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Experimental-Numerical Modal and Impact Analysis of Car Bumper

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Abstract- **The objective of this study is to validate the experimental modal analysis of bumper results with numerical modal analysis of bumper. The bumper model is created through CATIA V5 R20, meshing and analysis is done through HYPERMESH and OPTISTRUCT respectively. The main aim of the modal analysis is to find out natural frequency, mode shapes to avoid failure of car parts. If the natural frequencies of bumper or any other parts equal to natural frequency of the engine system leads to failure of system. Impact analysis is carried through ANSYS LS DYNA workbench which determines deformation and acceleration. Hence we design the bumper system, such a way that natural frequency of bumper and any other car parts should not coincide. Experimental results shows low values compare to the numerical results. The impact test is carried out at speed of 48km/h (13926 mm/s), in order to determine the deformation and acceleration. The new bumper model has lesser deformation and acceleration compare to old model, thereby it reduces the impact energy transformation and it will reduce the injuries to passengers.**

Keywords—CATIA V5 R20; HYPERMESH; Bumper; Optisruct; ANSYS LSDYNA.

I. INTRODUCTION

The bumper is one of the protection methods which is used to avoid the low speed accidents.it is placed in front or rear car body or other vehicles. Automobile bumpers are designed to observe the energy during front and rear impact of car such way that we can select best materials and geometry it should possess the above two requirements with minimum price. Bumpers are not able to avoid fractures at high speed it applicable only minimum speed Ranges (30-50 km/s).It is able prevents injury to passengers at low speed as well as design to protect the hood, fuel tank, exhaust and cooling system, trunk, grille ,headlamps etc. in low speed. The low speed front impact usually deforms the front bumper, which absorb most energy when vehicle is struck from front end. Since the impact speed of striking vehicle is very low, virtually no energy is transferred to the passengers of struck vehicle. At high speed front impact of car may cause injury to passengers and damages to vehicle. The front impact are conducted by taking 100 % overlap (100 % of width of widest part of the vehicle is considered). The bumper standards are provided by National highway traffic safety administration (NHTSA) that produces bumper standard to light passenger automobile vehicles. The bumper standards are applicable to performance requirement of passenger vehicles at low speed rear and front accidents.

Recently car bumpers have been vast amount of alteration over Decades as understanding of materials and safety improved; Modern bumpers are designed to expand aerodynamics and performance of car.To protect the passengers inside the car from crash/impact and those people who may hit while crossing the road, despite of these advances, still no good agreement between group of scientist.Research on modification of bumper design and material selection still under process.

II. GEOMETRIC MODELLING OF BUMPER.

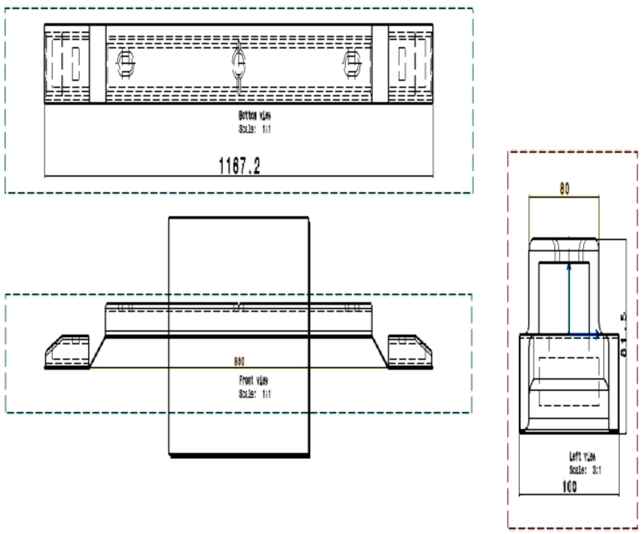

Fig 1 Drawing of bumper model

III. MESHED BUMPER MODEL

Fig-2 The meshed model

The model is meshed by using hyper mesh software's, taking element size as 5 mm. The meshed model consists of 12144 elements and 12172 nodes.
The element size = 5 mm
Types of element used= quad, triangles.

