Crash Analysis of four wheel vehicle for different velocity

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***Abstract*:-** With the improvements in roadways and implementation of new design technologies to automobiles, vehicle safety has found a tremendous turn in these days. Even then automobile community is making its continuous effort to improve automobile safety to reduce injury and death drastically. In the present work one such effort is showcased by carrying out crash analysis of hatch back car at different velocities using ANSYS Explicit Dynamics approach. Structural Steel wall was used as the obstacle and aluminium alloy was chosen as the body material for car model. It was seen that at low velocity majority of the impact force was absorbed by the front part of the car with slight deformation. But at high velocity, impact resulted in permanent deformation of the car model. The extent of plastic deformation of the car increased with increase in velocity with front part of the car absorbing the major part of the impact energy, Bumper, bonnet, A pillar and wind shield were the major parts to undergo plastic deformation. Also from the energy graphs it was clear that internal energy increased drastically and the kinetic energy decreased during the course of impact. After the impact the car body rebounds back and regains its kinetic energy, while the internal energy decreases.
Keywords— Small wind turbine;static analysis;Catia V5; ABAQUS.

1. INTRODUCTION

With increase in fuel price and need for safer vehicle, it is important to analyse the crashworthiness of automobile structure. Crashworthiness can be defined as the capability of a structure to safeguard its passengers during an impact. Based on the nature of impact and the type automobile involved in the crash, different parameters are used to determine the crashworthiness of the structure. Crashworthiness can be analysed either computationally, i.e. using computer tools such as MADYMO, PAM-CRASH, MSC Dytron, LS-DYNA or by experimental method.

1.1 Crash Test

In order to assure safety for different modes of transports or its related components and systems, proper design standards are maintained and destructive tests are performed to check for crashworthiness. This procedure of testing the automobiles and their component by destructive method is known as crash test. proper design standards are maintained and destructive tests are performed to check for crashworthiness. This procedure of testing the automobiles and their component by destructive method is known as crash test.

1.1.1 Types of Crash test

A. Frontal Impact Tests: This is the most common type of crash test. In this method vehicles are made to hit solid wall, usually made up of concrete, at different speeds. This type of crash test can also be carried out between two vehicles colliding each other.

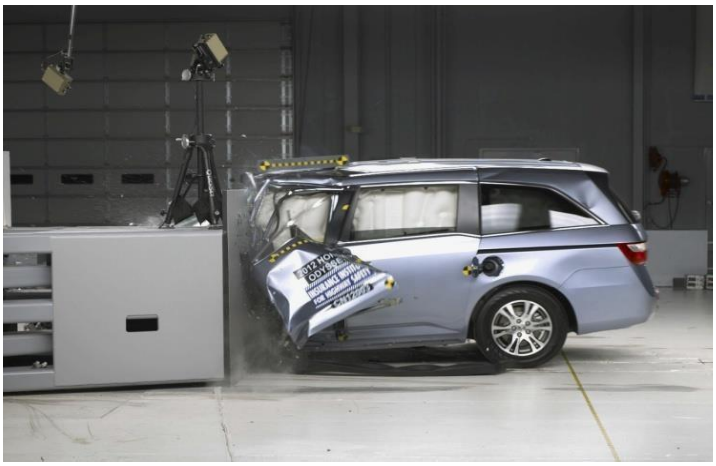

Figure 1: Frontal crash test carried for Honda Odyssey 2012.

B. Moderate Overlap Tests: This crash test is similar to Frontal Impact crash test, but only a small portion of the front part of the car impacts or hits the wall. These types of tests are important because the impact forces remain same during the collision but the area available to absorb the impact force is smaller.

C. Small Overlap Tests: In this type of test, only small part of the vehicle body or the structure hits the barrier such as tree or a pole. This is the case of impact where the vehicle structure experiences more impact force per square metre of area and is the most demanding crash test among all the tests.

