excellent energy dissipation properties. In addition, they are relatively cheap and allow great design flexibility, as they are easily modeled in complex geometric parts.

Ruediger heim et al. [6] studied the design parameters of foams and plastics to enhance vehicle safety. In this paper both foams and plastic solutions have been presented in different applications in the car providing energy absorbing capabilities and safety performance. The first area is that of structural foams in the car body cavities to enhance crash performance. The second area concerns integrated thermoplastic structures in the interior for absorbing impact energy while providing aesthetics and other functionality. Filling rigid foam inside the cavities of a vehicle body is being used for NVH as well as for stiffening purpose and crash energy management.

E Linul et al. [7] have studied different factors influencing the mechanical properties of polyurethane foams under dynamic compression. In paper the effect of density, loading rate, material orientation and temperature on dynamic compression behavior of rigid polyurethane foams are analyzed. Foams can be compressed to a relatively high strain under an approximately constant load. These parameters have a very important role, taking into account that foams are used as packing materials or dampers which require high energy impact absorption. In conclusion experimental results show that young's modulus, yield stress and plateau stress values increases with increasing density. One of the most significant effects of mechanical properties in dynamic compression of rigid PUR foams is the density, but also the loading speed, material orientation and temperature influences the behavior in compression. Finally at the end, one of the most significant parameter on mechanical properties in dynamic compression of rigid PUR foams is the foam density.

Babushankar et al. [8][15] 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.

Enver Serifi et al. [9] gave focus on modeling of foams using MAT83. In LS-DYNA for practical engineering purposes the foam model key word *MAT_FU_CHANG_FOAM (MAT83) is available. The main assumption of MAT83 is, that Poisson's ratio is equal to zero for foams and therefore no coupling between the material axes is present. This leads to a one-dimensional material law, where experimental curves of uni-axial test can be used directly. According to author the purpose of this work was to develop a computer code in order to supply load curves for different densities to be used in FEM calculations of EPP foam. As per there study the results of comparisons between models and real applications, numerically generated load curves, that demonstrate the behavior of foam material with a density lying within the range, is reliable. This saves a lot, for engineers who are working with different densities of EPP foam and don't have that big database including all the densities they use.

V.P.W. Shim et al. [10] studied two-dimensional response of crushable polyurethane foam to low velocity impact. Rigid polyurethane foam blocks are subjected to normal impact by gravity-driven impactors of different geometries, at velocities ranging from 2 to 4 m/s. Author has proposed a two-dimensional lumped mass numerical model was formulated to describe the impact response of cellular materials. Ease of analysis was facilitated by assuming that the effects of shear and normal stress are uncoupled and that a simple criterion for material failure and separation is adequate.

Gerhard slik et al **.** [11][15] have Presented advantages of applying high efficient energy absorption foams in padding use for protection of occupant in side impact crashes. The foam they have presented in there paper is a closed cell, styrenic foam, specially developed for energy absorption in automotive applications. The comparison is done between IMPAXX™, expanded Polypropylene (ePP) and semi-rigid Polyurethane (PUR) foam, all of similar densities. Parameters for LS-DYNA material model type 63 (*MAT_CRUSHABLE_FOAM) were identified for each foam grade from drop tower tests with a flat impactor . Finally the conclusion mentioned is that foam materials have great advantages to be used in development of side impact padding by improved load control, with short development time. Also Packaging space saving can be possible with weight reduction up to 50 %.

Gerhard slik et al. [12] [15] 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 .In there 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, MAT_LOW_DENSITY_FOAM and type 63 MAT_CRUSHABLE_FOAM was selected for the further process . 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 .

Vivek Srivastava et al**.** [13][15] 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. In current research authors have conducted a study showing the variation coming in results for two different material models for same material.

Vivek Srivastava et al. [14] In simulation environment, performance of EPP has been studied as a function of several parameters like constitutive and phenomenological material modeling, sectional properties and element types. Authors presented work using simulation modeling to investigate the change in performance of Expanded Polypropylene. FE Solver LS Dyna has different material models and sectional properties available to model the foams. In the present work Force –Time, Displacement, Force- Displacement and Internal Energy interactions for solid tetrahedral element were studied. In the analysis 45g/l EPP was simulated with three different element formulations for two material cards i.e. MAT57 (Low Density Foam) and MAT83 (Fu Chang Foam).

III. SUMMARY

Foam padding’s are gaining lot of importance in side impact crash considering occupant safety. Considering the literature, it shows that density is the primary parameter affecting foam behavior. The elastic moduli and strengths show increasing values with increasing foam density. Strength and energy absorption exhibit a strong dependence on the density and microstructure of the foams. Material models such as MAT57 and MAT83 showed good correlation with physical test values. These are the two cards that are most commonly used in the industry to simulate foams .

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