Crash and Impact Strength Analysis of Structural component of the vehicle for Occupant Safety

Ms. Gauri B. Mahajan[1], Prof. Dinesh. N. Kamble[2]

Abstract—**This paper describes a type of car's side impact performance on the BIW. The main intension is to co-relate the performance of the BIW frame (when vehicle undergo crash with a various angles towards rigid pole) and occupant safety after the crash. Initially, FEM model of BIW frame is created based on logical method to solve the problem. Then, analysis evaluation of the side impact safety, method of design and manufacturing processes and the results of the side impact feature will be discussed. Then, analysis of the intrusion level according to the FMVSS No.214 or EURO NCAP standards towards the occupant (boot) space and of the occupant injury levels is discussed.**

Index Terms—**Side impact model, FEA, FMVSS No.214, EURO NCAP, Response evaluation**

I. INTRODUCTION

In various incidents, the accidents of the vehicles on the road the side impact have highest contribution to mortality. In a side impact, the occupants on both the struck, or near side, of the vehicle and the occupants on the opposite, or far side, of the vehicle are at risk of injury. Hence, it is very crucial in vehicle industry to confirm the crashworthiness of car, which is forecasted by robust modeling and CAE analysis method. This paper evaluates the risk of side crash injury for occupants as a basis developing side impact injury countermeasures, which are based on FMVSS (Federal Motor Vehicle Standard Specifications) No. 214.

Crashworthiness is an engineering term used to define the ability of vehicle structure to protect its occupants during an impact. Crashworthiness is not limited to automobiles only, it is also applied to other transportation vehicles, such as ships, planes, and trains. In fact, the first systematic and scientific investigation of the subject was applied to railway axles between 1879 to 1890 by Thomas Andrews. In other words, crashworthiness is the process of improving the crash performance of a structure by sacrificing it under impact for the purpose of protecting occupants from injuries. To improve the structure design for crashworthiness, it is required to understand the different factors affecting the crash process. In the following, different fundamental aspects of design for crashworthiness have been described and pertinent works have been reviewed during project work.

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The FEM of a car should consider the factors, which influences the side impact response [1]. The quality of BIW depends on modeling methods of its sub systems and main parts, which in turn depends upon its structural features and response features in the impact process. The modeling side impact consists of four parts. Namely, first is body thin wall package, second car is chassis and power train systems, third body accessories, for this seat and interior decoration. The assembly of entire car is carried out as per the procedure of the car manufacturing, starting from connection of sub-assemblies and packaging of every sub-assembly to car modeling. The car is assembled through adding related connection units or constraints at the connecting points. At last, all boundary conditions and contact problems between impact parts are checked [2].

- **Step of Execution**

1. For Initial study,
   - I. Simulating BIW with metal plate (i.e. Aluminum) and studying impact of pole on crash with plate in order to check the energy conservation due to side impact.
   - II. To study the behavior of the material deformation of BIW component on side impact i.e. considering tabular aluminum structure fixing at one end and applying load on other end.
2. Executing actual case study, Behavior of B-Pillar structure of the BIW for crash analysis with specified loads, angles as per the standards.
3. Deformations of B-Pillar structure with respect to occupant safety will be studied by using ABAQUS and Hypermesh tools.
4. Validating the results against NHTSA, FMVSS or EURO NCAP standards for project completion
5. Based on the actual case study on deformation results and according to the standards, the conclusion for improvement will be suggested.

II. ESTABLISHMENT OF SIDE IMPACT MODEL

The modeling of this paper uses Hypermesh software. For effective and accurate modeling, it adopts the method of establishing respective ABAQUS key documents for the sub-systems [3]. The sub-systems of the model (As shown in Fig.1) include BIW system, closure system, chassis system, steering system, power train system, interior-exterior decoration system and safety system. The BIW structure contains approximate 25,000 to 30,000 elements, 120 to 200

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joints. BIW frame weight with full equipments is 75kg. The connection of frame with some stiffener is done by spot welding. The choosing of solder joints in the mode is mainly based on the decomposition chart of the parts and takes the procedure requirements of spot welding into consideration. As in practical connections of doors and endplate are pressing techniques and are realized through node constraints in modeling process.