D. Side Impact Tests: In this type of test a stationary test vehicle is fixed on the driver side and high velocity moving barrier which is deformable is made to hit the test vehicle at 90 degree angle on the driver side.

Figure 2: Dodge Grand Caravan 2018 Side impact test

E. Roll-over tests: This type of test is carried out to check the ability of the pillars and the roof held by those pillars to withstand the impact during vehicle roll over due to collision.

F. Old Versus New: It is important for the automobile manufacturing companies to test for advancements in their new generation car models as compared with old generation car models for crashworthiness. Usually big and old cars are compared against small and new cars of different generations.

Figure 3: NHTSA research crash test carried on two Ford 500.

G. Computer Model: Due to heavy cost involved in the full scale crash tests, engineers usually choose low cost simulation techniques using computer tools to check for crashworthiness.

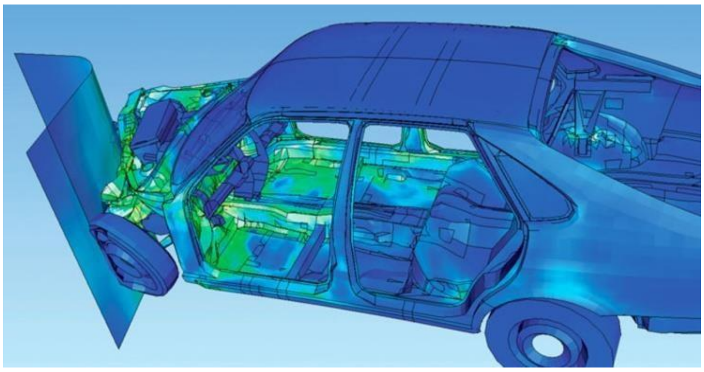

Figure 4: Simulation of car crash

H. Sled Testing: This kind of test is carried for examining vehicle components such as seat belts and airbags and is the most cost effective method.

1.2 Basic Definitions:

A. Stress: The intensity of internally distributed forces that tend to resist change in shape of a body is known as stress.

$Stress=Force/Area$

$\sigma=(P/A)\ \ N/mm2$

B. Strain: Change in length per unit length in linear dimension of a body is known as strain.

$Strain=Change\ in\ length/Original\ length$

$e=\partial L/L$

C. Elastic Range: The greatest stress up to which material

exhibits the characteristics of regaining its original shape and dimensions on removal of load is known as elastic range.

D. Hooke's law: It law states that when a material is loaded within its elastic limit, the stress is directly proportional to the strain.

$Stress \propto Strain$

$\sigma \propto e$

$\sigma=Ee$

Where,

E – Young's modulus in N/mm2

σ – Stress in N/mm2/

e – Strain

E. Deformation: In continuum mechanics, transformation of a system/ body from a reference shape to a current shape is called as deformation. It may be caused due to application of external load, gravity, electromagnetic forces, temperature changes etc.

F. Directional Deformation: The displacement of the body in a particular axis or user defined direction is known as directional deformation.

G. Total Deformation: Total deformation is the vector sum of all directional displacements of the systems

H. Plastic Deformation: Plastic deformation can be defined as permanent deformation occurring due to application of sufficient load which results in permanent change in size or shape of a body. It is also known as plasticity.

Some basic materials which can experience plastic deformation are metals, plastics, rocks, concrete etc.

I. Elastic Deformation: Elastic deformation is defined as the temporary deformation of material's shape, in which the material regains its shape after the removal of load. This phenomenon can be seen in metals and ceramics when stressed below elastic

2. METHODOLOGY

In order to simulate crashworthiness of a chosen scaled down sedan car model ANSYS Explicit dynamics tool is used. This typical simulation methodology involves

