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Drop Test Analysis of Impact Attenuator for Formula SAE Car

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***Abstract*-** Driver Safety is one of major research area in race car engineering. Researchers are designing advance active and passive safety system to assure the safety of the driver. Development time and cost of any product is reduced by great extend with the use of computer simulated software's. But the simulated results can't be used directly into real life without any validation with experimental results. Aim of this paper is to compare the computer simulated results of energy absorbing capabilities of low cost aluminium alloy impact attenuator using LS-DYNA with that of actual drop test performed in the laboratory. The analysis results are found in good agreement with experimental results obtained from crash testing in real time, performed at ARAI, Pune. Average deceleration of impact is less than 20 g as per the requirement of FSAE design rules.

***Index Terms*-** Drop Test Analysis, Impact Attenuator (IA), Formula SAE, Crash Analysis

I. Introduction

From the past so many years, teams around the world had proposed many successful designs of impact attenuator using different materials and geometry. M.T.J.Fonteyn, et al [1] proposed five different materials having different mechanical properties. Polymethacrylimide (PMI) used for IA is a type of hard foam having very good stress-strain properties. But properties of hard foam totally depend upon the density of foam. It is difficult to maintain the uniform density throughout the material of the IA. Giovanni Belingardi et al [2] performed the finite element simulation using Hypermesh software. The model includes two different type of materials: steel S275JR UNI EN 10025 (Fe430) and 6082T6 aluminum alloy. Results obtained by these materials are nearly same, but design of the IA is shell like structure and holes are punched on it as they are operating as triggers, that means have both the scope to decrease the weight of the structure itself and to obtain a better crush behavior by decreasing the first peak of the collapse force. Crash test was conducted considering face to face direct collision. In case when the collision divers the zero angle, the hollow structure will try to bend in different direction, instead of absorbing impact energy. It will not give acceptable results as in case of bulk material or any design having through connected members. Jon Hart et al [3] defines honeycomb pyramid design with 3003 Aluminum plates. Computer simulation results of crash testing shows no co-relation with that of experimental results. Hiroshi Enomoto et al [4] proposes designs KF-IA04, KF-IA05B, KF-IA06 and KF-IA07. But impact attenuator formed by the Vacuum assisted Resin Transfer Modeling (VaRTM), KF-IA07, could satisfy the 2007 FSAE rules. Jovan Obradovic et al [5] managed to simulate the carbon fiber IA using LS-DYNA code. Conducted experimental analysis shows stable behavior of the nose cone structure with flat curve. But cost involved material is very high. Thus it affects the financial targets of design team and limitations of manufacturing facilities in India.

Main goal of design team was to design an impact attenuator which fulfils deceleration and size requirement under SAE rules with minimum cost and weight.

II. Material Selection and Design

As per the rules, attenuator to be installed in the front of the bulkhead must be at least 200mm long with its length oriented along the fore and aft axis of the frame. It must also be 100 mm high, 200 mm wide with a minimum distance of 200mm forward of the bulkhead. In any case, it should not penetrate the front bulkhead. For a total vehicle mass of 300 kg run into a solid, non yielding impact barrier with an impact velocity of 7 m/s, the attenuator must give an average deceleration of less than 20g.
The present work concentrates on the impact performance of a structure made of Aluminium 6063 T6 [6] This paper aims at verifying the dynamic deceleration by drop test method.

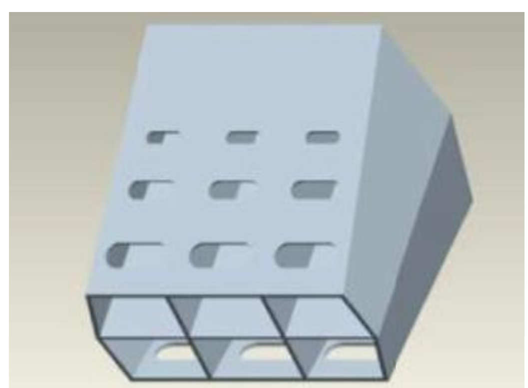

Figure 1 [6]

