NVH Characteristics Study of Automotive Car Door by Numerical Method

Chandru B. T[1] Maruthi B. H[2], Dileep Kumar[3] , Vinay. V. Nesaragi[4],
1, 2, 3,4 Dept. of Mechanical Engineering,
East West Institute of Technology,Banglore,India

***Abstract*—Cars have various types of doors. The swinging doors which are the most common are almost the most complicated parts in a car since they not only determine the general guidelines of car style, but also are vital for passenger's safety by protecting humans from side crashes. First, car door geometry is modeled in catia and meshed in hyper mesh software. Then, a modal analysis between 0-50 Hz is done by hyper mesh. A frequency map of the door is extracted and compared with a reference map to identify shortcomings.. An algorithm is proposed to improve the car NVH behavior. At last, in order to verify the present algorithm, forced vibration is analyzedunder real road inputs for the model before and after improvement.**

Key word: catia,hyper mesh, NVH,frequency

1. INTRODUCTION

FEA is based on various formulations [1]; checking up numerical methods used is essential for estimation of validity of results [2]. FEA is a powerful computational tool for analyzing complicated structures like doors. If it is compared to experimental work, it saves much time and costs. Various types of tests are essentials for door design [3]. Firstly, NVH analysis which is noise, vibration and harshness analysis to detect natural frequencies, must be performed to give general outlook about stiffness in the doors, to check whether each door fulfill the predetermined targets which came from a similar designed car. The dynamic modal analysis entailed determination of the lowest natural frequency of the car door.

first used for finding the largest eigenvalue of a matrix. After the first eigenvector/value is obtained, the algorithm is successively restricted to the null space of the known eigenvectors to get the other eigenvector/values. In practice, this simple algorithm does not work very well for computing a large number of the eigenvectors because any round-off error will tend to degrade the accuracy of the computation. Also, the basic power method typically converges slowly, even for the first Eigen vector. Lanczos algorithm is a modification of the basic power algorithm in which each new eigenvector is restricted to be orthogonal to all the previous eigenvectors. In the course of constructing these vectors, the normalizing constants used are assembled into a tri-diagonal matrix whose most significant Eigen-values quickly converge to the Eigen-values of the original system [4]

The NVH requirements for the car door were defined by determining the lowest natural vibrational frequency for the door in the close position [5]. Toward that end, an eigenvalue analysis of the closed car door was conducted and the Eigen-modes and their corresponding Eigen-frequencies were obtained using the Lanczos numerical Eigen-solver.

NVH is not only for that checks, but also essential for checking FE mesh and revealing any improperly attached part in the body, because the number of natural frequencies depends on number of free bodies in the system.

Secondly, static analysis which is test of strength of car doors by applying forces at carefully selected points in various components of each door for extracting the displacement and stresses results. This can also be divided into global stiffness FEA and closure stiffness FEA. In the former, the effect of force on the whole door is analyzed while in the later, certain closures in the door are analyzed. Stress results are compared with elastic limit of the material of the component. It must be lower than it with a certain factor of safety. Displacement results are used for calculating stiffness of the component at a specified point through dividing the applied force with resulting displacement and the calculated stiffness values are com-pared to target. If results of some tests do not match targets, modifications must be suggested to some components such as web addition or component thickness increasing or some related parameters changing. Any suggestions must be thoroughly studied since it may affect other criteria i.e. increase overall car weight or decrease stiffness of some other parts. Test must be performed several times to verify validity of the suggested modifications until matching targets is reached all over the door.

Mesh was made by Hyper mesh6[7] according to general rules of meshing: elements must be of global size 8 mm and not to exceed 16 mm. Elements are of shell elements, quadrat-ic but triangular elements are allowed such that not to exceed 5% of number of elements. Meshing was made roughly at first and it was refined step by step till it reached an optimum.

