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NVH Analysis of a Car Roof Using Numerical and Experimental Method

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Abstract - *The scope of the project is to comment on the current trends and new development in the field of experimental modal analysis. To reduce the vibration in component there are two methods in the analysis namely modal analysis through FE method and experimental analysis.*

To carried out the FE method the component is created using software called CATIA V5 R20 and analysis is carried out using software called Altair Hyperworks 12.0, FE method is done by free- free method to get the different natural frequency or mode shapes at different nodes. The analysis is carried out in two ways, with stiffener and without stiffener; the stiffener is used to reduce the vibration of the component. The solver is used to get the natural frequency is Optistruct.

FE method is also done by fixed method and harmonic analysis also carried out using solver called MSC Nastran.

To compare the modal analysis result we are doing experimental analysis. It is carried out using original component to get natural frequency or mode shapes at different nodes and it is done only for free - free method.

Key Words: FE Method, Experimental analysis, free- free method, optistruct, harmonic analysis.

1. INTRODUCTION

The automotive industry is currently spending millions of dollars to improve NVH performance. The new design methods are starting to consider NVH issues throughout the whole design process. This involves integrating extensive modeling, simulation, evaluation, and optimization techniques into the design process to insure both noise and vibration comfort.
To effectively reduce the noise floor within a vehicle, a combination of materials must be used. This technique will result in a greatly reduced installation time, a serious reduction in the amount of added weight to the vehicle and bunch of money is saved in your wallet. When trying to reduce or eliminate various types of automotive noise, it is often necessary to utilize a variety of specialized noise control materials.
In the present work a numerical method using finite element is done to evaluate NVH characteristics of the roof and Experimental analysis is used to validate the old results and we are only in the field of experimental that is only dynamic analysis. The vibration characteristics of analysis are frequency, damping and mode shapes, in our analysis we are using frequency and mode shapes, after finish of analysis getting all three characteristics.
The features of experimental analysis are interest in only load where acting with respect to time, per second there will be 1000 sinusoidal waves are occurring and interested to reduce the vibration or dynamics.
The material considered for the roof component is Steel and having material properties like Modulus of elasticity $2.1*10^5$ N/mm², Poisson's ratio 0.3, and Density $7.87*10^9$ kg/mm².

2. METHODOLOGY

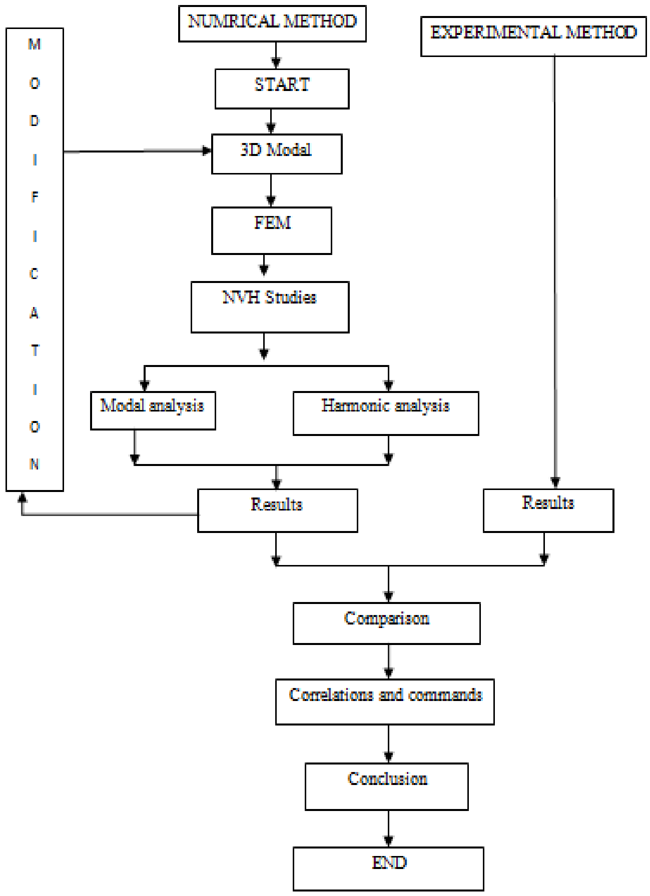

Figure.1. Methodology flow chart

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GEOMETRIC MODEL

Catia V5 software is used to create the geometric model of roof of a car as shown in Figure2.