- **Constructing FEA model BIW frame and Rigid pole**

The unit type of FEM includes shell element, entity unit, and quality unit. Besides other type of models is involved, such as rigid model, solder joint model, rigid constraint etc. The BIW frame(As shown in Fig.3) is modelled in CATIA or Uni-graphics and it is exported as neutral formats like **.igs** or **.stp** file for further usage. Then this model is pre-processed in Hypermesh using TRI, QUAD, SHELL elements and spot weld.

The rigid pole is construction as FEA model in Hypermesh by shell elements which are of cylindrical shape having 254 diameter and it is fully considered as a rigid and doesn't absorb any energy.

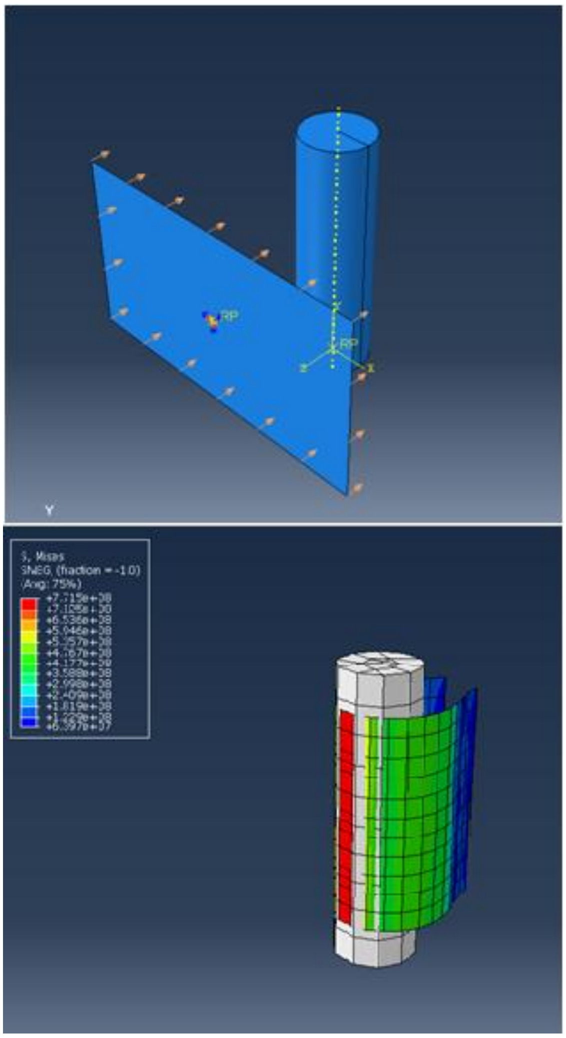

Fig.1. Analysis of pole with the plate

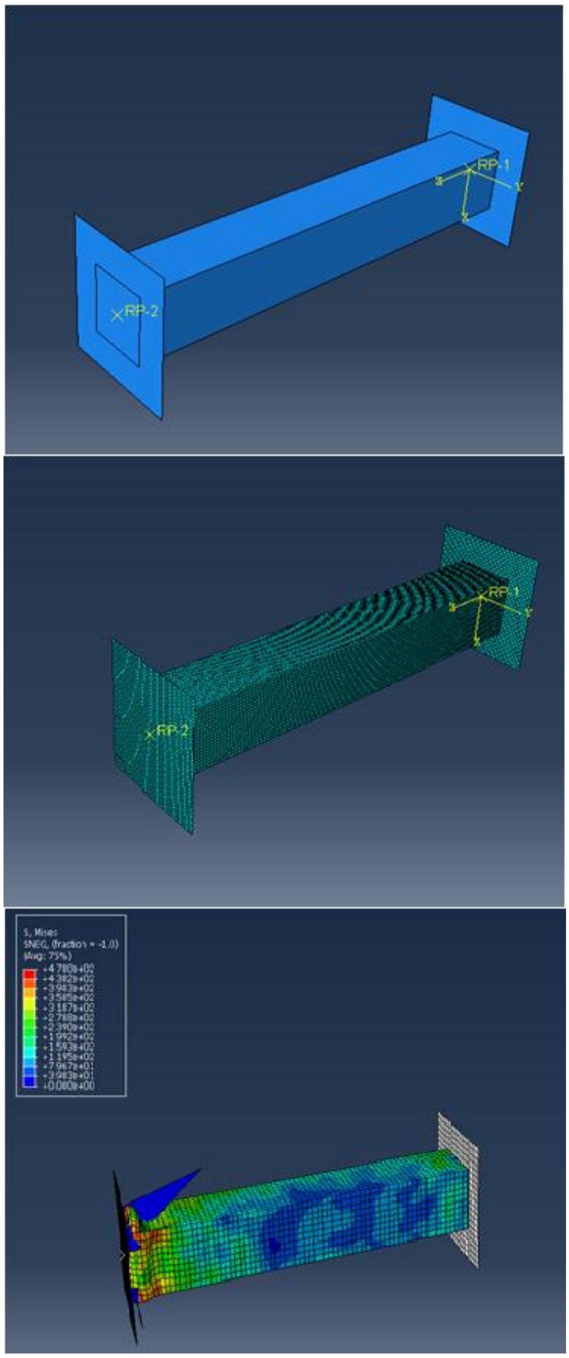

Fig.2. Analysis of tube

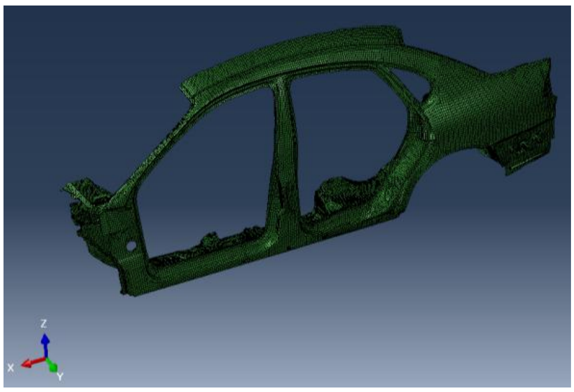

Fig.3. Meshed model for side impact test

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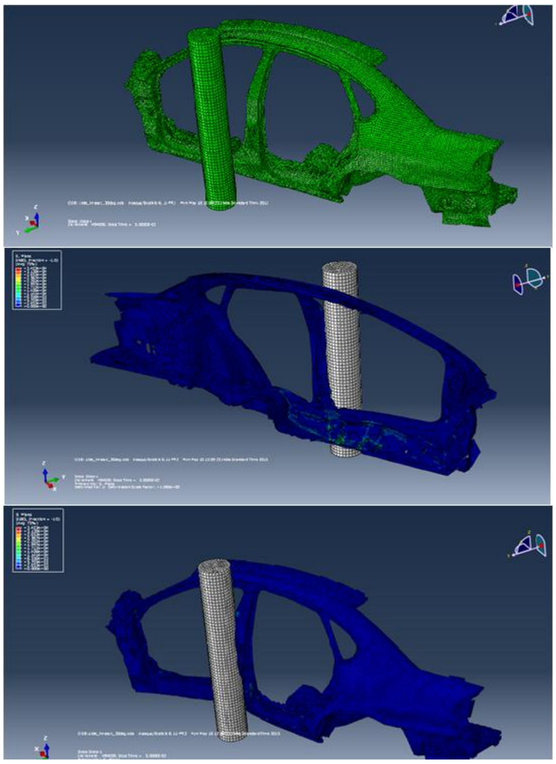

