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Implementation of Laminate Structure in Car Hood and Study of its NVH Parameters

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Abstract: This paper examines the implementation of Laminate structure and aluminium panels in Hood in place of conventional steel hood. In laminate structure, 3 layers is considered with aluminum as a face material and PVC Solid as a core material which helps in efficient energy absorption and provide necessary stiffness for the panel. It has been observed that the natural frequency is improved over conventional steel bonnets with benefit of weight reduction in hood assembly. To validate its NVH performance static stiffness, natural frequency and torsional stiffness has been calculated and it has been found that Laminate structure Hood has better performance than steel hood with overall weight reduction of 41.36%.
Index terms: Laminate Hood, Optimization, Natural Frequency, NVH, Static Stiffness, Torsional Stiffness

I. INTRODUCTION

Automotive industry today is growing vertically and horizontally as the demand for passenger vehicles is increasing day by day. The sales of vehicles has also been boosted in these pandemic time as people personal vehicles over public transport or car sharing.

The automotive manufacturers always had a prime focus on reducing the weight of the vehicle because it is directly related to cost of the car. Reducing weight helps in lowering the cost of raw materials, higher profits, performance improvement and higher reliability. Lighter cars are quicker and have good handling characteristics. Therefore manufacturers are spending huge amount of resources in Research and Development. Another focus in automotive industry is given to fuel consumption of car keeping in mind the tougher environmental rules. So lower the weight of the car, higher is the fuel efficiency. It has been proved that when the weight of the vehicle is reduced by 5%, the fuel economy is improved by 3% to 6%.

Reducing weight from or rear can helps in achieving the understeer or oversteer characteristics, lowering the centre of gravity, as suspension and tyres has less weight to handle. To reduce the weight laminate structure with aluminum and PVC solid is used , which can be used as per the desire characteristics by changing the thickness of core and face. A laminate structure is basically a sandwich of two metals skins bonded by a relatively low density material . These laminate structure has drastically high strength because of thickness with a very minimal weight increase. So by implementing the laminate structure and aluminium , it is possible to make lighter hood with better performance than the conventional steel Hood. The Laminate Hood has been validated for NVH performance parameters like natural frequency, Static Stiffness and Torsional stiffness and the performance is compared with the conventional steel hood.

II. METHODOLOGY

The objective of the study was to implement a laminate hood in place of conventional metal hood with better NVH performance, optimized for weight and higher natural frequency. The Hood requirements has been studied and then different material for laminate structure that can be used has been finalized. To achieve the best configuration for laminate hood, various thickness combination of face material and Core material is founded. The NVH Performance has been compared with Steel Bonnet and results are improved taking steel bonnet as benchmark. The Natural Frequency is validated by Frequency response function and taking the corresponding frequency with respect to max amplitude.

A. Requirements of Hood

A production car has to meet lot of requirements and demands before its gets into mass production car. Most common requirements is that ,the Hood should satisfy durability requirements i.e. the durability of system for different cycles under different loading conditions, the NVH requirement so as not to resonate with engine components or the BIW and also the crash requirements.

The hood hinge strength should be higher than the buckling force so that after the impact the hood should bend and not protrude into the passenger cabin. The Hood also has to be passed for Upper leg, Lower leg and Head impact HIC criteria defined by homologation agencies. Different region has different criteria’s for HIC. The hood should also be strong enough to be operable after the impact in the low speed damage regulation.[6]

Requirements	Need
No Vibration on hood	Overall Stiffness of hood
Pedestrian Protection	Energy Absorption
Deformation in case of external impact	Bending Stiffness

Table 1: Requirements of Hood

B. Sandwich Core Structure Material

Below are the material used in simulation. Aluminium is selected as face material because it has higher energy absorption and PVC solid core is selected because it has relatively low density than metals, helps in thickening the panel with drastic improvement in Stiffness and marginal weight increase. used as face 0.5mm thickness is used for aluminum and 3mm thickness is used for PVC Core.

Material	Young' Modulus	Density	Poisson's Ratio
Steel	210GPa	7850Kg/m3	0.3
Aluminium	69GPa	2700Kg/m3	0.35
PVC Solid	4.14GPa	400kg/m3	0.4
Epoxy adhesives	3.81GPa	1200/kgm3	0.41

Table 2: Materials properties used in simulation

III. DEVELOPMENT OF LAMINATE HOOD

The hood basically consists of Inner panel, Outer Panel, Hinge Reinforcements and Lock Reinforcements as its main Parts. The inner panel and Outer Panel contributes to the strength of Hood. The Inner panel is designed as such to absorb the maximum load during the Head Impact test and Pedestrian Protection tests.