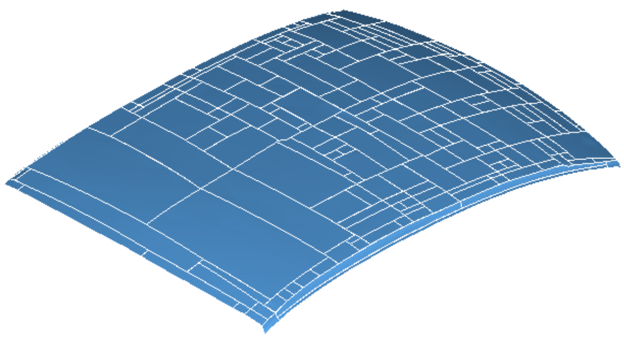

Figure.2.3-D view of geometric model of the roof of a car

FINITE ELEMENT MODEL

Meshing is carried out in Hyper mesh software. The meshed or FE model is as shown in Figure.3.

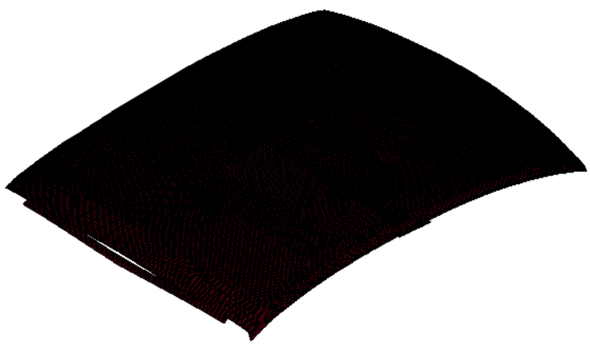

Figure.3. Meshed or FE model of the roof of a car

Table.1. General Statistics of meshed car roof

	Car roof
Element length	5
Number of elements	95654
Number of nodes	97214

LOADS AND BOUNDARY CONDITIONS

In the free - free analysis there are no loads and boundary conditions.

EXISTING MODEL

The modal analysis is done for roof component in terms of without stiffener and with stiffener to study the maximum displacement, minimum displacement and frequency occurs.

The figure.4.Shows the roof component having free - free condition and without stiffener.

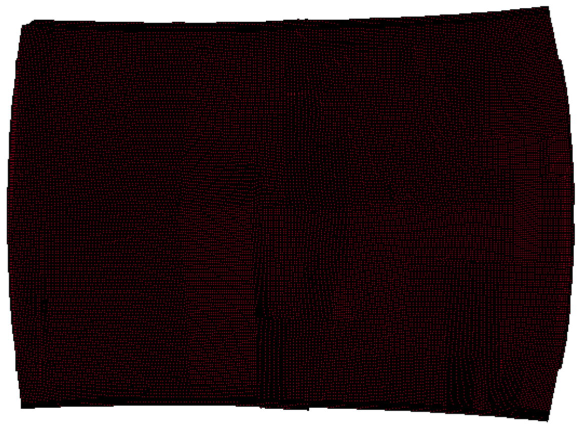

Figure.4. Meshed roof component in free- free condition and without stiffener

The figure.5 shows the maximum and minimum displacement occurred in the roof at mode 7th when the thickness of the roof plates is 1mm the maximum displacement occurred is 19.79mm and minimum displacement is 0mm.

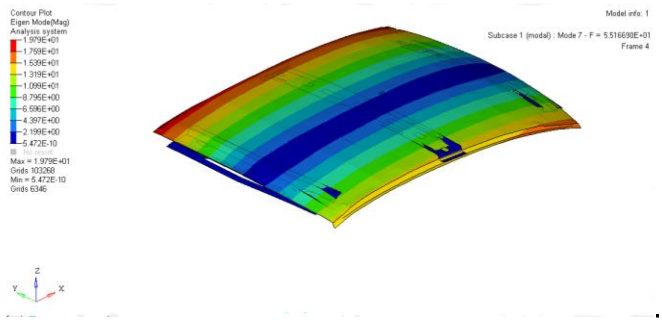

Figure.5. Mode 7th for free- free boundary condition without stiffener

The figure.6.shows the Mode 8th having maximum displacement of 22.09mm and minimum displacement of 0mm.