Fig.4. 30^0 (deg.) impact of BIW with pole

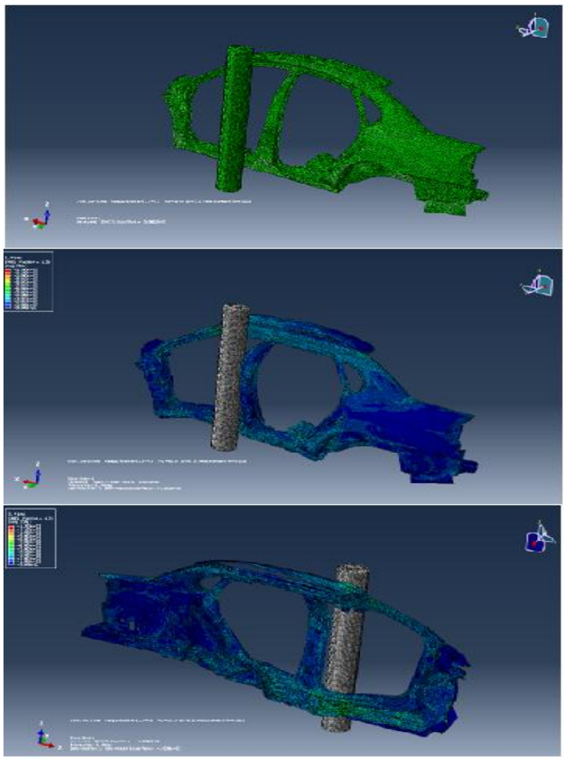

Fig.6. BIW with speed of 30km/h impact with pole

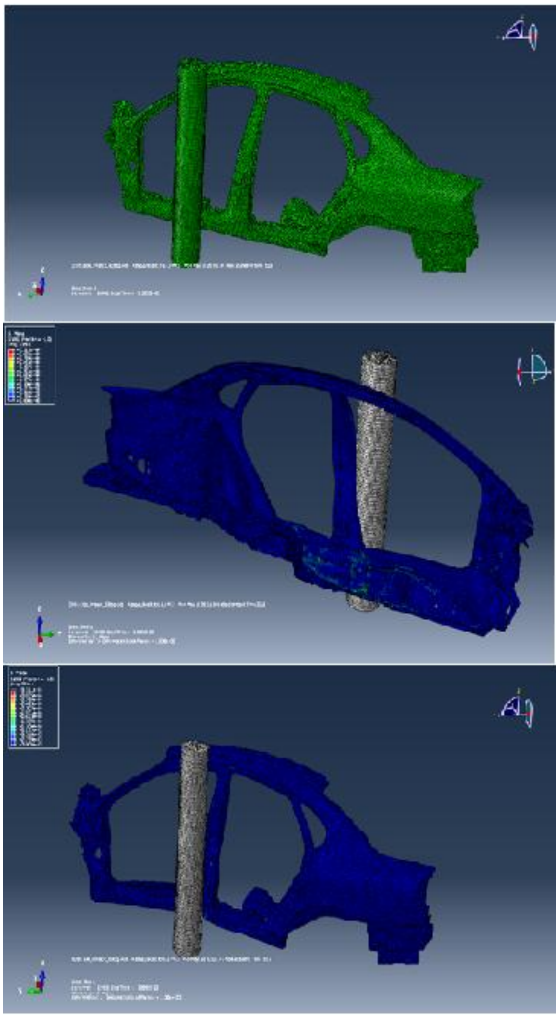

Fig.5. 60^0 (deg.) impact of BIW with pole

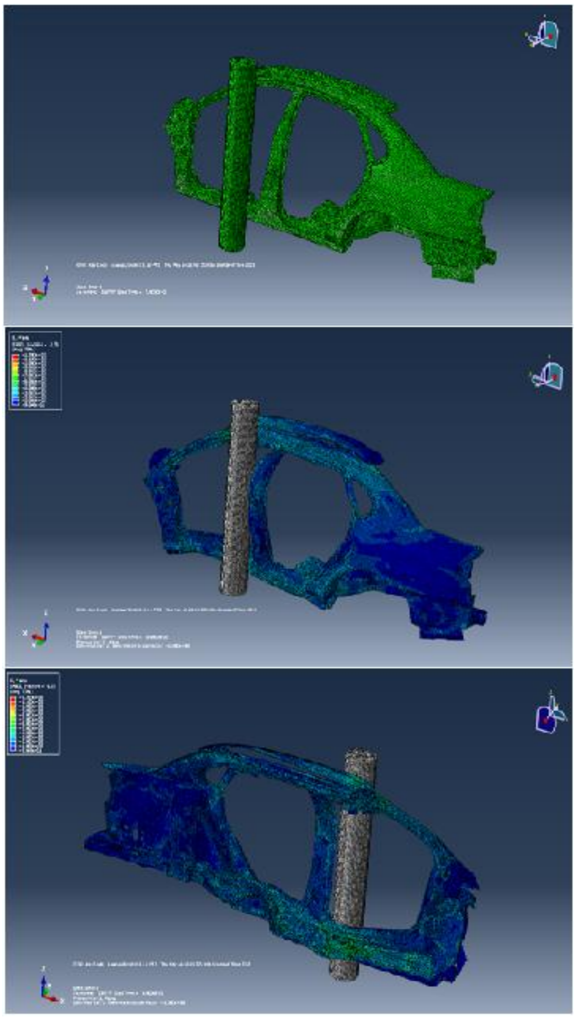

Fig.7. BIW with speed of 60kmph impact with pole

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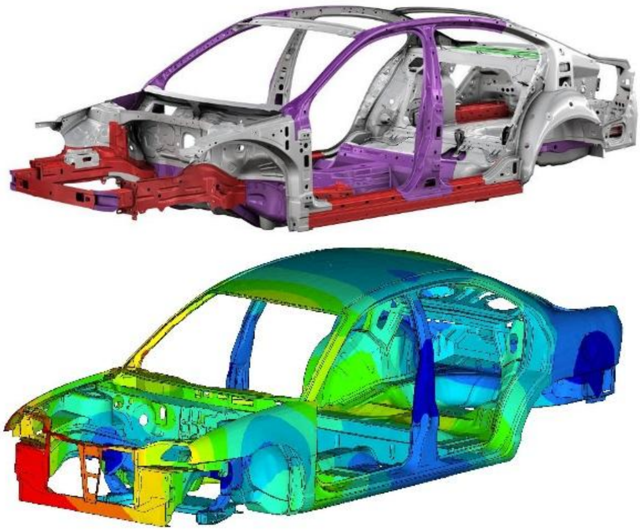

Fig.8. BIW Frame for Analysis

- **Importing Pre-processed models for Analysis**

Pre-processed models are imported in **.inp** format, which will be considered as input to the ABAQUS (As shown in Fig.7), which is further used for simulation. In ABAQUS material, section is assigned to the BIW component, steps, interactions are defined and load is applied in terms of predefined field i.e. applying load in terms of velocity. Finally boundary conditions are applied and job is created to submit for analysis. Analysis results will be in form of stress, strain and displacement. According to this analysis results, the intrusion level (displacement) and injury level of the occupant as per the standards will be decided.

Fig.9. Rigid Pole and Dummy representation for side impact

III. VERIFICATION AND EVALUATION OF SIDE IMPACT TEST

Consider as an initial study example, rigid plate and moving ball which is having velocity of 30m/s and 70m/s towards the rigid plate. When the ball hits the plate, considering that energy generated due to this action is absorbed by the ball. It is also considered that rigid plate will not absorb any energy. Hence the whole energy is transferred to the ball itself which is calculated by;