Aluminium 6063 T6 (alloy of Al with Mg and Si) is commercially available. Its sheets were used for the impact attenuator. This material is highly weldable using tungsten inert gas welding. It has good mechanical properties as per our requirements of the design. It is light in weight and cost effective. Fig. (1) depicts the designed CAD model of the attenuator. Overall dimensions of the attenuator were 250 x 250 x 250 mm^3. The sheet thickness eventually used was 1.5 mm. Contours of elliptical shapes with varying dimensions were extruded out of the upper and lower surfaces. These were placed symmetrically in horizontal rows. The presence of these elliptical cuts helped in attaining deformation in concertina fashion. Consequently, it yielded a sinuous graph of deceleration versus time, thus providing an ideal cushion for energy absorption.

III. Analysis of the Design

A. Simulation Using L S-DYNA Package

Simulation of CAD model requires proper boundary conditions. Carefully applied boundary conditions will only give good results which can be correlated with experimental results. As per the CAD model front rigid wall and IA with backside rigid wall were meshed with four noded and three noded reduced integrated shell elements. Surface-to-surface type contact interface was used for the contact between the front wall and the IA. This type was selected in order to prevent penetration of the IA's internal nodes as they could be in contact with the rigid plate during the simulation procedure. In-between contacts of the inner and the outer surfaces of the IA were assumed frictionless. To start with the simulation, we needed to define the material for the model and then define the boundary conditions. Boundary conditions are shown in fig.2

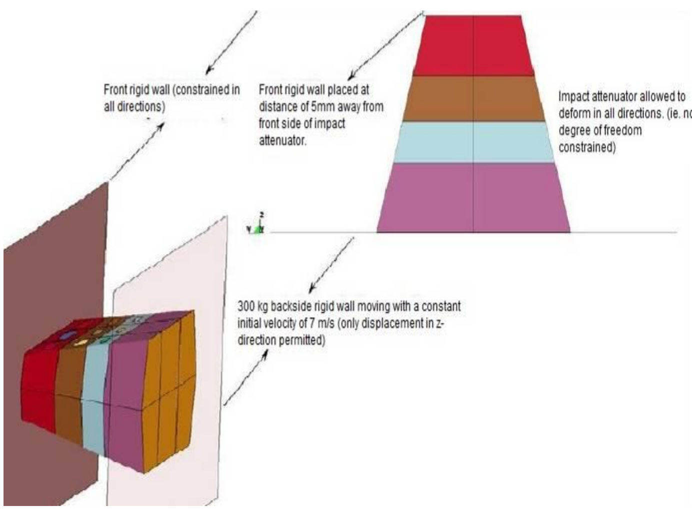

Figure 2 [6]

Simulated results obtained are shown in fig. 3[6]. Thae average deceleration of 18.8g was obtained with 29g as the maximum value of the deceleration. Fig. 4[6] shows the pattern of energy absorbed by the IA during crash.

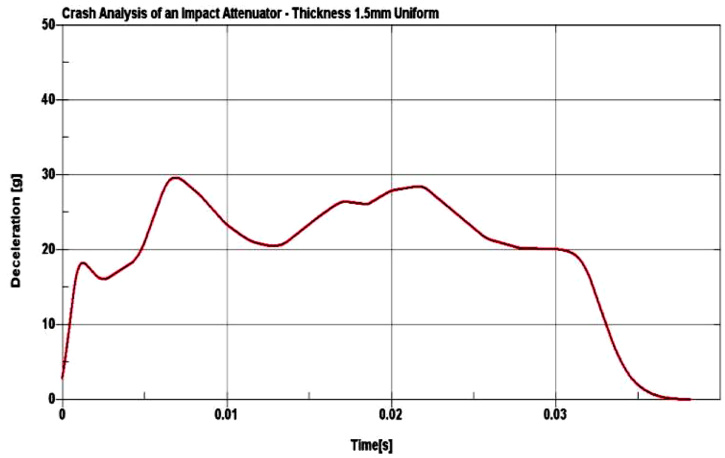

Figure 3

B. Drop Test

In order to verify results obtained in simulation on L S Dyna package, we performed the actual testing of impact attenuator, as discussed below:

This test was carried out by dropping a weight of 265 kg from a height of 2.8 m with an impact velocity of 7.4 m/s. This is equivalent to dropping a weight of 300 kg from a height of 2.5 m.

