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Design and Analysis of Sports Utility Vehicle's Chassis and Its Passenger Cabin Cavity in Hyper Mesh and Solved using Nastran

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Abstract
CAE, Computer Aided Engineering is widely used in automotive and aerospace structural analysis. The results obtained from the simulations describes the reality with accuracy and cost effective. In this paper a conceptual model of a Sport Utility vehicle was designed in Hyper-Mesh based on its body in white which is represented in 1D beam structures of different cross sections and analysed the chassis by obtaining the mode shapes and Modal Frequency Responses using SOL103 and SOL111 (solver functions) utilizing MSC Nastran. The vehicle's passenger cabin vibrations also analysed using the same procedure.

Keywords
CAE, Nastran, Structural Analysis, Cabin Noise, SUV

I. Introduction

Hypermesh is a Finite element pre-processor coded by Altair Engineering Ltd., It's a substantial software package used for designing of complex models, for static and dynamic structure analysis. The vital part about this software is ease of constructing the model using different dimensional accessibility. For simpler and basic design and analysis. 1D model is suitable whereas for highly detailed complex models 3D solid elements are considered. 2D modelling is the most optimized and feasible designing approach for faster and reliable results [1].
NASTRAN, is an acronym formed from NASA STRucture ANalysis. It is a finite element analysis (FEA) program is commonly utilized for performing structural analysis [2].

II. Vehicle Specifications

A. Technical Data

Table 1:

Height	1713mm
Length	4644mm
Width	1891mm
Wheelbase	2774mm
Track Front	1632mm
Track Rear	1586mm
Weight (w/8Speed gearbox)	2485kg

B. Body in White

Body in white or BIW refers to the stage in automotive design or automobile manufacturing in which a car body's sheet metal components have been welded together — but before moving parts (doors, hoods, and deck lids as well as fenders), the motor, chassis sub-assemblies, or trim (glass, seats, upholstery, electronics, etc.) have been added and before painting.
The BIW of XC60 is shown the figure. It used 3 different material which are Steel, Aluminium and Magnesium. There were 5 different grades of steel based on their tensile strength used to reinforce the structure.

III. Hyper-mesh Model Specifications

A. Components

Table 2: Component Specifications

ID	Component	Beam Section	Cross Section
1	Front End Support	Rectangle Box	2x40x50
2	Front Quartet Panel	Rectangle Box	2x40x50
3	A-Pillar Vertical Support Column	Rectangle Box	0.8x50x50
4	Base Support Column	Rectangle Box	1.5x80x60
5	B-Pillar	Rectangle Box	2.5x60x60
6	A-Pillar	Rectangle Box	2.5x60x60
7	C-Pillar	Rectangle Box	2x60x60
8	D-Pillar	Rectangle Box	2x60x60
9	Rear Bumper	T-section	50x50x5
10	Rear Roof Beam	Rectangle Box	3x60x60
11	Front Roof Support Column	Rectangle Box	2.5x70x30
12	Moon roof Support Beam	Rectangle Box	2.5x70x30
13	Wind Shield Support Beam	Rectangle Box	2.5x70x30
14	Internal Support Beam	Solid Circular Beam	20
15	Front Bumper Support Column	Rectangle Box	2x40x50
16	Front Bumper	T-section	50x50x5
17	Front Collision Support Column	Rectangle Box	3x40x50
18	Front Impact Bar	I-section	40x40x20x5
18	Support Links	Circular Tube	18x20 (Ri x Ro)
20	Tunnel	Rectangle Box	2x30x30
21	Seat Mountings	I-Section	50x50x5

B. Material and its Properties

Table 3: Beam Material's Properties

Material	Young's Modulus[E]	Poisson Ratio [Nu]	Density [Rho]	Damping [GE]
Steel	2.1e+08	0.300	7.8e-06	0.010
Aluminium	7.2e+07	0.330	2.8e-06	0.030

C. Nodes

There were more than 100 temporary nodes created, translated and reflected to make the BIW of the vehicle. The component front end itself has 27 node to enhance detail of the structure.