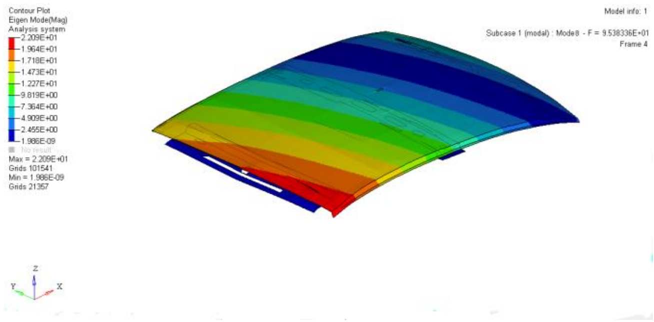

Figure.6. Mode 8th for free- free boundary condition without stiffener

Table.2. The frequencies and displacement of without stiffener condition

Mode No	FE Method	
	Without stiffener Frequency in Hz	Maximum displacement in mm
7	55.16	19.79
8	95.3	22.09
9	117	63.45
10	163	71.10
11	234	96.23

The figure.7.shows the roof component having free- free condition and with stiffener. The stiffener material used in the component is steel and having thickness of 6mm.

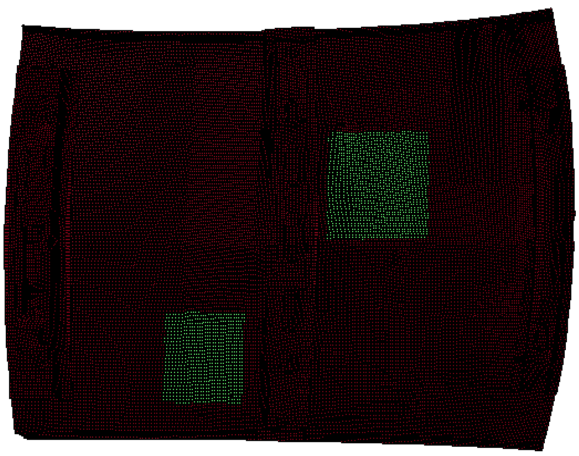

Figure.7. Meshed roof component in free- free condition and with stiffener

The figure.8.shows the maximum and minimum displacement occurred in the roof at mode 7th when the thickness of the roof plates is 1mm and stiffener thickness of 6mm the maximum displacement occurred is 11.23mm and minimum displacement is 0mm.

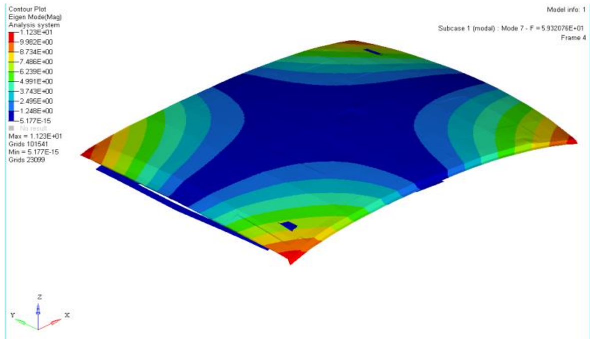

Figure.8. Mode 7th for free- free boundary condition with stiffener

The figure.9.shows the mode 8th having maximum displacement of 11.81mm and minimum displacement of 0mm.

