VIBRO ACOUSTIC ANALYSIS OF LAMINATED COMPOSITE PLATE ROOF OF CAR BODY

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ABSTRACT - *The study of vehicle interior acoustics in the automotive industry has gained importance due to Legal restrictions, growing demand for comfort, to reduce the number of prototypes and High performance of modern computers. The comfort noise level that accepted by human being is between 55 to 60 DB. The ability to predict the interior acoustic sound field in a vehicle is important in order to avoid or to minimize unwanted noise conditions, such as boom or high pressure levels at cavity resonance frequencies. In this project a car is designed and a 3D model is created using CATIA. In this work an acoustic modal analysis is carried out for a maruthi swift car model. The analytical procedure is discussed and some results are shown. Acoustic modal analysis is used to find out the resonance frequencies and validated with theoretical readings. And engine and interior part sound pressure is considered to predict the noise in the car. As well as six types of car roof materials are considered to improve the low resonance amplitudes. Analysis done in ANSYS 19 Workbench.*

KEYWORDS: vibro acoustic analysis, study on sandwich material damping and material comparison.

INTRODUCTION

In the highly competitive automotive industry, there is an ever increasing need to reduce interior noise in passenger vehicle cabin which is important quality issue for a passenger vehicle. The increase in interior sound pressure causes an undesirable booming noise at lower frequencies of 0 to 200 Hz and is induced due to the road or power train input. An acoustic boom is a complex phenomenon caused due to the interaction of the car structure and the air inside. Historically, it has been difficult to predict this phenomenon as multitude of design features interact to produce this noise. In the design of cars, finite element software's are used to determine the level of vibration and the acoustic levels inside a car.

The interior noise inside the passenger cabin of automobiles can be classified as structure-borne or airborne. In this study, we investigate the structure-borne noise, which is mainly caused by the vibrating panels enclosing the vehicle. Excitation coming from the engine causes the panels to vibrate at their resonance frequencies. These vibrating panels cause a change in the sound pressure level within the passenger cabin, and consequently generating an undesirable booming noise. It is critical to understand the dynamics of the vehicle, and more importantly, how it interacts with the air inside the cabin.

LITERATURE REVIEW

Saide et al., [1] presented the study of previous research by scientist and to include the extended higher order modes. The natural frequencies and modal characteristics of coupled composite plate-cavity system is also investigated due to the effect of coupling. This study is lead to be very helpful for the researchers working in this field. On the other hand, the coupling characteristics of isotropic and composite plate cavity system are also presented in this study.

Genovese et al., [2] explained a numerical and experimental study of the structural behavior and the vibro-acoustic response of an innovative composite rail vehicle car body roof. On the basis of structural and vibro-acoustic response the traditional metallic roof is compared with the new proposed solution in this paper. The vibration behaviour of the entire rail vehicle is changed due to the different stiffness and the different mass of the roof; therefore, the transmission loss is defined by the term vibro-acoustic analysis. The study results in the use of composite materials for making the sandwich structures because it provides good results in terms of weight, flexural stiffness and vibro-acoustic behavior.

Sadri et al., [3] presented the first analytical model to investigate the vibro-acoustic behavior of sandwich structures coupled with an acoustic enclosure. The sandwich structure is coupled with an air cavity through a coupled boundary condition. Laplace domain and Durbin`s formula is used to predict the time responses of the free and forced vibroacoustic responses of the system. The effect of parameters such as cavity depth, resilient layer stiffness, aspect ratio and thickness on the natural

frequencies and the forced time and frequency responses of the mechanical system is predicted in this study.

INTRODUCTION TO CAD

Computer aided modeling

Initially, CATIA name is an abbreviation for Computer Aided Three-dimensional Interactive Application the French Dassault Systems is the parent company. Using this software Car domain, body and roof plate is created.
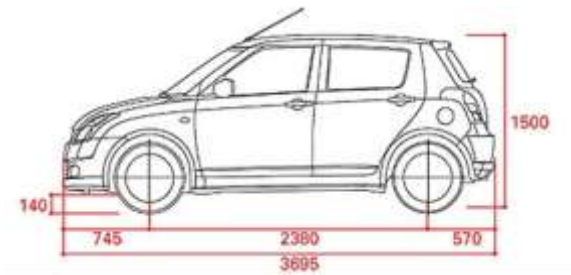

Fig 1: Detailing of car body.