$$\text{Kinetic Energy} = ½\, mv^2$$
$$\text{K.E energy} = ½\, m(v*\cos\Theta)^2$$

i.e.
v= initial velocity of ball
m=mass of the ball
Θ= angle of impact

As the ball comes and hits in a perpendicular direction (As shown in Fig.10), kinetic energy of the ball is calculated. But, if the ball is hitting at an angle (30°) to the plate then the inclined component of velocity is resolved into two components sine and cosine components (As shown in Fig.10), on which cosine component is responsible for the deformation of ball. The deformation value of ball in angled should be less than perpendicular ball impact, then it is said that deformation value for impact is permissible.

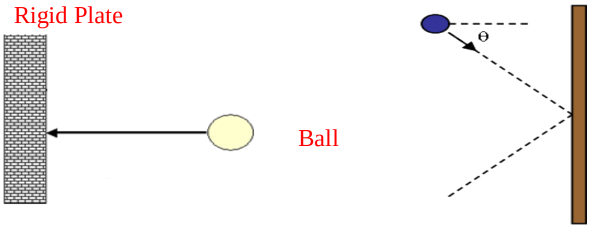

Fig.10. Perpendicular and angled motion of Ball

- **Calculations**

As with an initial study example, theoretically values of perpendicular direction impact is more than the inclined angle impact, hence we can consider the design is safe.

- **For 30m/s**

$$\text{K.E}=1/2*75*(30)^2$$
$$=33{,}750\text{J}$$

2. For 70m/s

$$\text{K.E}=1/2*75*(70)^2$$
$$=183{,}750\text{J}$$

Calculations for angle impact:

1. 30° Angle and 30m/s

$$\text{K.E}=1/2*75*(30*\cos30)^2$$
$$=25{,}312.5\text{J}$$

2. 30° Angle and70m/s

$$\text{K.E}=1/2*75*(70*\cos30)^2$$
$$=137{,}812.5\text{J}$$

3.1 Deformation Analysis on BIW Frame

As in actual calculation, the displacement value of the BIW frame towards the occupant is evaluated by the simulation study.