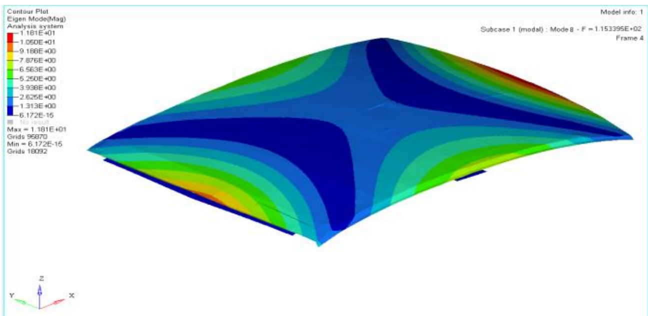

Figure.9. Mode 8th for free-free boundary condition with stiffener

Table.3. The frequencies and displacement of with stiffener condition

Mode No	FE Method	
	With stiffener Frequency in Hz	Maximum displacement in mm
7	59.30	11.23
8	115.3	11.81
9	118.3	30.56
10	209.2	33.42
11	245	56.23

3. EXPERIMENTAL MODAL ANAYSIS

Figure.10. The roof component hanged freely

The roof component is hanged freely using hangers and is shown in the figure 9 to minimize the stress in component and to allow the rigid body modes obtained from roof. After hanging the roof component, on the surface of component marked the points to measure the natural frequencies (there are 130 points marked in the roof surface). A mini accelerometer is fixed at certain reference point (here reference point is 70) for the set of FRF's measurement. Accelerometer is connected to DSA (Digital Signal Analyzer) through channel and other channel to hammer. The whole setup is connected to Laptop or PC to carry out the experiment, in Laptop or PC the ME scope software should installed early before start of experiment. All this arrangements of experiment is shown in figure 10.

Figure.11. The arrangement of experimental analysis

Using impact hammer the inputs is given to the roof and the frequency is noted on Laptop, here FFT analyzer samples the input signal and computes magnitude of its sine and cosine components, and displays the spectrum of these measured frequencies.FFT analyzer measures all the frequency components at same time hence this technique is speed.