For mild steel

Mode-1

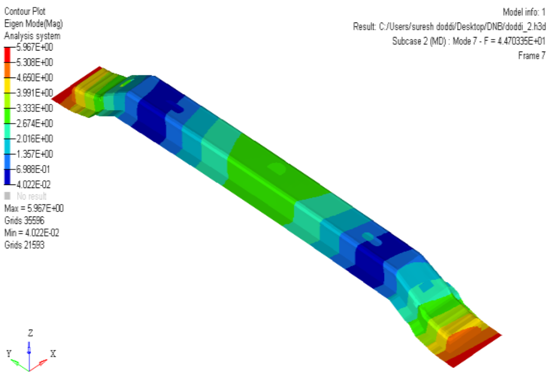

Fig -3 Mode shape for free-free model analysis, mode -1

Mode-2

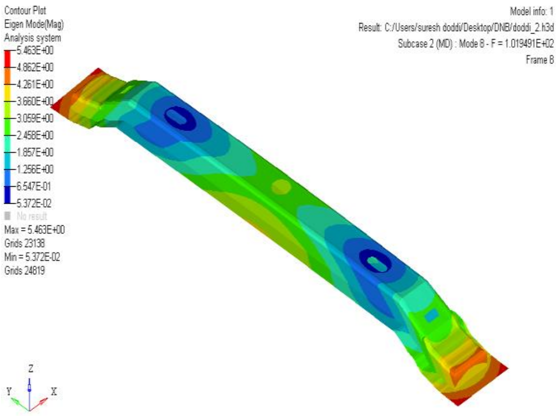

Fig -4 Mode shape for free-free model analysis, mode -2

Mode-3

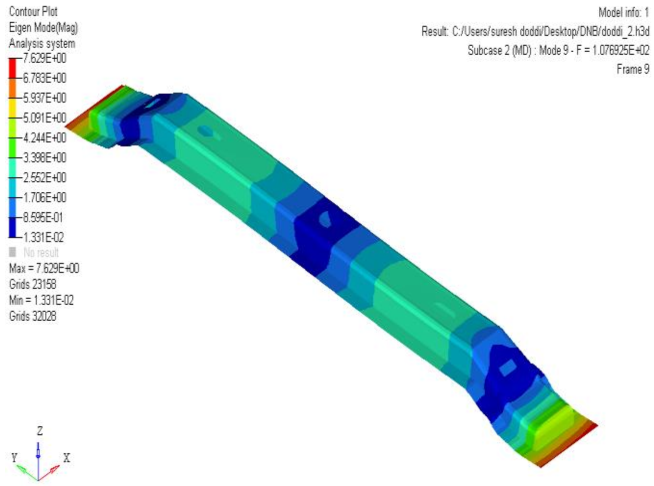

Fig -5 Mode shape for free-free model analysis, mode -3

Mode-4

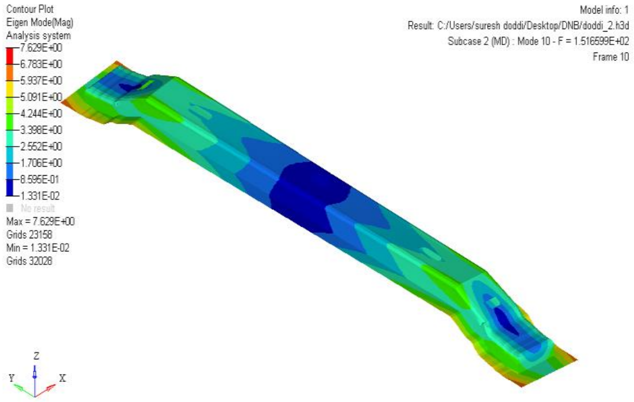

Fig -6 Mode shape for free-free model analysis, mode -4

Mode-5

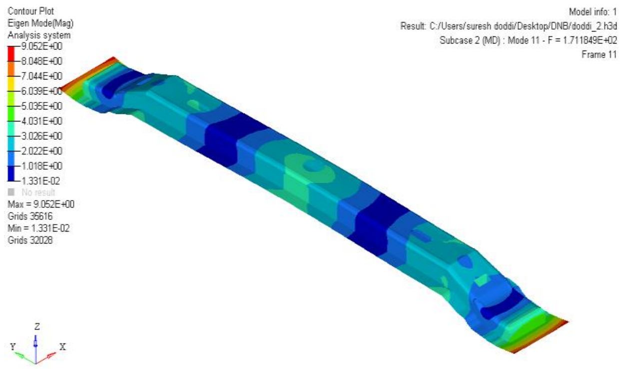

Fig -7 Mode shape for free-free model analysis, mode -5

Mode-6

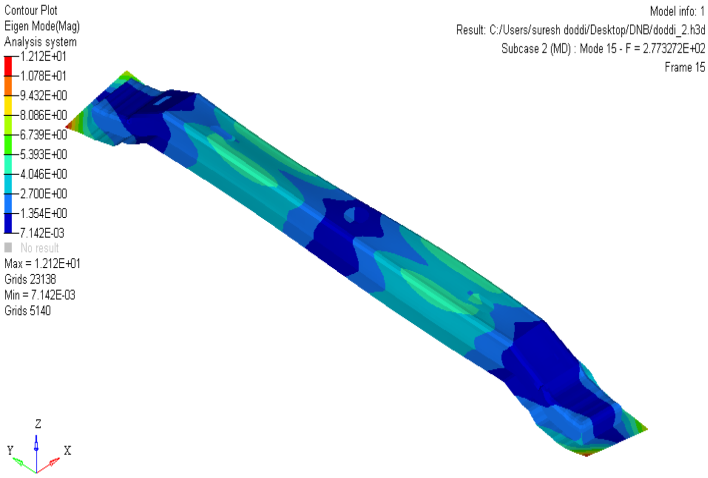

Fig -8 Mode shape for free-free model analysis, mode -4

IV EXPERIMENTAL METHODS

Using Experimental analysis we can find out natural frequency, mode shapes and damping ratio. We can find out the natural frequency anywhere of structure on single point on excitation of structure by hammer or any other different method. In our experiment we used hammer technique but at single point excitation we cannot find out mode shapes it requires different point on structure to find out mode shapes. Hence we conclude that mode shapes is local property and NF is global property of structure.