The hinge stiffness is important as it in case of accident, it should not allow hood to intrude into the passenger, and for this hinge strength should be higher than the bending strength of the Hood. The hinges also should be robust enough to not damage during the regular usage of Hood.

The NVH performance has been analyzed in these paper. The total mass of Hood is 16.49Kg.Following are the parts of Steel Hood

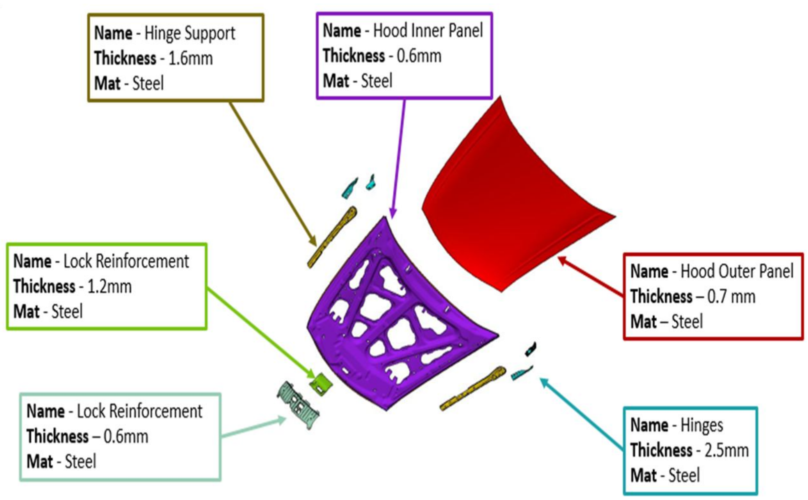


Figure 1: Description of part in Steel Hood

Steel Hood performance has been enhanced by replacing the outer panel with laminate structure of Aluminium & Hood and inner panel is replaced with aluminium. As both the alunmium panels are used it is feasible to weld these panels.

In the optimization steps the inner panel design has been changed for better stiffness performance which help in higher energy absorption during the impact.

To achieve the torsional performance, one new part is added near the front stops of thickness 1.6 mm with aluminium as material.

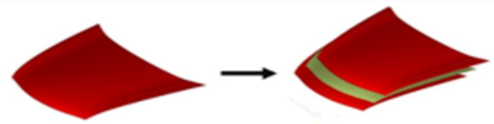
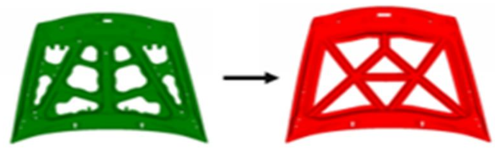
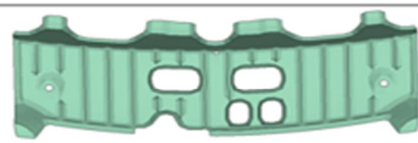
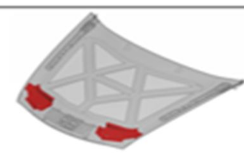
Sr. No.	Changes Description	Image	Advantage
1	Steel Hood outer Panel changed with laminate Panel of Aluminium as a Face material(0.5mm Thickness) and PVC Foam(3mm Thickness) as a Core Material.	 **Steel Panel** → **Laminate Structure Panel of Aluminium and PVC Foam**	• Increase in Hood Natural Frequency • Increase in Local Static Stiffness • Helps in weight reduction
2.	Hood Inner Panel Design change and changing material from Steel to Aluminium.	 **Steel Panel** → **Aluminium Panel**	• Helps in weight reduction • Improvement in Dynamic Stifness
3.	Hinge Support material change from steel to aluminium.		• Helps in Weight Reduction
4.	Lock Reinforcement Upper material change from steel to aluminum. Thickness increase from 0.6mm to 1.5mm.		• Helps in Weight Reduction • Improvement in Frontal Region Local Stiffness
5.	Additional part with thickness 1.6mm and aluminium as material is added in Front Region. (Highlighted in Red)		• Improvement in Torsional Stiffness

Table 3: Changes made in Steel Hood to improve performance

IV. COMPARISON OF STEEL HOOD AND LAMINATE HOOD NVH PERFORMANCE

In NVH Performance Analysis , Modal Analysis is very important to calculate a natural frequency of a system so as to check whether it will resonate with other systems or not. Modal analysis is the study of the dynamic properties of systems in the frequency domain. Dynamic properties are dependent on the mass, stiffness and damping distribution on the structure, and determine structural vibration behavior when exposed to operational loads. The main objective of modal analysis is to calculate the natural frequency and study its modes.

