Natural Frequency Analysis of Automobile Seat

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ABSTRACT
In this paper, analysis of automobile seat for natural frequency is presented. The IGES model of automobile seat is analyzed on HyperMesh and post processing is done by using NASTRAN solver. All the pre-processing steps are described in details. In pre-processing automobile seat components are meshed with quads and tria elements and solid components are meshed with hex element. Analysis is conducted for free vibration by considering each component separately. Only a fundamental natural frequency is considered in the analysis of critical components.

Keywords
Fundamental natural frequency, finite element analysis, free vibration.

1. INTRODUCTION
Automobile Seat is one of the most suited components for the tactile response, as the passengers and driver is in contact directly with the seat. From Noise vibration Harshness (NVH) point of view in an automobile structure seats are the most important part. The human body can accept vibration up to certain limit beyond that it may cause discomfort to the human body.

Automobile seat is the interface between vehicle and human body. Whatever vibration are generated by the vehicle or by roads, they are transferred to the human body though the seat. Hence it is necessary to understand its behavior towards vibration response. Vibrational analysis of an automobile seat is done using finite element analysis (FEA) softwares HyperMesh and NASTRAN. Solution Sequence 103 (Normal modes Analysis) has been used to solve the characteristic equation by Lanczos Solver, a standard for dynamics by all the means. The seating system components have been treated as if they are in isolated conditions as this is a valid assumption where most of the structure of the seat is joined by flexible joints with free ends. An excellent example of this is the components like the arm rest and the backrest.

2. AUTOMOBILE SEAT
In an automobile, vibrations are generated by the engine and the road excitation which are transferred to the cabin. The human body has direct interface with seat. All the vibrations are transferred to the occupant through the seat. So to control the vibration, automobile seat investigation is required. Automobile seat is made up of number of components and each component has its own natural frequency. If the natural frequency of any component matches with the natural frequency of human body part there is a great chance of resonance.

Any component if disturbed it will vibrate freely with certain frequency, that frequency of the component is called as the natural frequency of that component. Every component has a different natural frequency and when it matches with the natural frequency of environment resonance will occur [2]. To avoid this all the natural frequency of the component need to be studied to check the safety of the occupant.

3. FINITE ELEMENT MODEL
The pre-processing of the model is done on HyperMesh 11 in which quick editing of the geometry is done, then, geometry is cleaned up to remove the unwanted edges like suppressed edges, non-manifold, free edges are removed and model editing is done. While geometry editing all the free edges are removed, other edges like suppressed edge non-manifold edges shared edges are checked and geometry of the components are modified for the meshing. All the major component of the seat is shell components and only one is solid component i.e. Arm Rest. Shell components are meshed with first order quad and tria element and solid element which is arm rest is meshed with hex element. The seat components are made up of low carbon steel of Modulus of Elasticity is $2.1*10^5$ N/mm^2, Paisson's Ratio 0.3 and Density $7.8*10^{-9}$ tone/mm^3. Fig 1 shows the finite element model of automobile seat. Few elements like cross wire, small spinders and large spinders are not considered in the analysis.

In the finite element analysis all the components are studied for the calculation of natural frequency for that all components are separately analyzed. Components of automobile seat are disassembled and geometry editing is done separately which include quick editing of the geometry, quality indexing, removing unnecessary edges joining of surfaces for proper meshing of the component.

Lower riser is one of the components of seat as shown in Fig 2 on which all the necessary editing is done in the pre-processing. All components are presented in different colors to avoid the confusion while analysis. In geometry editing different color edges are found which are red, green, blue and yellow. Red color edge indicates only one surface is available in the geometry which has to be removed to complete the meshing which are called as fee edges. All the red color edges have to be removed otherwise meshing will not be accepted by the component especially for the solid models. Green color edges show the intersection of two surfaces which are required in the pre-processing all the edges should be green, which shows that geometry is done with the editing. Green color edges are called as sheared edges. Blue color edges are suppressed edges which can recall whenever needed else they were kept as suppressed. Non-manifold edges presented by yellow color which shows that there are three or more surfaces passing though that edge.