IV. Designing Methods

Note: the designing process is begun with creating material, properties and components.

A. Nodes Creation

The temporary nodeswere created using the node option from the geometry menu.

B. Lines

The lines from the geometry option were used to create the lines by switching the components between the nodes. For creating curved lines and arcs two different option smooth lines and 3point arc were utilised.

C. Cross Section

The cross section that are mentioned in table designated for different components were created using the Hyperbeam option in 1D menu.

D. Meshing

Meshing of the components were executed using Line mesh option from 1D menu, by switching the components and assigning the property the meshing was done, which reduces the step for assigning property separately. Fig. 1 show the top, left hand side view and isotropic view of the meshed model.

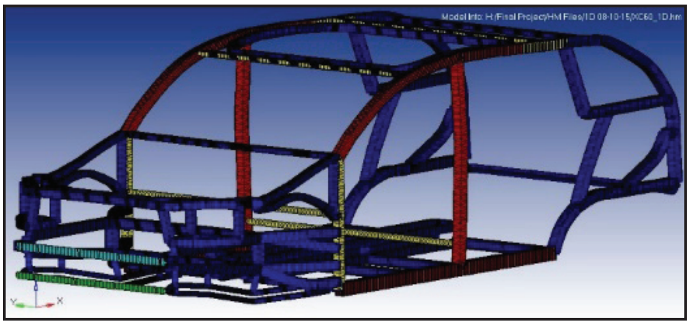


Fig. 1: Isometric view of Meshed Model

E. Mass of the Vehicle

The weight of the BIW must be around 300-400 kg. The model designed weighs 334.311 kg, which is acceptable mass for an SUV.

V. Mode Shapes and Frequencies Results

A. Torsion

The Mode 7 carries torsional deformation of the vehicle having frequency of 19.08Hz. The deformation show in the fig. 2, depicts the front end and pillars are having enough structural rigidity towards displacement whereas the rear undergoes for maximum displacement.

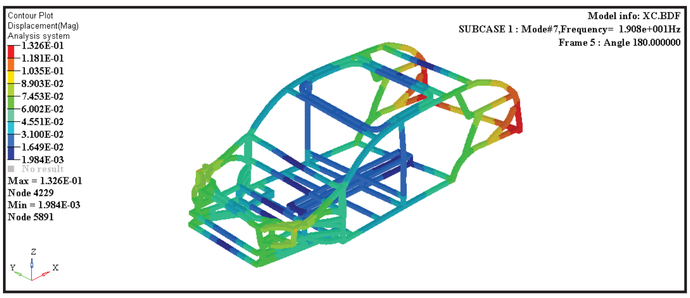


Fig. 2: Torsion Deformations

B. Lateral Bending

Mode 8 shown in the fig. 3, depicts the lateral bending of the structure along 'y - direction' having the frequency of 25.61Hz with maximum tail deformation.

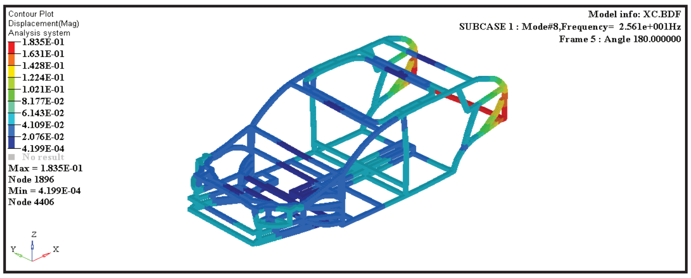


Fig. 3: Lateral Bending

C. 2nd Order Lateral Bending

The second order lateral bending having frequency of 28.32Hz occurring maximum displacement at moon roof and c-pillar beam along 'y-direction', shown in the fig. 4.