We have also calculated the Static Stiffness and Torsional Stiffness to validate its performance.

The Hoods are constrained at the hinges location which is mounted on BIW and near to the front side where it is locked.

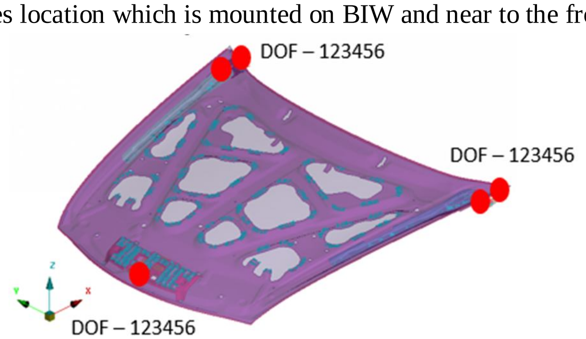


Figure 2: Boundary Condition of Hood for Modal Analysis

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So we have compared the modal analysis of Steel Hood and Laminate Hood. The natural frequency of Steel hood is found out to be 28.70Hz.

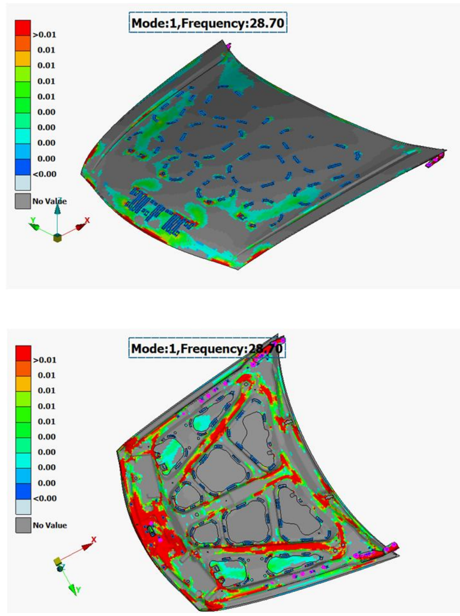

Figure 3: Modal Analysis of Steel Hood

In laminate hood, the upper panel is replaced by laminate of Aluminium and PVC Corea and the inner panel is replaced with aluminum . The inner panel design is optimized for higher stiffness and to reduce the weight.
The modal analysis of laminate Hood with the changes is performed with mentioned constraints, the natural frequency is found out to be 33.83Hz.

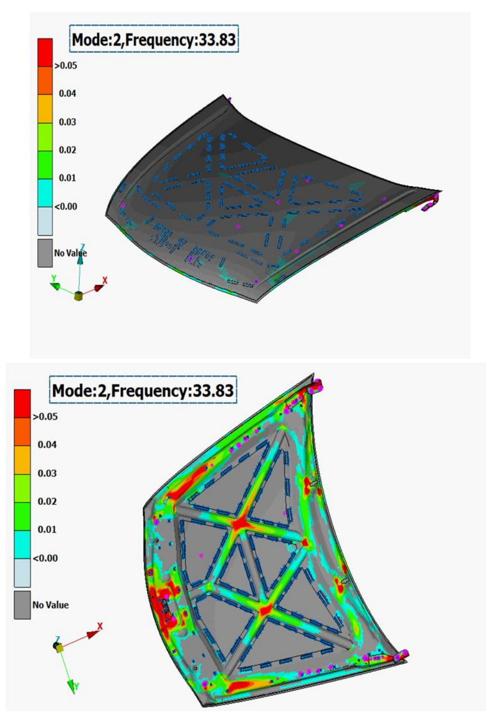

Figure 4: Modal Analysis of Laminate Hood

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Static Stiffness is very crucial in NVH as it directly affects the performance of the vehicle. Static stiffness can significantly affect vehicle NVH, ride and handling, and durability performance. Higher the static stiffness more is the ability to absorb energy and less transmissibility.