Before using sketch select the plane of the CATIA display and then go to sketch. So that generating of face can be done in CATIA. Draw the drawing which is having an accurate dimension then convert to three dimensional solid.
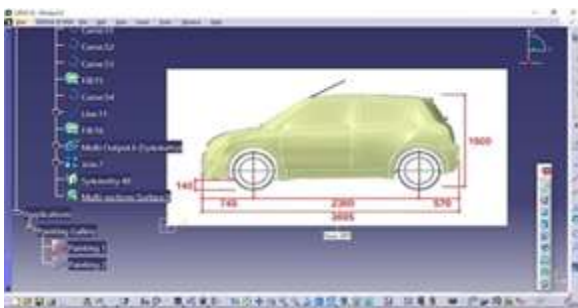
Fig 2: surface model of car in Catia.

Total surface model is created in wireframe model. Here multi section, fill and split commands are used to create the model. CATIA software is used to create it. all dimensions are taken in mm. sketch is created using line, arc and fillet commends.
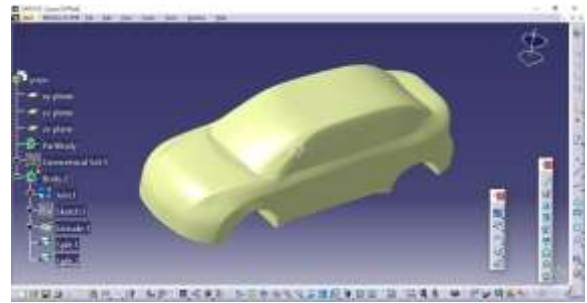

Fig 3: 3D model of swift desire. the above image shows the 3D model of swift desire. here surface options in Catia is used to create the model.
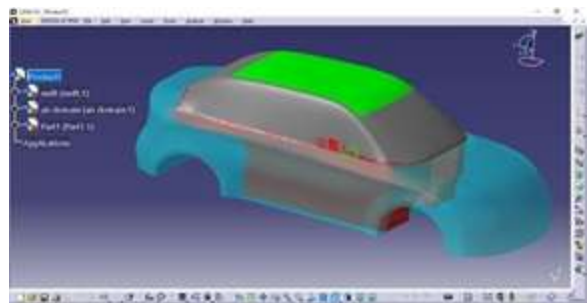

Fig 4: acoustic model in CATIA.

One model is created, it was imported in to Ansys software to run the vibro acoustic analysis. In this present work, initially we took different geometric parameters are taken form existing optimized article. In this acoustic model, using detailing drawings we created in CATIA software and saved as IGS Software in particular location of the computer.
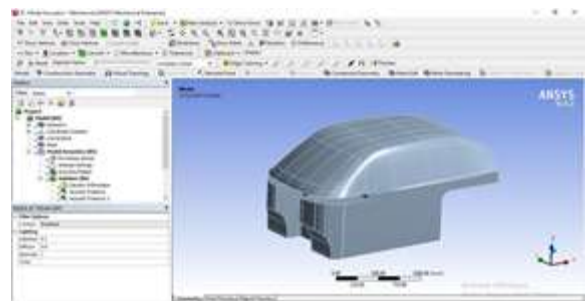

Fig 5: Geometry model of acoustic model.

In ANSYS workbench, important materials are already inbuilt in the software. We can either modify the material parameters or else duplicate materials can be created. Different materials can be assign to different solids can be assigned.

material properties				
	youngs moduls	poission ratio	density	speed of sound
	G.pa		kg/m 3	m/sec
air			1.225	343
steel	210	0.3	7860	5790
aluminum	72	0.33	2500	6420
com posite	20	0.3	1200	343

It is an important technique in Finite element methods. Generally mesh 200 element is available in the ANSYS workbench. These elements are used to solve in the shell and solid element. When there is number of element present we can get the exact results. At the same time, hexagonal meshing gives best results.
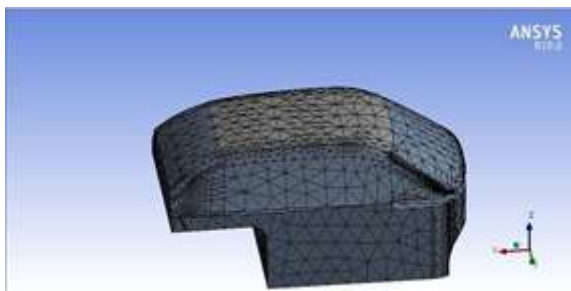