In initial case study, BIW frame is simulated for as metal plate in order to check the energy conservation due to side impact i.e. steel plate is impacted by the rigid pole and results are evaluated on the basis of standards FMVSS No 214 [4]s or EURO NCAP. Secondly the material deformation is evaluated by considering tabular tube fixing at one end and applying load at free end.

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In actual case the BIW frame is modeled and impacted by the rigid pole. The vehicle is simulated for velocity 30m/s and 70m/s for 0-100ms against pole at different angles like 30° and 75°. The test results are in the form of intrusion (mm) which compared with the FMVSS No.214 or EURO NCAP standards.

3.1.1 Geometric modeling and meshing

The unit type of FEM includes shell element, entity unit, and quality unit. Besides other type of models is involved, such as rigid model, solder joint model, rigid constraint etc. The BIW frame) is modeled in CATIA or Uni-graphics and it is exported as neutral formats like **.igs** or **.stp** file for further usage. Then this model is pre-processed in Hypermesh using TRI, QUAD, SHELL elements and spot weld. While the mesh pattern on the BIW consisted of 120 to 200 joints and 25,000 to 30,000 elements. BIW frame weight with full equipments is 75kg.

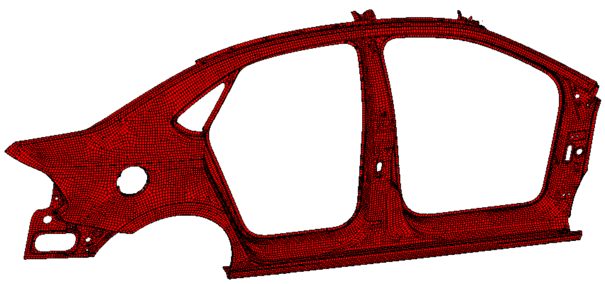


Fig.11. Meshed model of BIW

The rigid pole is construction as FEA model in Hypermesh by shell a element which is of cylindrical shape having 254mm diameter and it is fully considered as a rigid and doesn't absorb any energy. Pre-processed models are imported in **.inp** format, which will be considered as input to the ABAQUS, which is further used for simulation. In ABAQUS material, section is assigned to the BIW component, steps, interactions are defined and load is applied in terms of predefined field i.e. applying load in terms of velocity.

Fig. 12. Pole and vehicle position

Finally boundary conditions are applied and job is created to submit for analysis. Analysis results will be in form of stress, strain and displacement. According to this analysis results, the intrusion level (displacement) and injury level of the occupant as per the standards will be decided.

3.1.2 Material Properties

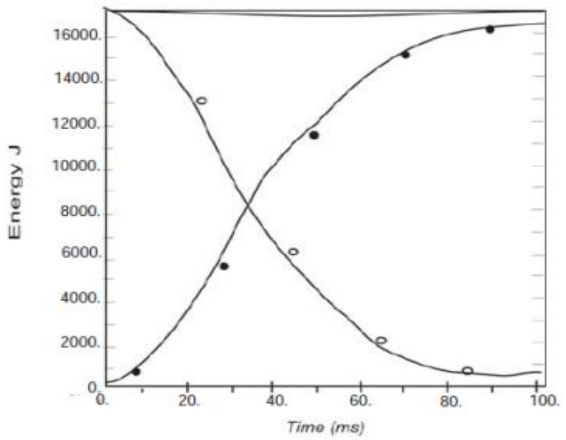
Material Name: Aluminum
Density: 2770 (kgm^3)
Young's modulus (Pa): 7.10 E+10
Poisson's ratio: 0.33
Yield strength (Pa): 2.80 E+08

3.1.3 Assumptions

The following assumptions are made in the simulation of a crash –

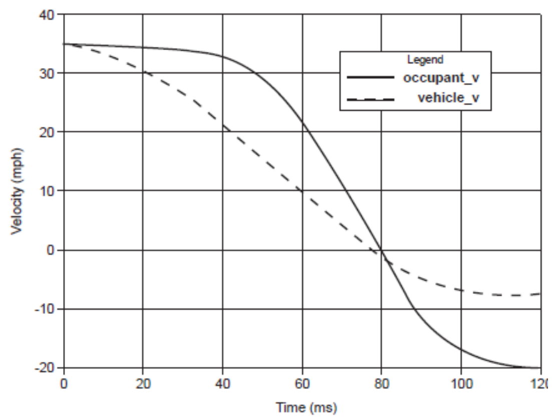
- The BIW is approximated to be the length of vehicle.
- The pole is assumed to be a rigid support.
- The BIW is subjected to an initial velocity and constant acceleration.
- Air drag on the body panel's surface is neglected.