METHODOLOGY

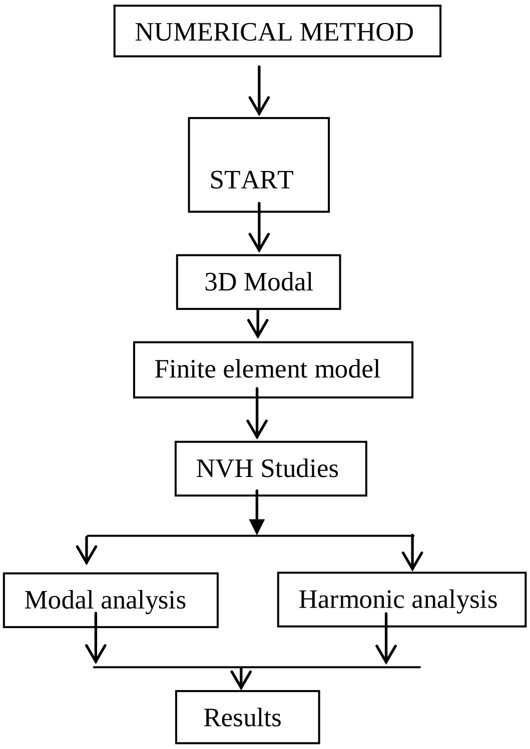


Fig: 1 methodolog

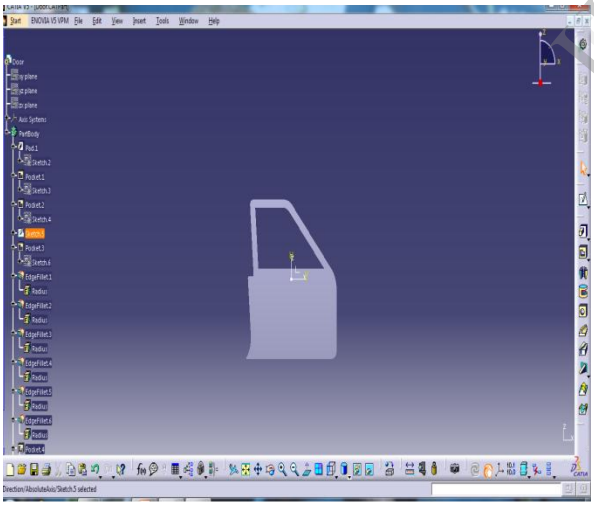


Fig:2 car door catia model

Basic concepts of CATIA software

1. CATIA software consists of 3D solid geometry and documents.
2. Drawings are created by models by drafting views in drawing work bench.
3. In the software we can refine the design by adding editing or we ordering feature.
4. We can generate drawings are assemblies at any time in design process.
5. It's a User friendly tool.
6. Almost all aerospace and automotive industries, the CATIA software can be used.
7. The surface modeling is very strong compared to other software [ex; UG, solid Works, pro-e].
8. In CATIA for different workbenches is available for different modeling Operations.
9. Option available in this software is more compared to other software.

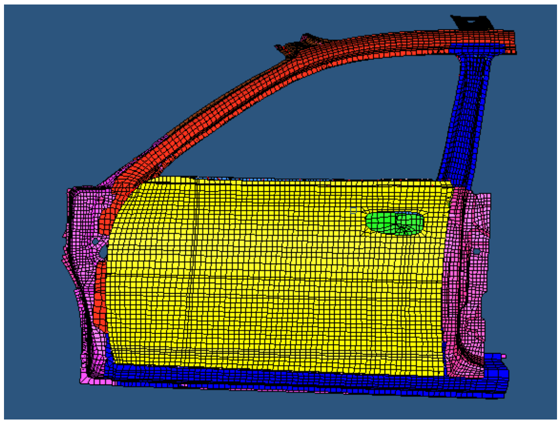


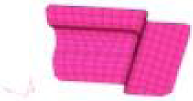
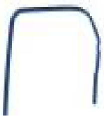
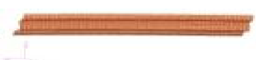
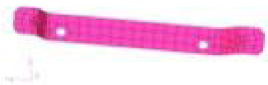
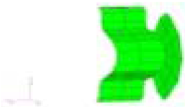
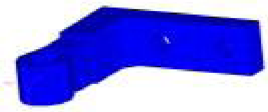
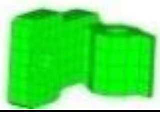
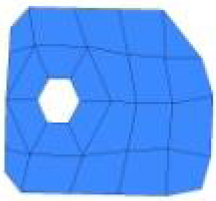
Fig: 3 meshed car door model

*Meshing*The goal of meshing in Workbench is to provide robust, easy to use meshing tools that will simplify the mesh generation process. These tools have the benefit of being highly automated along with having a moderate to high degree of user control. In order to carry out a finite element analysis, the model we are using must be divided into a number of small pieces known as finite elements. Since the model is divided into a number of discrete parts, FEA can be described as a discretization technique. In simple terms, a mathematical net or "mesh" is required to carry out a finite element analysis.