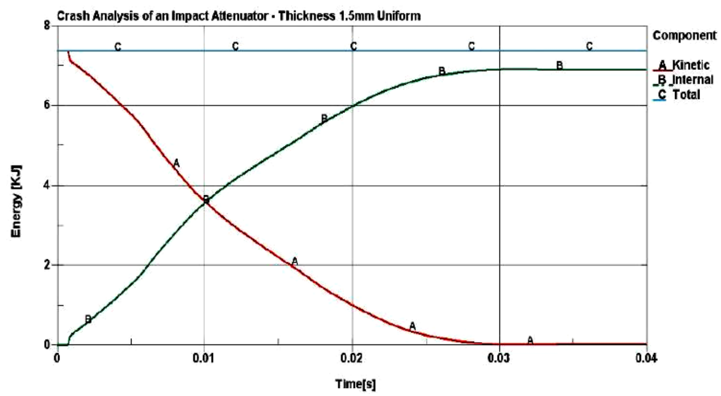

Figure 4

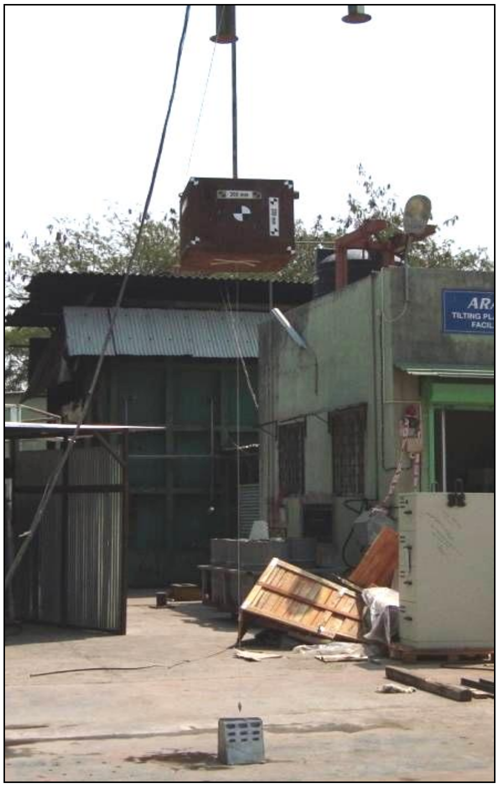

Figure 5

Fig.5 shows the setup of impact test in the testing facilities of ARAI, Pune. The impact attenuator was kept on plain ground and a weight of 265 kg was lifted to 2.8 m height using Goliath crane and was freely dropped using a quick release mechanism. High speed digital cameras were used to record the subsequent displacement with time of the marked up positions as shown in fig.7 on the weight box. These cameras recorded the displacement of 4 markers placed on the weight. The relative displacement of marker 1 and marker 3 with time yielded the velocity versus time plots. Fig 8, Fig 9 and Fig 10 gives displacement, velocity and deceleration plot for marker 1 and 3 respectively. Fig. 6 shows the deformed attenuator after the drop test. The average deceleration obtained in experimental drop test is 13.5 g .