Dynamic signal analyser very important tool to conduct experiment because it acts as transfer device, hammer is known as input device and finally we got output through accelerometer it is connected to system. We can see the results in ME scope software. The ME scope software is very advanced version software it able solve the problems with isotropic, linear and time invariant. The random signals obtained during experiments that signals are converted into linear or sine waves through FFT techniques and gives results in digits.

Experimental setup includes all shown devices

1)Hanger/ wooden table
2)DSA(Dynamic signal analyser)
3)Accelerometer(O/P)
4) Hammer (I/P)
5)Computer
6)ME scope software

The ME scope software is used to analyze noise and vibration problems in machinery and structure by using experimental analytical data.

V. EXPERIMENTAL RESULTS

Table 1 Natural frequencies and damping percentage obtained from Experimental results

Mode Shape	Frequency (Hz)	Damping Percentage
1	.162	.379
2	59.6	1.41
3	146	.332
4	150	.211
5	279	.311

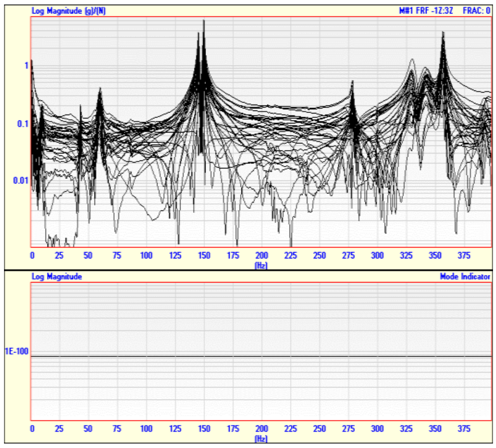

Fig 9 Log magnitude gravity divided by force g/F (m^2/s/N) V/S Natural frequency (Hz) for multiple modes, experimental results.