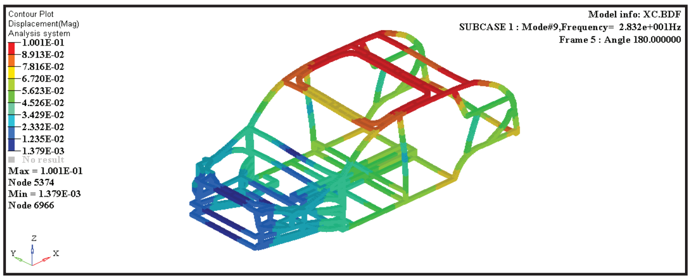


Fig. 4: 2nd order Lateral Bending

D. Bending

Bending of the structure take the mode 10 having the frequency of 30.50 Hz with maximum displacement at the tunnel only rest of the structure has enough rigidity to with stand the bending moment, shown inthe fig. 5.

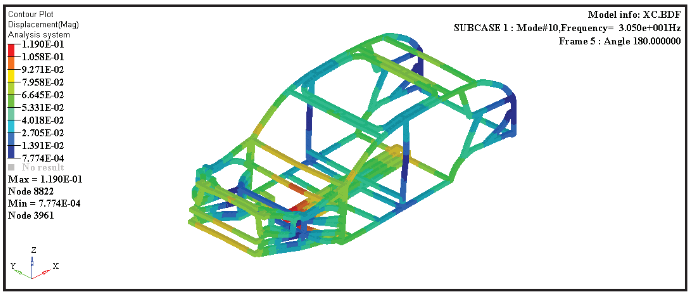


Fig. 5: Bending

E. 2nd order bending

The mode 11 having the 2nd order bending having 36.72Hz frequency with maximum displacement at the rear base column, Front quarter panel and A-pillar, shown in the fig. 6.

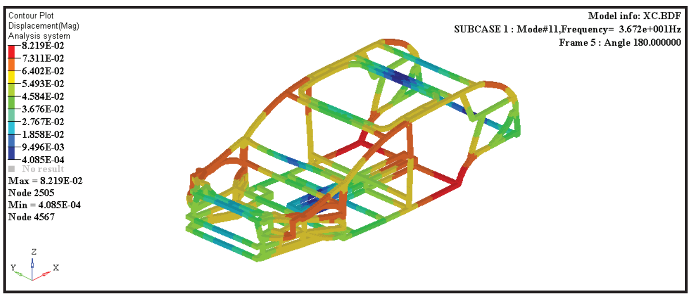


Fig. 6: 2nd Order Bending

F. 2nd order torsion

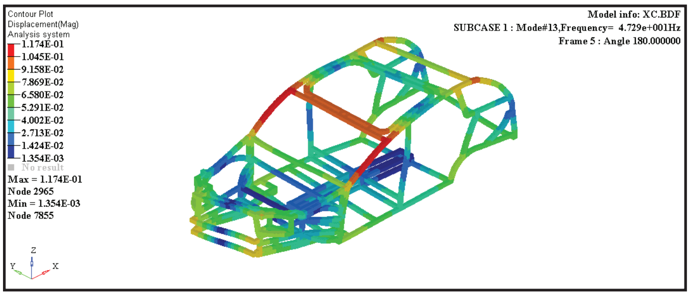


Fig. 7: 2nd order Torsion

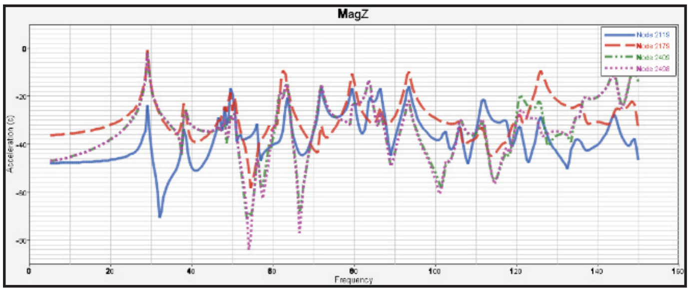
Mode 13 with 47.29Hz carries the 2nd order torsion of the structure with the maximum displacement at the 'A-pillar, shown in the fig. 7.