If the system under investigation is 1D in nature, we may use line elements to represent our geometry and to carry out our analysis. If the problem can be described in 2 dimensions, then a 2D mesh is required. Correspondingly, if the problem is complex and a 3D representation of the continuum is required, then we use a 3D mesh.

Fig:4 different name car door companents

Table:1Components statistics of front door

Sl no	name	materia l	image
1	Hinge reinforcement	St42	
2	Intrusion bar bracket (up.&Low	St42	
3	Intrusion bar	St42	
4	Latch reinforceme nt	St42	
5	Window regulator main bracket	Low carbon steel;	
6	Window sash	St42	
7	Outer Belt line	St42	
8	Inner Belt line	St42	
9	Outer Belt line reinforcemt	St42	
10	Outer panel	St42	
11	Inner Panel	St42	
12	Window regulator auxiliary bracket	St42	
13	Handle bracket	St42	
14	Fixing hinge	St42	
15	Mobile hinge	St42	
16	Hinge reinforceme nt plate	St42	

Forces and boundary conditions were inserted to the resulted mesh according to each case as discussed below and analysis was carried out by hyper mesh Modeling of spot welding in FEA generally and in hyper mesh specially passed through several steps Cowed were per-formed according to general guidelines Taking into con-sideration its behavior under dynamic analysis and strength under various loadings Materials of door components are given in Problems; revealed by the FEA; are treated mainly by changing designs e.g. decrease an opening, duplicating hinges, but modifying material remains an option. Strength to weight ratio of both doors components still has an opportunity to be increased by changing material used. Checking of material used was carried out . In which it is noticed that the highest strength steel used is steel 42 and its weight percentage to all door material is 25%. That means that, from strength point of view, there is still wide opportunity to decrease total door weight This can be achieved by changing material of door components to ultra-light steel.

Table:2General statistics of mesh of car front

	Front door
Number of nodes	39858
Number of elements	37640

Table :3Connectors statistics of front

	Front door
Spot weld	563
Rigid bars	94
Spiders	10

WORK AND DISCUSSION

modal analysis for structural steel

modal analysis is used to obtained for natural frequency for door component result extracted for different modes with different condition.

MODAL ANALYSIS FOR FREE FREE CONDITION

Fig:5 mode number 6th for free condition.

Fig:6:mode number 7th for free condition.

MODAL ANALYSIS FOR FIXER CONDITION

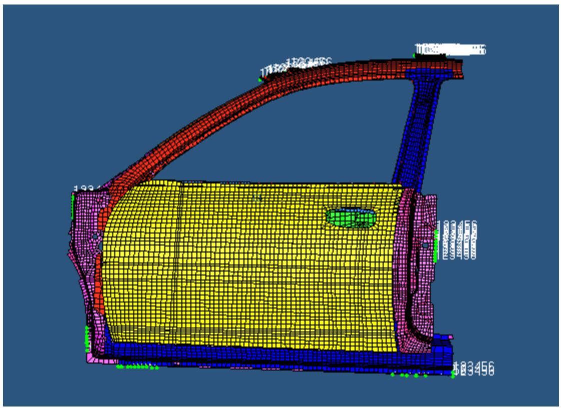


Fig:6 boundary condition for fixed modal analysis.

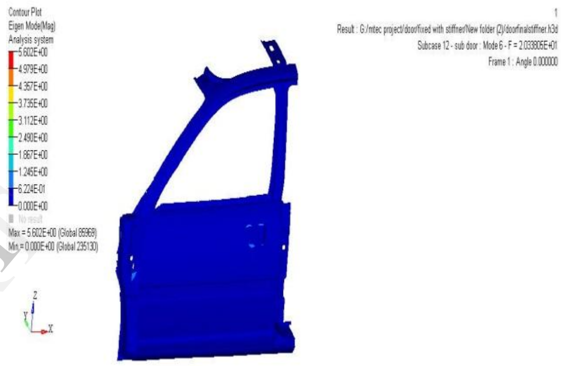


Fig:7 mode number 6th for fixed modal analysis.

Fig:8 mode number 7th for fixed modal analysis.

Table:4 different frequency for different condition.