1. Creation of Geometry (Sedan Car model and Wall) using CATIA V5 modelling tool.

2. Meshing the Geometry.

3. Setting up interaction and boundary conditions.

4. Solving the non linear dynamic response of car model with respect to time at different velocity.

5. Examining the results obtained using the ANSYS post processing tool

3. COMPUTATIONAL ANALYSIS OF CAR CRASH

3.1Geometry Creation

In the present work, since the main objective was to simulate the car crash to know the material behaviour at different velocities and at different intervals of time, wheels were neglected, so that the simulation becomes simple. Scaled down model of a commercially available Sedan car was chosen for analysis having the Length= 0.22m, Width =0.15m and Height = 0.1 m. The wall was modelled with a dimension having Length = 0.1m, Height = 0.15m and thickness = 0.01m. The initial distance between the car model and the wall was made to be 0.1m.

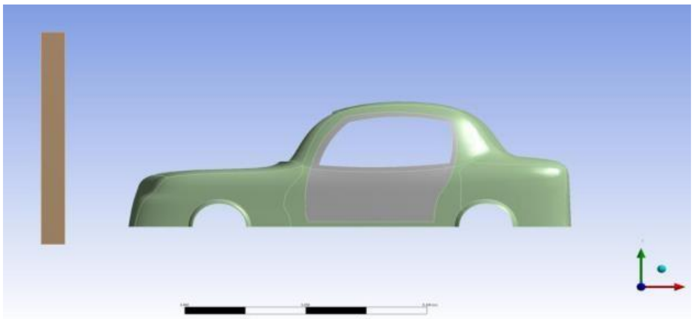

Fig- 5(a): Sedan car model

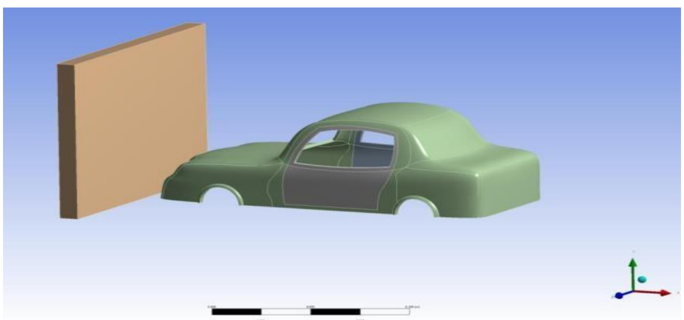

Fig- 5(b): Sedan car model

Table 1: Geometry Details

Object Name	Geometry
State	Fully Defined
Definition	
Source	C:\Users\Rigel\Documents\crash100_files\dp0\SYS\DM\SYS.agdb
Type	DesignModeler
Length Unit	Millimeters
Display Style	Body Color
Bounding Box	
Length X	0.21893 m
Length Y	1.e-001 m
Length Z	0.15 m
Properties	
Volume	1.9352e-004 m³
Mass	1.298 kg
Scale Factor Value	1.
Statistics	
Bodies	4
Active Bodies	4
Nodes	4338
Elements	7937
Mesh Metric	None
Basic Geometry Options	
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\Rigel\AppData\Local\Temp
Analysis Type	3-D
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Table 2: Geometry Parts details