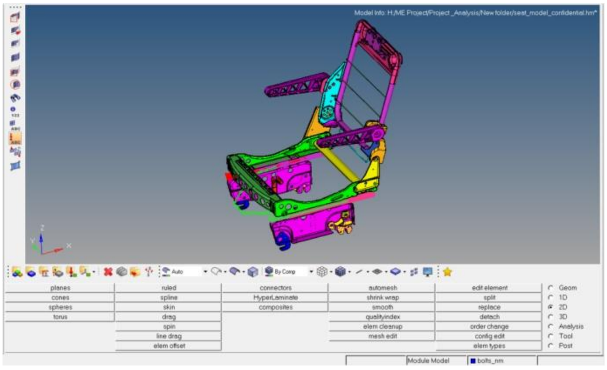

Fig. 1 Finite Element Model of Automobile Seat

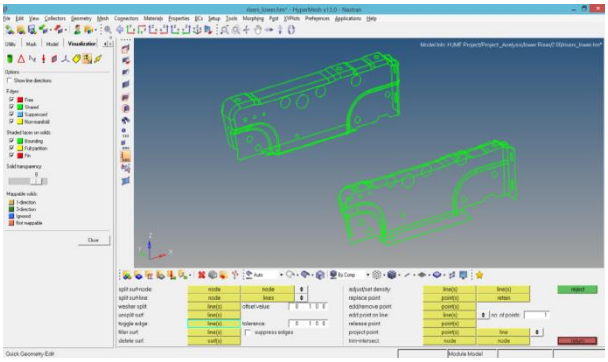

Fig. 2 Geometry Editing of Lower Riser

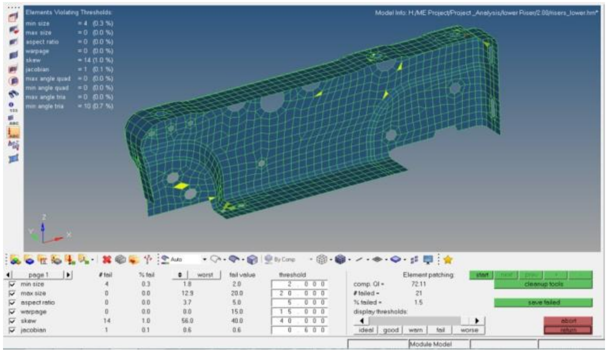

Fig. 3 Quality Indexing of Lower Riser

The next step is meshing of the component. In the meshing various factors which affect the results like minimum angle, maximum angle, aspect ratio, warpage, skew, Jacobian these factors need to check after meshing the component. Fig. 3 shows the quality indexing of lower riser which shows that the meshing is correct and it will no fail in the analysis. Similarly, all the components are meshed and analysis is done. The components are manufactured by various techniques such as fabrication, extrusion but these effects are very difficult to incorporate into FE framework. The typical material properties that the software requires are Young's Modulus, passion's ratio and Density.

4. FINITE ELEMENT ANALYSIS

The main goal of modal analysis in structural mechanics is to determine the natural mode shapes and frequencies of an object or structure during free vibration. The natural frequency is nothing but the frequency with which the any object will vibrate if disturbed and allowed to vibrate on its own without any external force. Presented work is dealing with the free-free analysis i.e. No external force is applied to the component at the time of analysis. Any single object allowed to vibrate freely, should show first 6 modes as rigid (natural frequencies = 0) & 7 modes onward deformable modes with positive value of natural frequency. Any number of zero frequency modes greater than 6 means that the model has free connections. All the real life objects have infinite natural frequencies, but the finite element analysis can compute natural frequencies equal to the degrees of freedom of the FE model only and the lowest natural frequency is known as fundamental frequency.

Fig. 4 shows the front cross member of the seat has first fundamental frequency is 119.2709 Hz. The result shows that there is the maximum displacement at the edges of front cross member and displacement is minimized at the central part of the model. This natural frequency is very close to the human body frequency range. Fig. 5 shows the upper cross member of seat has first fundamental frequency is 145.7044 Hz.