Table-2 Comparison of experimental modal analysis results with Numerical modal analysis results

Modes	NUMERICAL(Hz)	EXPERIMENTAL(Hz)
1	43	42
2	59.6	53
3	125	146
4	145	150
5	238	-
6	282	279

VI. IMPACT ANALYSIS OF BUMPER

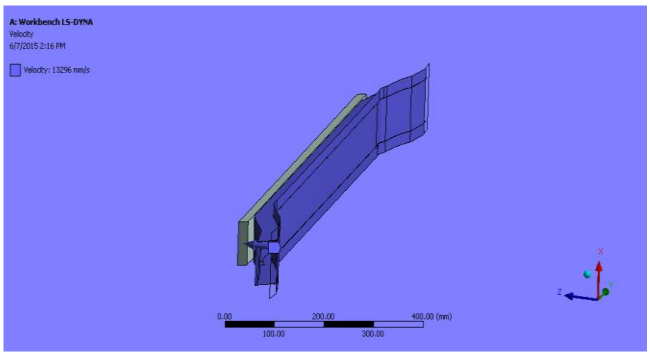

Fig-10 Bumper model with 100% surface offset

The element size =5mm
Total no of elements =2481
Total no of nodes =2481
Type of elements = Hex8, Tria, Quad4

The impact test is carried out in ordered to determine the deformation with respect to time; the analysis is done through ANSYS LS-DYNA workbench. Assume the car is running at speed of 48km/h (13926 mm/s), then it hits to another object (Considering the 100% surface offset). The LS-DYNA is example of explicit function.

The bumper model created in CATIA, and then it is imported to ANSYS LS DYNA workbench. The model is meshed and to create the rigid wall for hitting purpose. Assign the material property and physical property. Then apply the boundary conditions (Here we apply velocity as boundary condition), to create control cards for defining output of the result. Then solve the problem and determine the results.

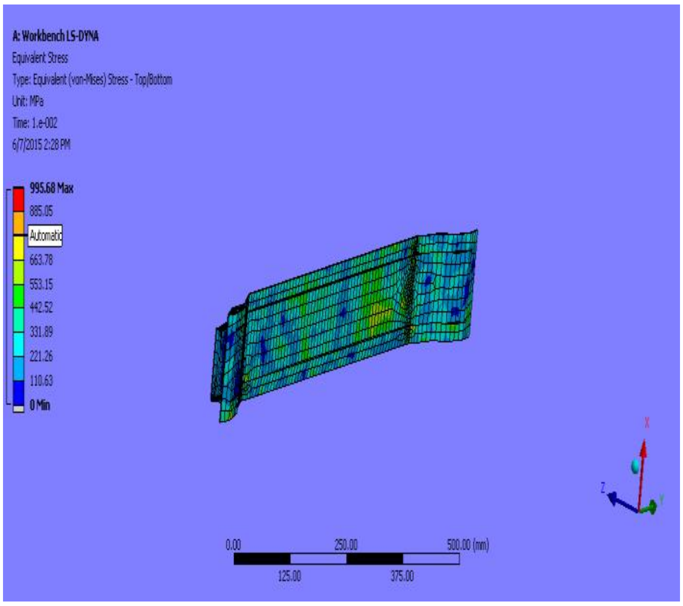

Fig-11 the von-mises stresses for impact analysis

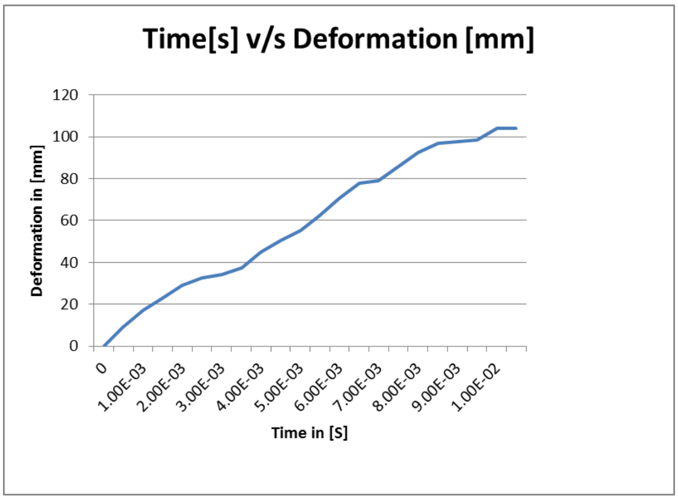

Fig -12 Deformation v/s Time graph for impact analysis for new model

From above graph we can analyse that, deformation increase as time increases, this test is carried out for every .002sec and their corresponding deformation shown in graph. According to FMVSS - 208 rules, the deformation values are safer for passengers as well as vehicle structure.