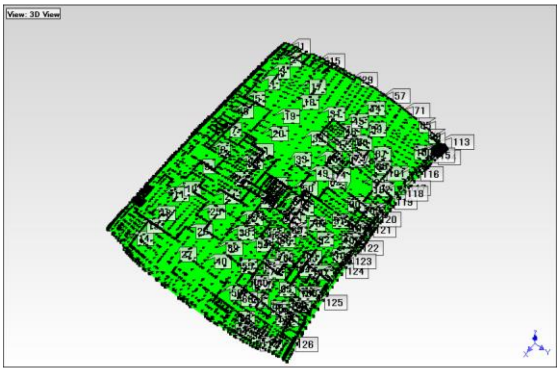

Figure.12. The nodes applied or marked on the surface of roof component

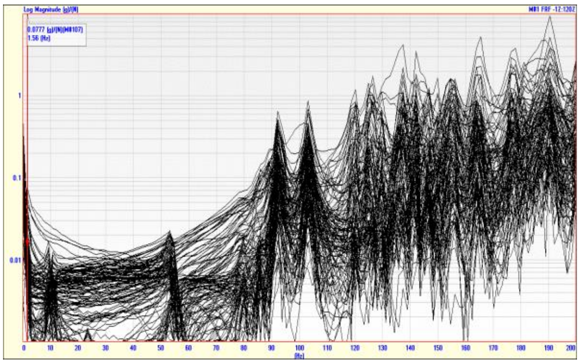

Figure.13. The combination of all frequencies occurred at different points

Figure.14. The roof component hanged freely using hangers without stiffener

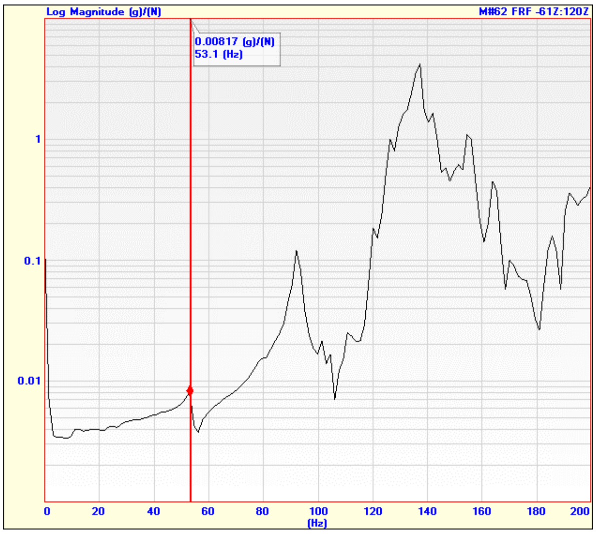

Figure.15. Mode 7th on free- free condition without stiffener

Table.4. The frequencies of without stiffener condition

Mode No	Experimental analysis without stiffener Frequency in Hz
7	53.9
8	92.5
9	111.0
10	120.0
11	130.0

Figure.16. The roof component hanged freely using hangers with stiffener

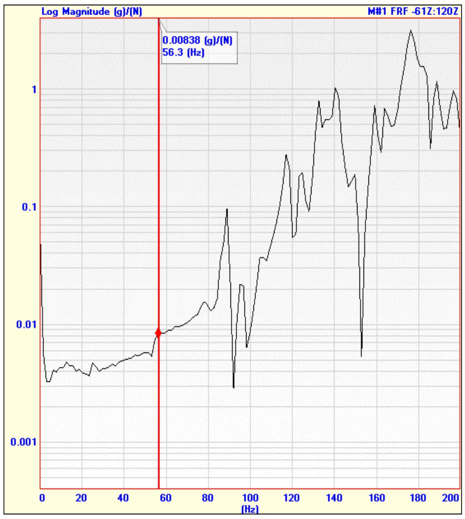

Figure.17. Mode 7th on free- free condition with stiffener

Table.5. The frequencies of with stiffener condition

Mode No	Experimental analysis with stiffener Frequency in Hz
7	56.3
8	95.3
9	117
10	125
11	136

4. RESULT AND DISCUSSION

Table.6. The comparison of FE Method and experimental modal analysis with stiffener

Mode No	Modal	Experimental
	Frequency in Hz	Frequency in Hz
7	59.3	56.3
8	115.0	95.3
9	118.3	117
10	209.2	125
11	215	136

Table.7. The comparison of FE Method and experimental modal analysis of without stiffener

Mode No	Modal	Experimental
	Frequency in Hz	Frequency in Hz
7	55.16	53.9
8	95.3	92.5
9	117.0	111.0
10	163.0	120.0
11	234.0	130.0

Table.8. The comparison of with and without stiffener of FE Method

Mode No	FE Method	
	Without	With stiffener
7	55.16	59.3
8	95.3	115.3
9	117	118.3
10	163	209.2
11	234	215

Table.9. The comparison of with and without stiffener of experimental modal analysis

Mode No	Experimental analysis	
	Without	With stiffener
7	53.9	56.3
8	92.5	95.3
9	111	117
10	120	125
11	130	136

Fixed- fixed mode without stiffener

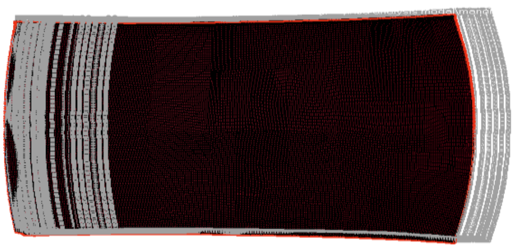

Figure.18. The roof component in fixed method without stiffener

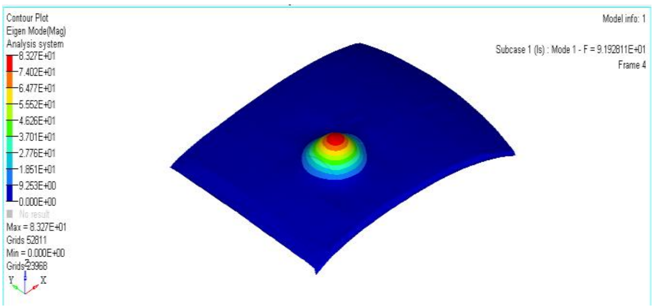

Figure.19. Mode 1st for fixed boundary condition without stiffener

Table.10. The frequencies and displacements of fixed-fixed mode without stiffener