Object Name	car-1	car	CORPUS	Solid
State	Meshed			
Graphics Properties				
Visible	Yes			
Transparency	1			
Definition				
Suppressed	No			
Stiffness Behavior	Flexible			
Coordinate System	Default Coordinate System			
Reference Temperature	By Environment			
Reference Frame	Lagrangian			
Material				
Assignment	Aluminum Alloy			Structural Steel
Bounding Box				
Length X	6.2857e-002 m	6.2858e-002 m	0.18277 m	1.e-002 m
Length Y	5.1742e-002 m		5.9046e-002 m	1.e-001 m
Length Z	1.0888e-002 m		8.4e-002 m	0.15 m
Properties				
Volume	3.2905e-006 m³	3.2809e-006 m³	3.6945e-005 m³	1.5e-004 m³
Mass	9.1147e-003 kg	9.0881e-003 kg	0.10234 kg	1.1775 kg
Centroid X	2.8786e-002 m	2.8784e-002 m	2.4145e-002 m	-0.105 m
Centroid Y	2.7917e-002 m	2.792e-002 m	3.5356e-002 m	5.e-002 m
Centroid Z	3.8922e-002 m	-3.8921e-002 m	-1.0602e-004 m	2.4835e-017 m
Moment of Inertia Ip1	1.3877e-006 kg·m²	1.3881e-006 kg·m²	1.0617e-004 kg·m²	3.1891e-003 kg·m²
Moment of Inertia Ip2	2.7295e-006 kg·m²	2.7308e-006 kg·m²	4.6971e-004 kg·m²	2.2176e-003 kg·m²
Moment of Inertia Ip3	4.0885e-006 kg·m²	4.0903e-006 kg·m²	4.1972e-004 kg·m²	9.9106e-004 kg·m²
Statistics				
Nodes	355	352	2035	1596
Elements	780	778	5407	972
Mesh Metric	None			

3.2 Meshing

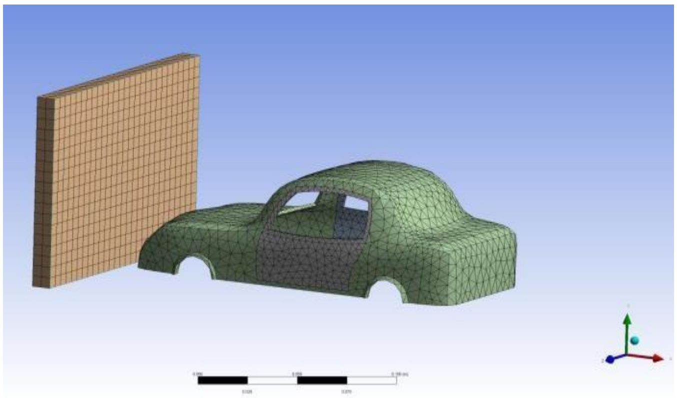

Figure 6: Tetra Meshed Sedan Car Model

Meshing process was carried out in ANSYS Workbench. Auto mesh was generated, with the elements of car model being tetragonal in shape and that of the wall being hexagonal in shape. Total number of nodes and elements were found to be 4338 and 7937.

Table 3: Mesh Details

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Explicit
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Medium
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Slow
Span Angle Center	Coarse
Minimum Edge Length	1.9485e-005 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	Explicit
Element Midside Nodes	Dropped
Straight Sided Elements	
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Full Mesh
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
Statistics	
Nodes	4338
Elements	7937
Mesh Metric	None

4. RESULTS AND DECISIVE GRAPHS

Simulation of Crash for a Scaled down Sedan car model was carried at different velocities using ANSYS Explicit Dynamics Approach. The initial distance between the wall and the front bumper of the car was 0.15m.