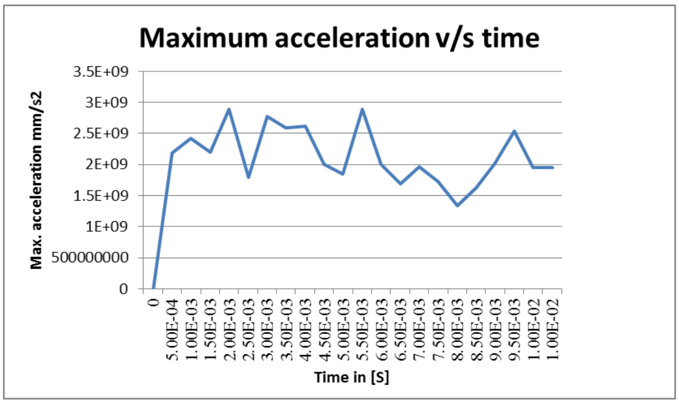

Fig -13 Maximum acceleration v/s Time graph for new model

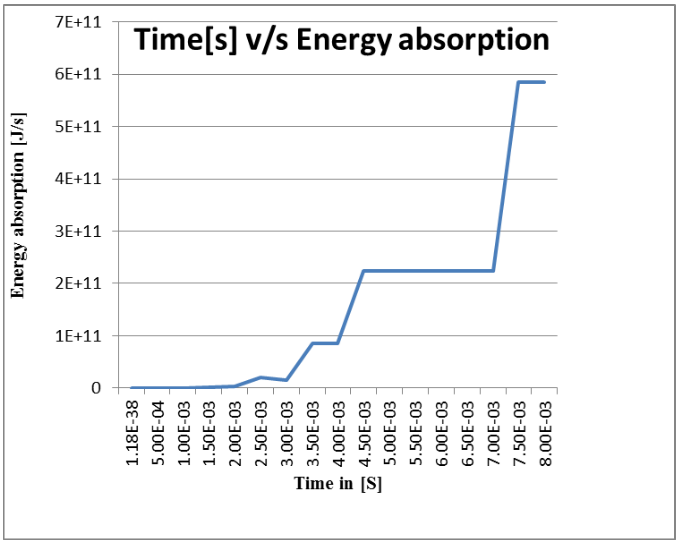

Fig -14 Energy absorption [J/s] v/s Time[s] for new model

VIII CONCLUSIONS

With our experimental results, we can conclude that experimental and numerical results are matched for some modes, but for few modes, it gives different natural frequency and mode shapes because in experimental analysis the model is partially fixed. Hence we got the different natural frequency and mode shape. For free-free modal analysis we got lesser frequency compare to fixed-fixed modal analysis, because fixing of model, it will increase the stiffness thereby increases the natural frequency. By adding stiffener to bumper it will increase the natural frequency of system, because increase stiffness of model. Mild steel has lesser natural frequency compare to aluminum, as the Natural frequency is function of both geometry and materials. The sharp corner geometries have lesser natural frequency compare to curved shape geometries. From experimental result we understand that natural frequency is local property and mode shapes are global property. From impact analysis results we analyse that, the new bumper model has lesser deformation and accelerations compare to older model, hence it will able to avoid the damage of other car parts. The deformation of bumper model mainly depends on structure, if the structures have circular holes and rectangular pockets; it will decrease the deformation of bumper there by increasing the energy absorption capacity bumper.

Further work is carried out on modal analysis and impact analysis, where in modal analysis, to increase the natural frequency by adding different stiffeners and also by changing geometries based on applications and usage of parts. Similarly in impact analysis energy absorption capacity is increased by providing crumple zone to new model, thereby it may reduce deformation bumper.

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