VI. Modal Frequency Response Results

For FRF analysis, nodes 7568 and 7279 were taken as input which is on ends of impact bar at the front of the model and nodes 2119, 2179, 2409, 2498 were taken as output node which on the corner of the base column in both side of the vehicle.

A. In-phase Excitation

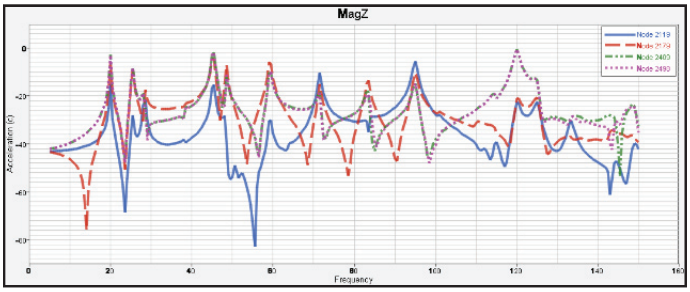
For the inphase excitation the force were applied on the 'Z-direction' with same magnitude.2nd order lateral bending, Bending, 2nd order bending and 2nd order torsion at the frequencies of 28.32, 30.50, 36.72 and 47.29 hz respectively occurred due to inphase excitation shown in the graph 1.



Graph 1: In-phase excitation

B. Out Phase Excitation

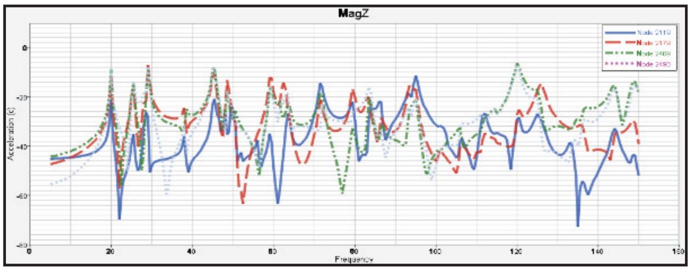
Out phase excitation is generated by opposite magnitude of forces applied in the 'Z- direction', by the torsion and lateral bending deformation were obtained at the frequencies of 19.08 and 25.16 Hz, shown in the graph 2.



Graph 2: Out-phase Excitation

B. Single Node Excitation

Single node excitation was generated by applying load to one node on the structure which created the Torsion, Lateral Bending, 2nd order lateral bending, 2nd order bending and 2nd order torsion with frequencies of 19.08, 25.61, 28.32, 36.72 and 47.29 Hz shown in the graph 3.



Graph 3: Single Node Excitation

VII. Cavity Modelling and Results

A. Compression

Mode 2 having the frequency of 66.56Hz undergoes compression mode of the cavity with maximum displacement at the tail, 3rd row seat of the vehicle, shown in the fig. 8.

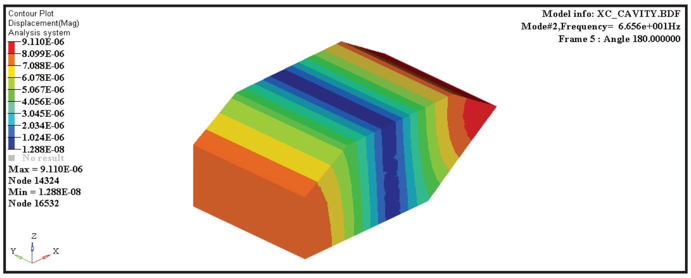


Fig. 8: Compression

B. Lateral Bending

Mode 3 having 101.3Hz depicts the maximum displacement at the lateral side of the cavity along 'x – direction', shown in the fig. 9.