Mode no	Forfree free condition (Hz)	Forfixer condition (Hz)
6	20.34	20.39
7	20.36	20.47
8	20.40	20.49
9	20.43	20.56

Shown in above table 4 the first two modes that are local modes while the second two modes are global modes. The local modes are shown in Figure 5 and 6with natural frequencies 20.34 Hz respectively.and oscillates mainly inner surface while the global modes are shown in Figure 7 and 8 natural frequencies 20.56 get >47Hz) respectively and oscillates mainly outer surface of the door. The first mode of the global modes is out of target and so, indicates that it needs to increase its stiffness This can be achieved by inserting metal partition inside the opening, to increase the local stiff-ness near lower slide fixing..

HARMONIC ANALYSIS FOR CAR DOOR

WITHOUT STIFFENER HARMONIC ANALYSIS.

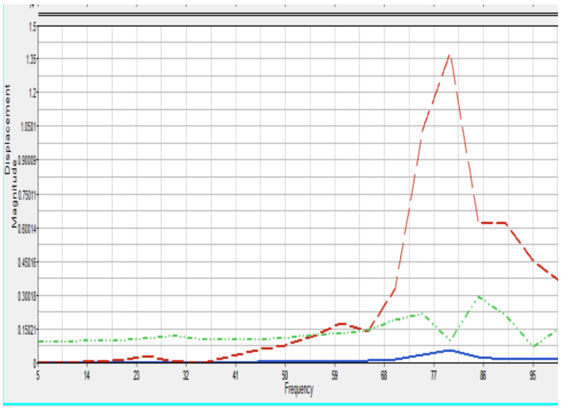


Fig:8 displacement and frequency graph with stiffener in car door.

WITH STIFFNER HARMONIC ANALYSIS

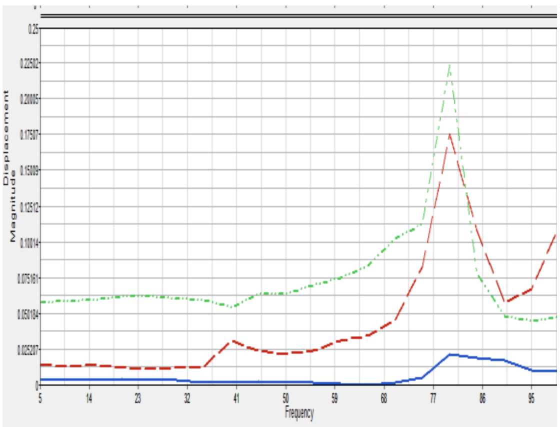


Fig:9 displacement and frequency graph with stiffener in door

Table:5 displacement and frequency.

	Without stiffener	With stiffener
Frequency (Hz)	73	75
Displacement (mm)	1.3	0.175

From the table 5 without door stiffener the displacement is 1.3 mm and without stiffener the displacement is 0.175 mm and frequencies are almost same so for better design and safety with stiffener is preferred.

CONCLUSIONS

1. Modal analysis of front doors reveals that they is in target.
2. modal analysis results is obtained for 10 different modes.in that first 5 modes are local modes and remaining is global modes.
3. The modal frequencies are obtained is >20 Hz which well away from the engine excitation of 16Hz.
4. This results is for ideal condition of engine.(engine at 1000 rpm and load at ideal)
5. Harmonic analysis is performed with and without stiffener for automotive car door .
6. In harmonic analysis displacement were obtained for both condition.
7. With stiffener displacement were less and safe design.

REFERENCES

[1] M. B. Kanchi, Matrix Methods of Structural Analysis, New Delhi: Wiley Eastern Limited.2nd ed., 1993
[2] R. D. Cook, D. S. Malkus and M. E. Plesha, Concepts and Applications of Finite Element Analysis, 3 ed., New York: John Wiley & Sons, 1989.
[3] M. Grujicic, G. Arakere, V. Sellappan and J. C. Ziegert, "Multi-Disciplinary Design Optimization of a Composite Car Door for Struc-tural Performance, NVH, Crashworthiness, Durability and Manufactur-ability," Journal of Materials Processing Technology, 2008.
[4] R. W. Clough and J. Penzien, Dynamics of Structures, 2 ed., Singapore : McGraw Hill Book Co., 1993.
[5] C. Lanczos, "An Iteration Method for the Solution of Eigen Value Problem of Linear Differential and Integral Operators," J. Natn. Bur. Stand., vol. 45, pp. 255-282, 1987.
[6] T. J. Hughes, "The Finite Element Method–Linear Static and Dynamic Finite Element Analysis," Prentice-Hall, Englewood Cliffs, 1987.
[7] A. E. Inc., "Hyper Study, User Manual," Troy, MI, 2007.