1N Unit Load is applied as a static load on Z direction and Displacement is taken as output. This result is compared against the static stiffness of steel to check the performance improvement.

$$\text{Stiffness} = \frac{\text{Force}}{\text{Displacement}} \text{ N/mm}$$

As we have taken unit load i.e. 1 N, the stiffness is given by

$$\text{Stiffness} = \frac{1}{\text{Displacement}} \text{ N/mm}$$

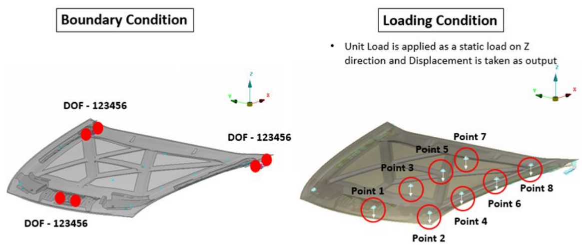

Figure 5: Boundary Conditions for Static Stiffness Calculation

The stiffness for both the steel and laminate hood is compared against each other to check its performance improvement.

Sr. No.	Steel Hood [N/mm]	Laminate Hood [N/mm]	Change [%]
1	877	650	-26
2	210	304	45
3	182	484	166
4	248	305	23
5	77	445	478
6	211	347	65
7	86	289	237
8	63	243	288

Table 4: Static Stiffness Comparison

Torsional Stiffness determines the torsional rigidity of a system. A Force of 100N is applied on front bump stops of Hood in Opposite Direction. The Displacement is calculated and torsional Stiffness is calculated by the following Formula

$\Phi = \tan^{-1}$ (Displacement/420)

Φ = X Degrees

Torsional Stiffness = 100 N.mm/ X Degrees

Torsional Stiffness = Y N.mm/Degrees

	Load [N]	Displacement [mm]	Torsional Stiffness [N.mm/Deg]
Steel Hood	100	0.6147	1190
Laminate Hood	100	0.6161	1188

Table 5: Torsional Stiffness Comparison

To validate the natural frequency of Hood, Frequency response function is performed. A front bump stop has been exited by 1N unit load and its acceleration has been measured.

The maximum acceleration will occur at the natural frequency of the system. We can see from the graph that the peak from **28.70Hz** is shifted to **33.83Hz** which denotes that we got the improvement of 5.13Hz.

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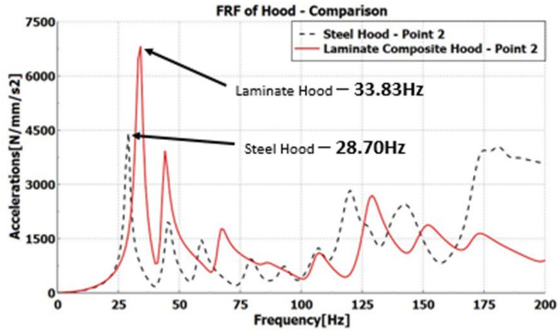

Graph 1: FRF comparison of Steel and Laminate Hood

V. SUMMARY OF RESULTS

The Steel Hood and Laminate Hood is compared against each other for different NVH performance parameters.

The Laminate Hood Natural frequency is improved by 5.13Hz as compared to steel hood, along with increase in static stiffness of 56.83%. The torsional Stiffness and Dynamic performance remains same as steel hood.

So with the application of laminate structure and aluminium material, 6.82Kg weight is reduced which means Laminate Hood has 41.36% less weight than Steel hood and still has better performance.

Sr. No.	Performance Parameters	Results		% Change	Comments
		Steel Hood	Laminate Hood		
1	Weight Reduction	16.49Kg	9.67Kg	-41.36%	**6.82** Kg weight is reduced
2	Natural Frequency Improvements	28.70Hz	33.83Hz	+17.87%	Hood Natural Frequency is improved by **5.13Hz**
3	Static Stiffness Improvements (Average of all points)	244.45 N/mm	383.3 N/mm	+56.83%	**56.83%** improvement in Hood Static Stiffness
4	Dynamic Stiffness Improvements	-	-	-	Same performance as of Steel Hood
5	Torsional Stiffness	1190 N.mm/Deg	1188 N.mm/Deg	0%	Torsional Stiffness Performance is same as of Steel Hood

Table 6: Summary of results.