4.1 At 100m/s

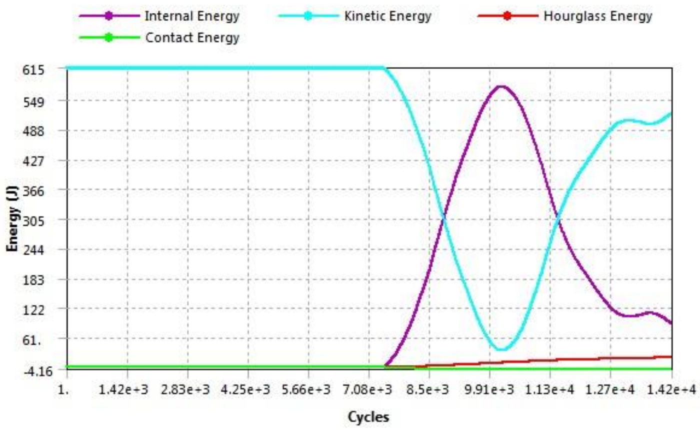

Chart-1: Energy vs. cycle graph at 100 m/s

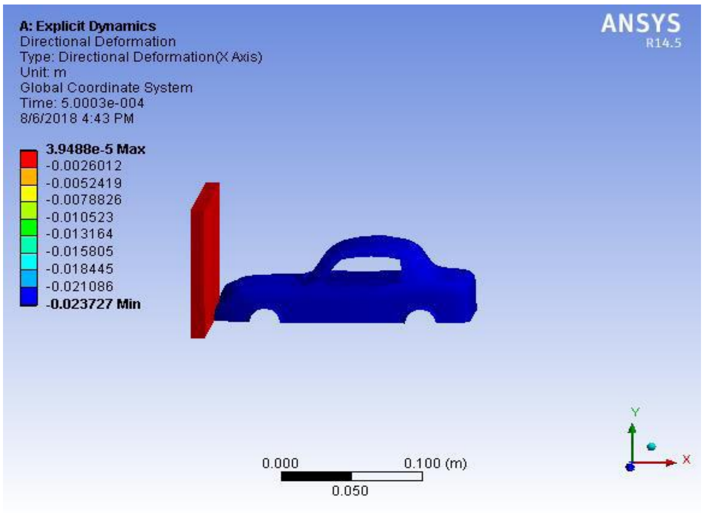

Fig-7: Directional deformation at 100 m/s

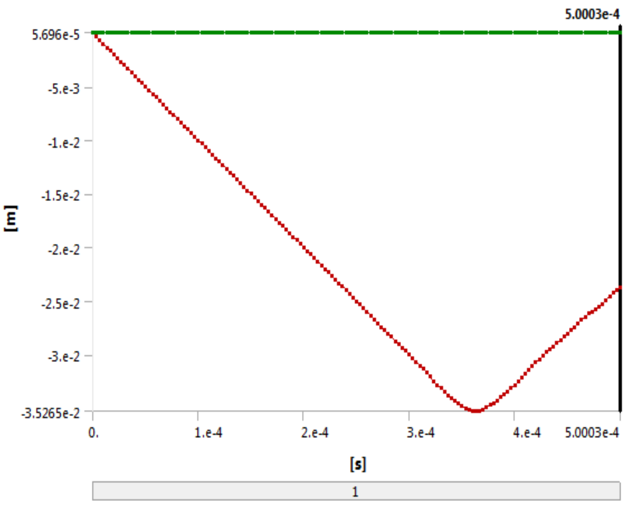

Chart-2: Directional deformation graph of deformation vs. time at 100 m/s

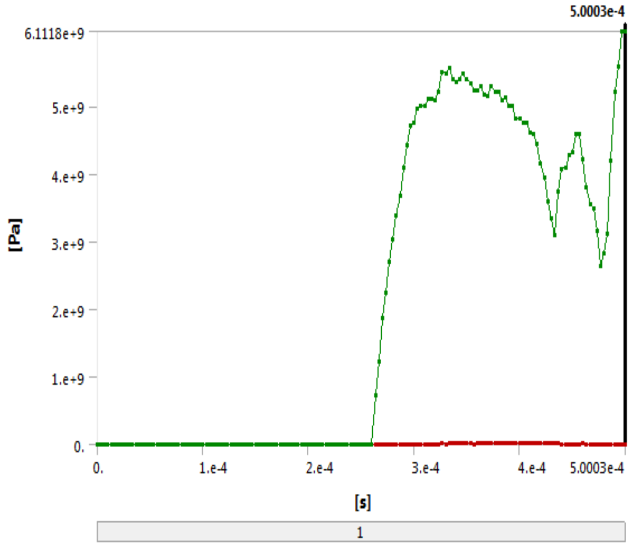

Chart-3: Equivalent stress graph of Pressure vs. time at 100 m/s

4.2 At 250m/s

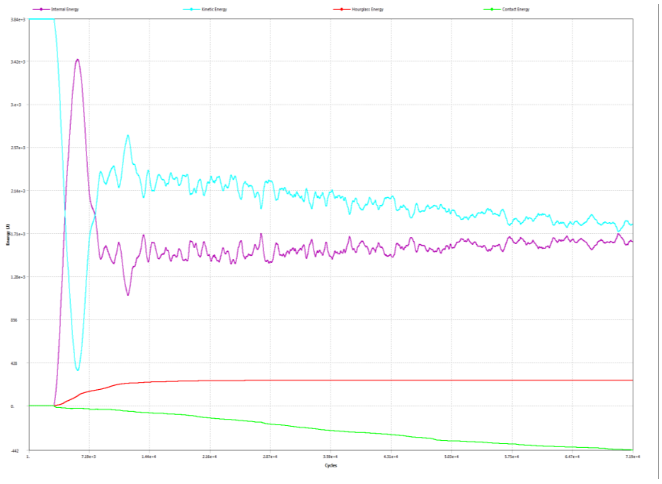

Chart-4: Energy vs cycle graph at 250 m/s

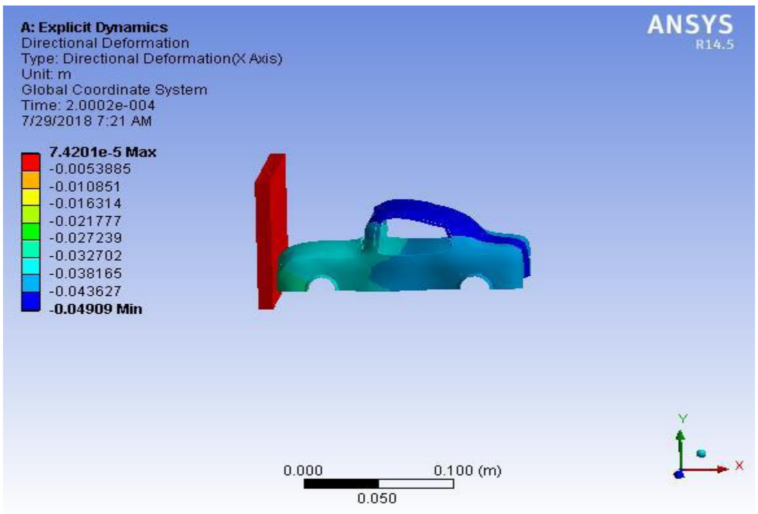

Fig-8: Directional deformation at 250 m/s

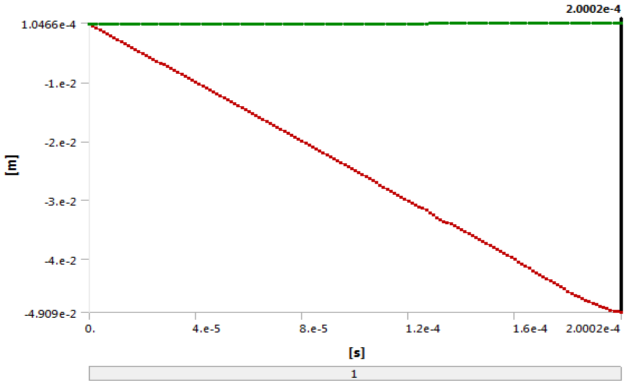

Chart-5: Directional deformation graph of deformation vs. time at 250 m/s

5. CONCLUSION

In the present work crashworthiness of the scaled down sedan car model was tested using the computational approach using ANSYS Explicit Dynamics tool. It was seen that the extent of plastic deformation of the car increased with increase in velocity with front part of the car absorbing the major part of the impact energy, Bumper, bonnet, A pillar and wind shield were the major parts to undergo plastic deformation. Also from the energy graphs it was clear that internal energy increased drastically and the kinetic energy decreased during the course of impact. After the impact the car body rebounds back and regains its kinetic energy, while the internal energy decreases

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