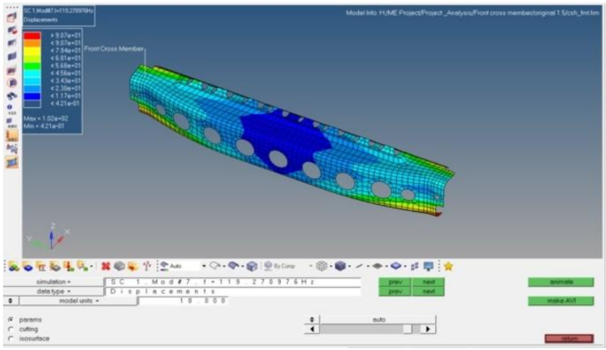

Fig. 4 Modal analysis of front cross member

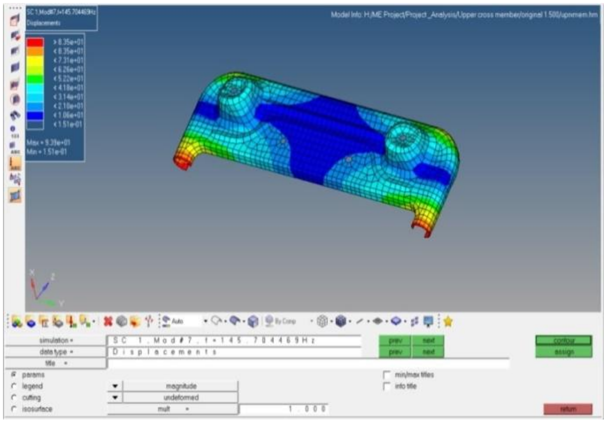

Fig.4 Modal analysis of the upper cross member

Accordingly, all the other components are analyzed on HyperMesh and NASTRAN. The fundamental natural frequency of the entire components is calculated and presented in tabular format.

Table 1.
Natural Frequency of Various Parts of Automobile Seat

Sr. No.	Name	Original thickness (mm)	Freq. (Hz)
1	ARBTLN	2.5	1803.406
2	ARBTOUT	2	1275.182

3	Back tube	1.3	72.4597
4	Cushion Tube	1.8	915.6581
5	Cusidmb	1.8	121.4026
6	Front Cross Member	1.5	119.2709
7	Head Rest	1.5	324.0828
8	Lower Pivot Bracket-L	2	779.6977
9	Lower Pivot Bracket-R	2	403.7089
10	Lower Riser	1.8	144.5645
11	Lower Track-L	2.2	475.7008
12	Lower Track-R	2.2	474.6252
13	Part-1	1.5	0.00125
14	Part-4	3	0.00154
15	Part-7	3	806.3643
16	Part-8	2	4950.017
17	Part-9	2.2	6317.415
18	Part-10	1.8	10358.4
19	Rear Hook	3	0.002889
20	REINFBT	1.5	493.3375
21	REINFBT-A	2	531.4475
22	REINFPLT	2	430.6703
23	Release Tube	1.15	68.04986
24	RsrSupTb	1.5	1180.066
25	Stop Bracket	3	2831.746
26	Upper Cross Member	1.5	145.7044
27	Upper Track-L	1.8	255.7507
28	Upper Track-R	2.2	474.6252

It has been observed that there are some components which have natural frequency very close to 80 Hz to 120 Hz. The natural frequency of the human body is 1-80 Hz [3]. The frequency range of few components has results which are very close to the human frequency range, hence there is a chance of resonance and discomfort in to passengers. These components need to be kept with a higher frequency range which will lead to increase the comfort level of occupant. It has been observed that when thickness increases the natural frequency of the component also increases.

5. CONCLUSION

The model analysis of automobile seat for vibration is studied and model is analyzed by using HyperMesh and NASTRAN. Components are studied for their quality indexing to insure the proper meshing of the component. Determination of natural frequency and identification of vibration parts of automobile seat is done. The results are presented in the tabular format which shows the natural frequency of the component with their fundamental frequency. Few components have a very low frequency range, which is close to the human frequency range that can cause discomfort to the occupant and chances of damage due to resonance are high. To avoid that the natural frequency range of components like back tube, front cross member, lower riser etc. should be kept at a higher level or they should be properly isolated to avoid resonance.

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