Fig 6: Finite element model of acoustic model

There are different types of boundary conditions that can be applied to edge or faces. In this there is generally fixed support, displacement, remote displacement and frictionless support are used in ANSYS workbench.
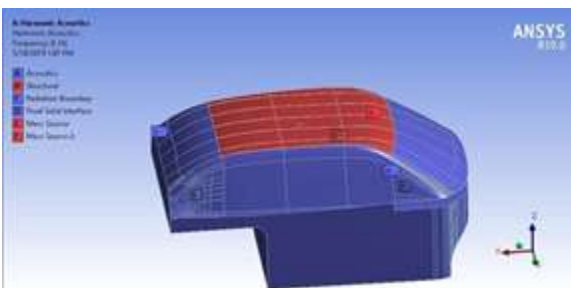

Fig 7: boundary condition on acoustic model.

Post possessing is output of analysis. After we solved the problems, to check the results postprocessor is used. In this we can find in different direction for deformation, strains and stresses. And this can be converted into an image and we can paste it in the report.

To run the Analysis, 64 bit operating system, 4GB ram And ANSYS 19.0 is used. Without any problem, to run analysis software this configuration is very apt. The previously created IGS file is imported on ANSYS file geometry. In ANSYS, static structure and modal analysis are performed. The table which is shown below, different materials for different components are used car assembly. Solid mesh 200 element are used to divide the geometric body in to small strips (Finite elements)

In the present work, the entire car assembly are divided into 32136 tetrahedron elements and 54869 nodes.
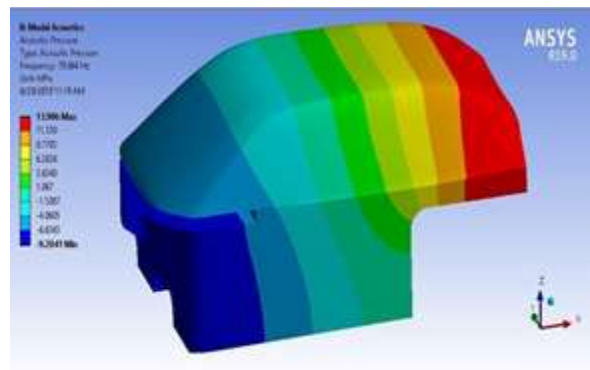

Fig8:1st modeshapeofcaracousticmodel.

In the above image shows the sound pressure at 79.864 Hz, it is first mode in X- direction. This way of sound distribution along X- direction. The red indicate the maximum sound pressure and blue indicates minimum sound pressure. Maximum sound pressure occurs at back side of car air domain. Minimum sound pressure appears at the front portion of car air domain and we can clearly able to see in the above image.

Overall dimensions of cavity

Length = 2.574m

Width = 1.482m

Height = 1.257 m.

Modal analysis is done for the car cavity and the natural frequencies are obtained using theoretical calculation and ANSYS.

•The frequency range of interest is 0-200 Hz.

•   Theoretical calculation is made considering a rectangular box with the overall dimensions. This enables a quick verification of computed frequencies.

$$f = {}_2 \sqrt{(_l)(_w)(_h)}$$

Where,

c is the speed of sound in air, L is the length of the car cavity, W is the width of the car cavity, H is the height of the car cavity.

modes	ANSYS	theoretical
(1,0,0)	79	78
(0,1,0)	114.9	115.7
(0,0,1)	115.72	137
(1,1,0)	131.7	139.52
(2,0,0)	144.7	155.9

Table 1: acoustic frequencies of model.

Sandwich materials are introduced in to car roof plate to improve the damping character. Initially transient analysis is performed on sand witch beam. Transient dynamic analysis is a technique used to determine the dynamic response of a structure under a time-varying load. The time frame for this type of analysis is such that inertia or damping effects of the structure are considered to be important. Cases where such effects play a major role are under step or impulse loading conditions, for example, where there is sharp load change in a fraction of time. If inertia effects are negligible for the loading conditions being considered, a static analysis may be used instead.