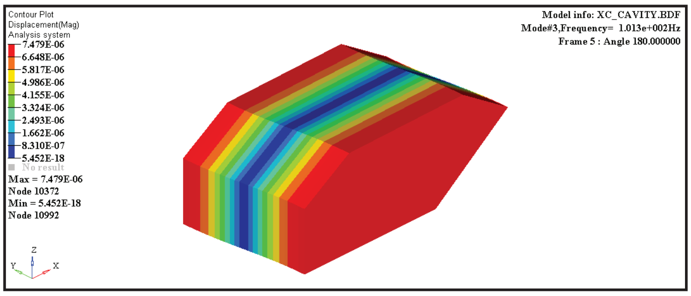


Fig. 9: Lateral Bending

C. 2nd Order Lateral Bending

Fig. 10 shows the 2nd order lateral bending moment at the corners of the cavity having the frequency of 121.2Hz with max displacement at rear corners.

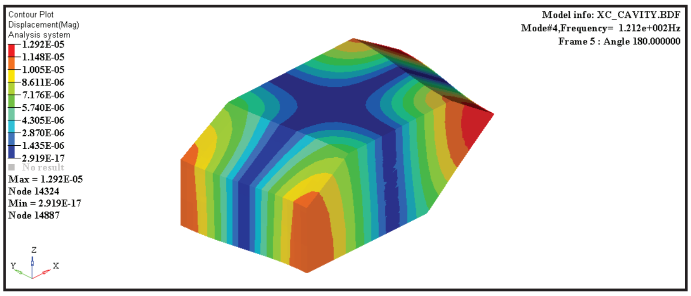


Fig. 10: 2nd order Lateral Bending

D. Compression and Tension Deformation

Mode 5 having the frequency of 122.9Hz carries the compression and tension deformation which represent the forces acts along 'x –direction' on the face of the cavity at front and rear, with maximum displacement at the rear, shown in the fig. 11.

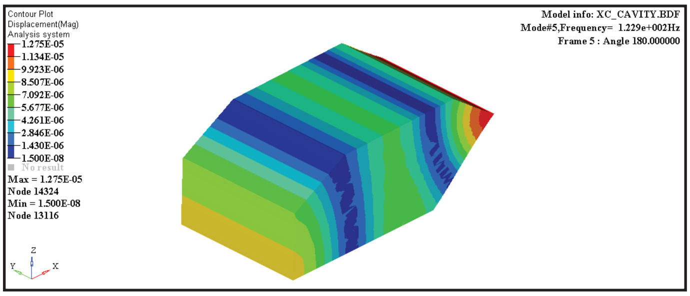


Fig. 11: Tension and Compression Deformation

VIII. Discussions and Future Development

A. Mode Shapes and Excitation Relation

Depends on the excitation forces acted on the structure, mode shapes takes place based on displacement frequency. Bending, Torsion, Lateral bending are the major deformation which is to be analysed in a structure. Table 4 discusses about the mode shapes and excitation relationship.

Table 4: Mode Shapes and Excitation Relationship

Frequency, Hz	Mode	Excitation phase
19.08	Torsion	Out-phase, Single node
25.61	Lateral Bending	Out-phase, Single node
28.32	2nd order Lateral bending	In-Phase and single node
30.50	Bending	In-phase
36.72	2nd order bending	In-Phase and single node
47.29	2nd order Torsion	In-Phase and single node

1. Front structure have enough rigidity to withstand the deformations.
2. Rear bumper and roof beam has higher displacement when compared to other components.

B. Future Development

In terms of design:

1. Increasing the detail of the model by adding 2D and 3D elements like sheets, Glass, connectors, welding points.
2. Modifying the cross section of the beam for better structural rigidity.
3. Adding doors, suspension mounting hill, floor panels.

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Hariharan Perumaal Rajasekaran received his Bachelor of Technology in Mechanical Engineering from SRM University, Chennai, India, in 2011-2015, He had worked on a project of "Parameter Optimization in High Speed Machining of Magnesium Alloys - ZE41 & AM60" in SRM University. He is currently pursuing his Master of Engineering in Automotive Engineering at Royal Melbourne Institute of Technology, Melbourne, VIC, Australia. He is interested in Automotive CFD, FEA design and analysis of cars, currently working in CFD analysis of car body with and without spoiler and Electric Vehicle trends and its future in Indian Automotive Market.