Figure 6

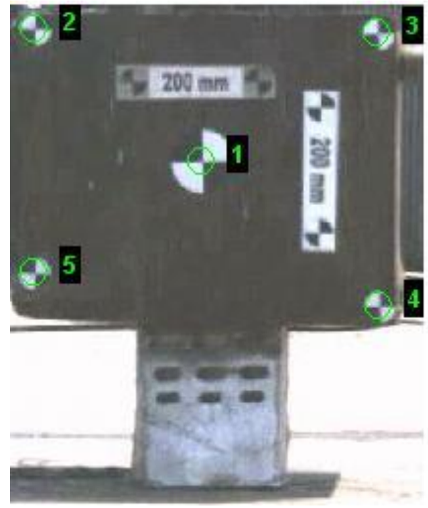

Figure 7

IV. Results and Discussion

The average deceleration using LS Dyna Package simulation is 18.8g and the average deceleration using experimental drop testing is observed to be 13.15g (at marker 1). The experimental testing showed better results, though both confirmed to the Formula SAE rule of not to exceed average deceleration of 20g. The total energy is the sum of the Kinetic, Internal Damping and Sliding energy. Thus variation in results may be attributed to damping and sliding energy considerations and the welding done on the attenuator sheet.

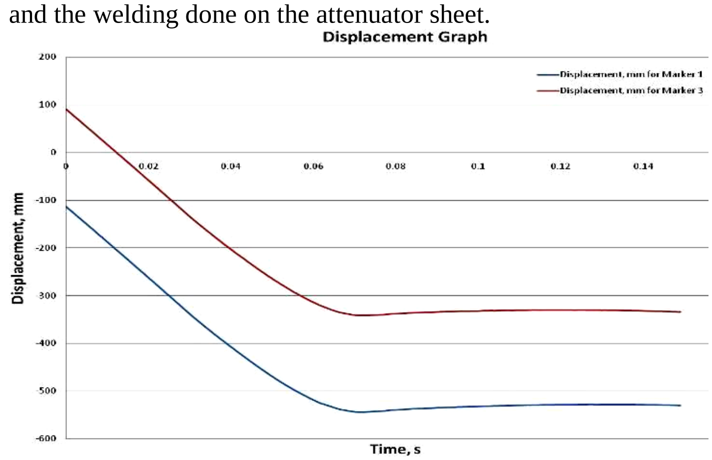

Figure 8

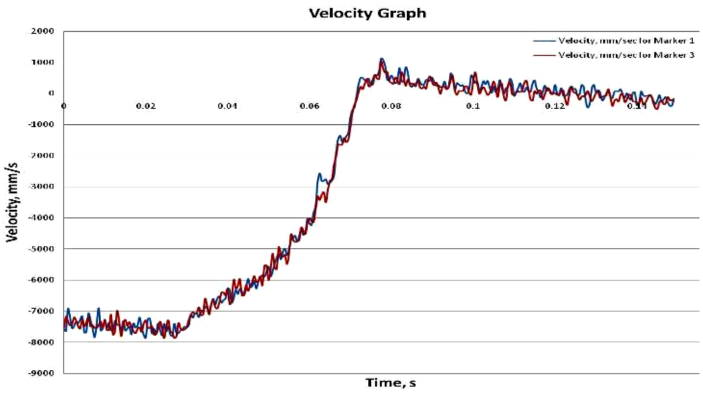

Figure 9

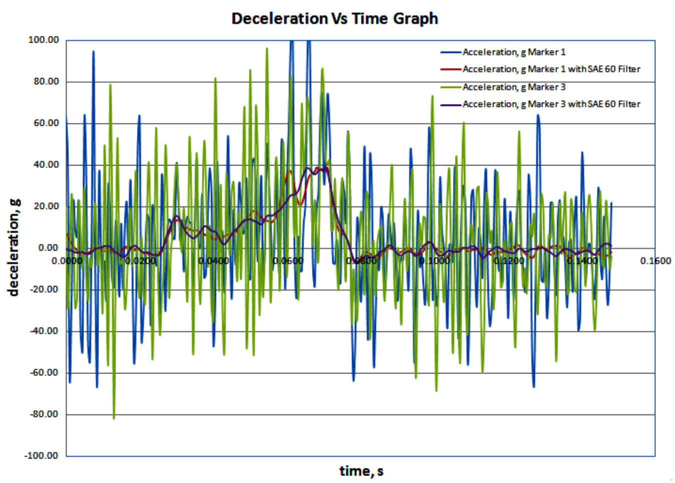

Figure 10

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