VI. CONCLUSION

Lighter hood is possible with the use of laminate structure. Use of Laminate structure in hood helps in reducing weight and improve the NVH Performance. In Laminate Hood, Aluminium as a face material helps in deforming elastically & the stiffness and elongation property of PVC Foam helps in good energy absorption. A 41.36 % weight reduction is achieved with the help of Laminate structure and aluminium material.

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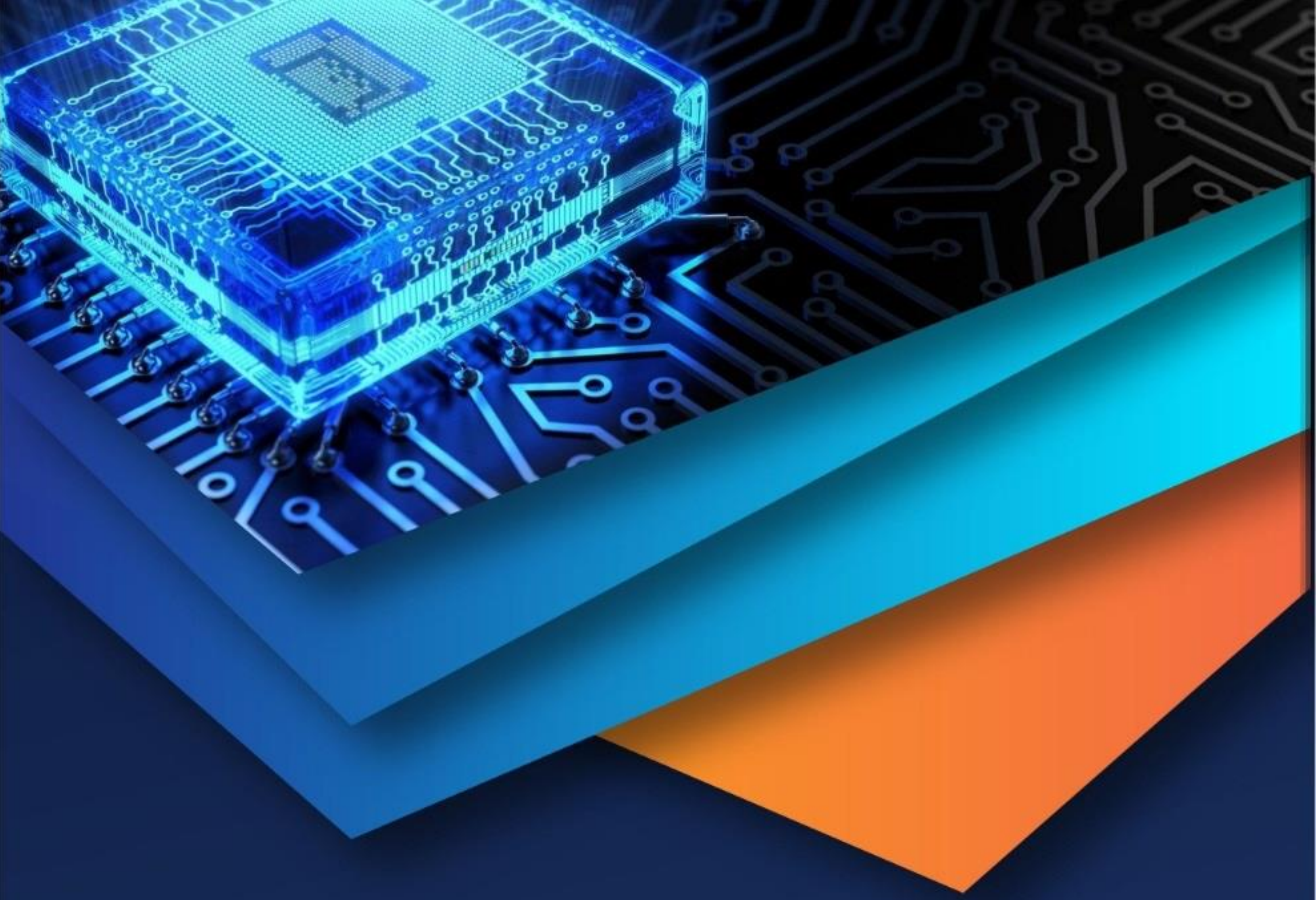

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