3.1.4 Frame of references for future analysis



Graph.1. Energy Vs Time

This is energy balance for a typical run. It can be observed that the total energy remained approximately constant throughout the 100 ms duration, and the rise in internal energy and the decay in kinetic energy are smooth. This attests to very little interpenetrating among the contacted segments.



Graph.2 Velocity Vs Time

Deceleration at Rocker/B-Pillar shows a typical deceleration time (*Gv-T*) history of a mid-size vehicle during a fixed barrier impact test at 30 mph

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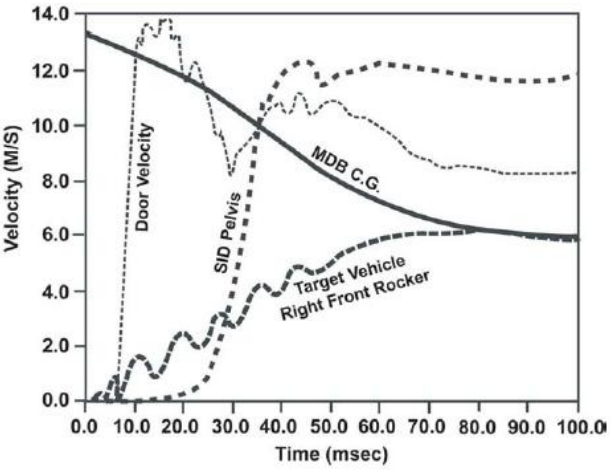

Graph.3 Typical velocity profile in side impact

- **Material Optimization for Crashworthiness**

Material's role is of paramount importance to crashworthiness. Lighter materials are being developed to reduce automobile's weight for cost and emission reduction. At the same time these lighter materials should maintain the safety of the automobile according to regulations. Significant research work has been conducted to achieve both objectives. The research in this area can be classified according to the type of material into four categories: (1) steel, (2) composite materials, (3) aluminium and (4) magnesium. A brief overview of the published literature is presented in the following:

a) Steel

Steel sheets have been used in vehicle structures for more than one century. Its low production costs, consistent properties and the huge accumulated and available knowledge about its production processes make it the material of choice for automobile manufacturers. Its crashworthiness performance has been studied by several researchers.

b) Composite Materials

Composite materials have been investigated for their probable use as impact energy absorbing elements. Some of the composites that have been investigated for use in crashworthiness are random chopped fibre reinforced composites.

c) Aluminium

Aluminium has been used in some automobile structures due to its low density. In 1993, Audi introduced the aluminium space frame sedan, and in 1999, GM introduced the first all wrought aluminium cradle.

d) Magnesium

Magnesium has recently received a great attention from the automotive industry due to its attractive low density. It is the lightest of all structural metals (78% lighter than steel and 35% lighter than aluminium). Moreover, it is also one of the most abundant structural materials in Earth's crust and in sea water. Due to its excellent casting properties, it has been used in several automotive components, such as, engine block, engine cradle, transmission case, and instrument panel. Also, it has been used as inner door frames and seats. However, it has not fully replaced steel in vehicle structures due to the following challenges:

Magnesium has a Hexagonal Closed Packed (HCP) crystal structure and has limited slip systems, mainly in the basal planes; hence it is difficult to form especially at low temperatures.

Magnesium has high affinity to react with oxygen which causes corrosion; hence expensive treatments are required.

There is a considerable amount of research to overcome the challenges that hinder the full use of magnesium alloys in vehicle structures.

IV. CONCLUSION

As in actual calculation, the displacement value of the BIW frame towards the occupant is evaluated by the simulation study.

In initial case study, BIW frame is simulated for as metal plate in order to check the energy conservation due to side impact i.e. steel plate is impacted by the rigid pole and results are evaluated on the basis of standards FMVSS No 214 or EURO NCAP. Secondly the material deformation is evaluated by considering tabular tube fixing at one end and applying load at free end.

In actual case the BIW frame is modeled and impacted by the rigid pole. The vehicle is simulated for velocity 30m/s and 70m/s for 0-100ms against pole at different angles like 30° and 75°. The test results are in the form of intrusion (mm) which is compared with the FMVSS No.214 or EURO NCAP standards.

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