In this part Transient Dynamic analysis of the 15 mm core thickness of sandwich is calculated using the same specifications as given in the static analysis. Transient Dynamic analysis is needed because the output of this analysis is used in calculating the damping factor using Log Decrement method.
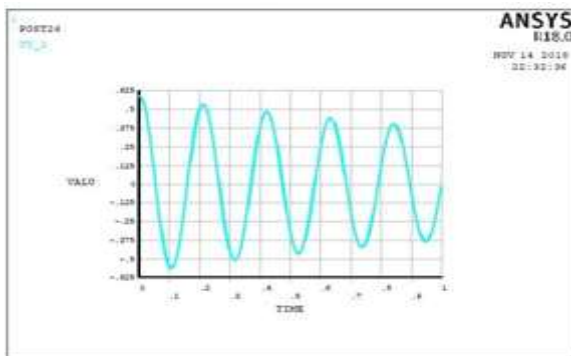

Fig 10:Transient Dynamic Analysis for 15 mm core.

15 mm core thickness of sanwich damping value can be calculating using logarthamaic decrement method.

$$x_1 = 0.624 \,, \ x_2 = 0.53$$

$$\delta = 1_{n \frac{x_1}{x_2}} = 1_n \left(\frac{0.624}{0.53}\right)$$

$$= 0.163 \quad : \quad \delta = \frac{2\pi\varepsilon}{\sqrt{1-\varepsilon^2}}$$

$$0.163 - 0.163 \, \varepsilon^2 = 40.68 \, \varepsilon^2$$

$$\therefore \ \varepsilon = \sqrt{\frac{0.0730568}{39.55147}} = 0.063$$

Harmonic acoustic analysis is performed on car body. Here different types of materials are used to reduce the acoustic vibration amplitude.
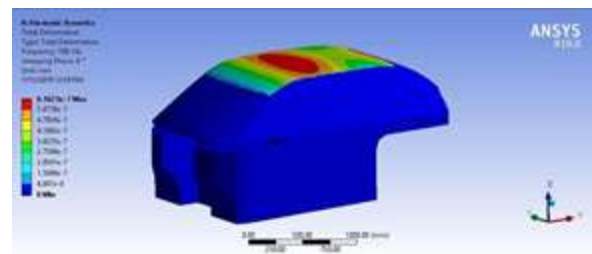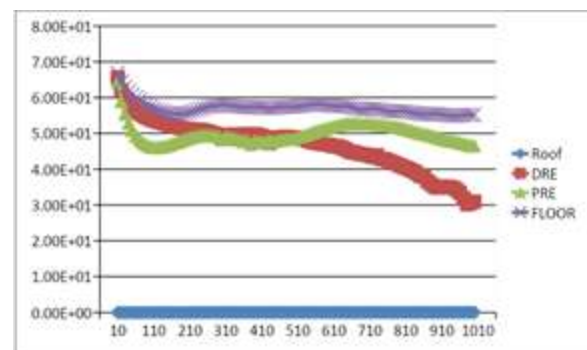

Fig 11: Steel Car roof amplitude at 100 Hz.

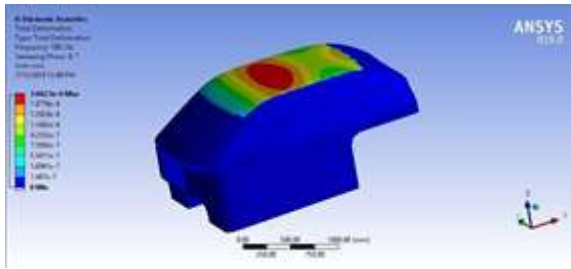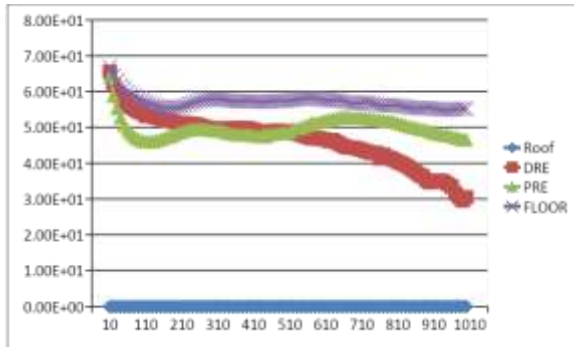Graph 1: Acoustic amplitude on Steel car Roof.