Mode No	Fixed- fixed mode without stiffener	
	Frequency in Hz	Displacement in mm
1	91.92	83.27
2	134.07	98.88
3	144.56	70.79
4	151.95	69.81
5	160.55	67.07
6	171.43	90.02
7	174.41	51.93
8	183.89	65.45
9	186.05	48.79
10	189.05	82.57

Fixed-fixed mode with stiffener

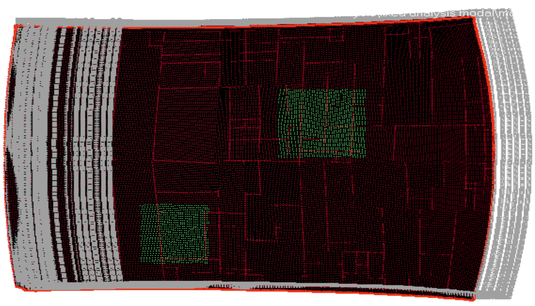

Figure.20. The roof component in fixed method with stiffener

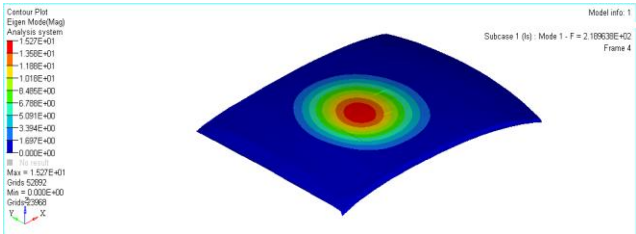

Figure.21. Mode 1st for fixed boundary condition with stiffener

Table.11. The frequencies and displacements of fixed-fixed mode with stiffener

Mode No	Fixed -fixed mode with stiffener	
	Frequency in Hz	Displacement in mm
1	218.06	15.27
2	255.87	13.15
3	267.66	11.50
4	320.98	12.57
5	342.86	11.40
6	362.24	10.44
7	379.04	9.96
8	381.93	11.62
9	422.50	9.48
10	428.60	13.08

Harmonic Analysis

Simple harmonic motion is the motion of a simple harmonic oscillator; the motion is periodic, as it repeats itself at standard intervals in a specific manner-described as being sinusoidal, with constant amplitude. The harmonic analysis is carried out using MSC Nastran which is characterized by its amplitude, its period which is the time for a single oscillation, its frequency which is the number of cycles per unit time, and its phase, which determines the starting point on the sine wave.

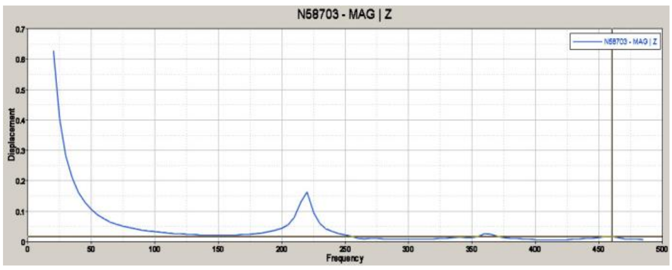

Figure.22. Simple harmonic analysis is performed in fixed-fixed mode with stiffener displacement Vs Frequency.

Table.12. Displacement and Frequency

	With stiffener
Frequency (Hz)	218
Displacement(mm)	16

The simple harmonic analysis graph compares the fixed-fixed mode shape frequency values. The key material properties that are pertinent to maintenance cost and structural performances are density, young's modulus and poison's ratio.

5. CONCLUSIONS

The analysis and improvement of a vehicle body structure based NVH behavior is investigated by FEM or numerical method. Firstly, the surface modeling is accomplished for the vehicle body in Catia and method in hyper mesh software. Then the FE method is analyzed through free- free and fixed mode shapes and experimental modal analysis also done in free -free mode condition.

From the two conditions with stiffener and without stiffener the frequency values obtained from the FE method and Experimental method are compared due to increase in the frequency values the vibration of the component decreases and also due to decrease in the vibration automatically the noise of the component also decreases.

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