Fig 12: Aluminum car roof and air Domain amplitude.
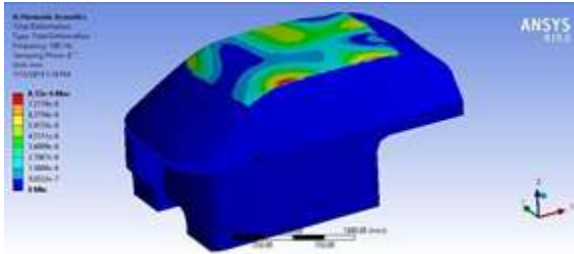

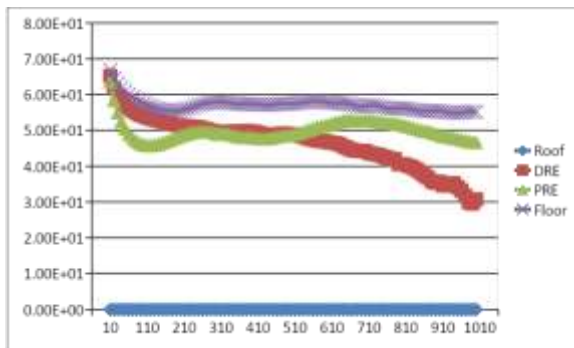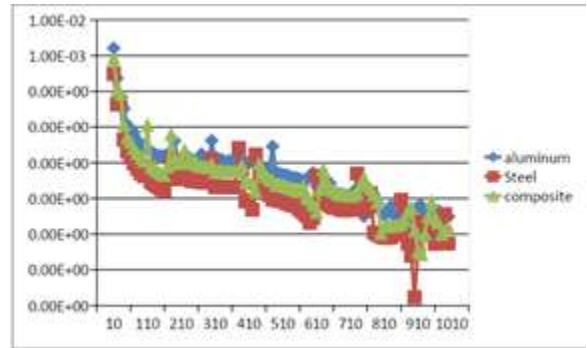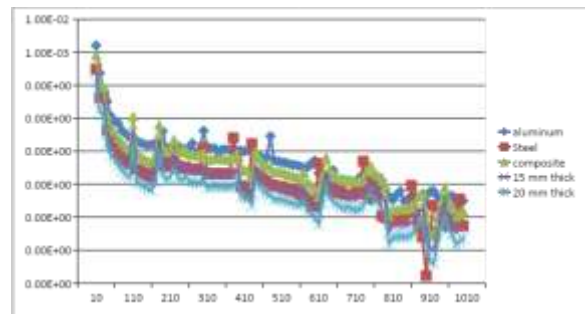Graph 2: Acoustic amplitude on car Domain and Aluminum Roof.

Fig 13: Composite car roof and air Domain amplitude.

Graph 3: Acoustic amplitude on car Domain and Composite Roof.

Graph 4: Car roof amplitude for different materials.

Graph 5: Car roof amplitude for different materials and sandwich.

CONCLUSION

Now a days, transportation plays main role in every person's life. In this, cars play a main role for transportation. Every year car manufacturing companies develop different designs based on people's demand and comfort. After many years, sound produced in car engine and sounds created in the moving parts of car will cause disturbance to the drivers and passengers. Because of these issues, I mainly concentrated on acoustic vibration analysis of car body. Maruti shift desire car has used mostly now days due to more space and comfort. Initially, acoustic modal analysis is performed in ANSYS 19.0 and has found the natural frequencies of car air domain. These ranges are observed 70Hz to 200Hz on directions. In present days, sandwich materials are in great use in automobile, aerospace and wind power generation. Due to this, the structure's bending and damping strength can be improved. In this work, sandwich is considered from 15mm core to 40mm core. The damping ratio is highly increased if we increase the core thickness. It was implemented on car roof and found in acoustic vibrational amplitude is decreased instead of aluminum and steel material. By using these sandwich materials, we can create passenger will have comfort while driving.

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