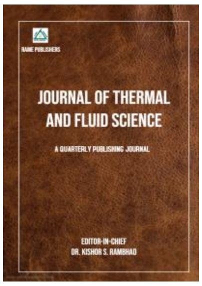

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A Material Substitute for Column A-Pole of LCV by Using Composite Reinforced Aluminium

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***Abstract* - Automobile industry is always in search to find an alternative methodology to implement the continuous changes in passenger car norms and customer expectations. Weight is main factor of the vehicle which has dominant effect on emission, performance and efficiency of the vehicle. Now day's use of Mild Steel is reduced with lightweight materials like Aluminium and its alloys, Glass fiber, Plastic and others. The work has been carried out to decrease the weight of the A-Pole reinforcement of the passenger car SUV class and to fulfill the vibration requirement. A traditional material Mild Steel is replaced by composite of Glass fiber with Aluminium reinforced. Project executed in three stages. At initial stage present geometry details are reverse engineered like its dimensions and thickness. Continued by setting base line targets for new material by FEA method for vibration and linear static analysis. Correlation of light weight structure is achieved with different iterations with help of tools like ANSA, Hypergraph Metapost, Hypermesh, Optistruct and Nastran. Results comparison shows that the Aluminium with reinforced glass fiber reduces the mass of A-Pole by 30% by mechanical strength.**

Keywords - A-Pole, BIW SUV, Vibration analysis, linear static analysis, FEA Methodology, Weight reduction

I. Introduction

Increase in automotive world competition with high expectations from customers needs appropriate passenger car optimization with special importance to vehicle vibrations and noise characteristics. Noise and vibrations of passenger vehicles are more and more important for the automotive industry, particularly for car manufacturers and assembly suppliers. In order to achieve extraordinary vehicle performance, a tendency is growing into a design process to use light weight metals in vehicle components manufacturing. Light weight metals reduce the largely vehicle weight that reduce emissions and advances vehicle performance, but light weight components reduce vibration and noise absorption and damping capacity, which causes further concerns for engineers. A continues increase in expectation from the customer on vibration and noise side gaining the importance of NVH analysis.

Yearly in case of rollover accidents many peoples are killed because of head and neck injuries. A weak structure of A-Pole, B-pillar and roofs may be a key reason of severe face neck and head injuries to passenger.

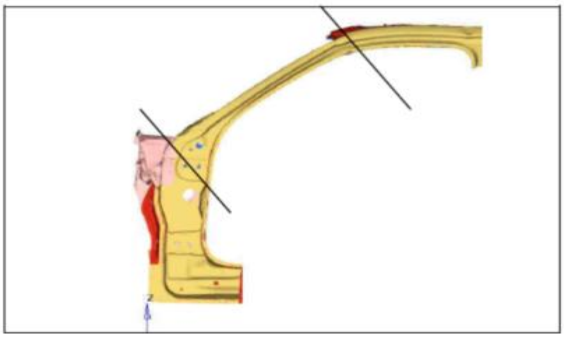

Fig.1 A-Pole Assembly

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In this paper an A-Pole of a passenger car is considered to understand performance of vibration as well as strength of the A-Pole by performing Modal and FRF analysis to check mechanical strength.

A. Problem Statement

Weight reduction of Body In White(BIW) of passenger car is an main issue which has an added advantage on safety and emission norms. It also has dominant effect on vibration and noise charecteristics of BIW because of change in mass and stiffness. Heavy electrical battery equipment has been added to the standard vehicles. A-Pole of the BIW is considered for this research work to understand the effect of use of alternative material on vibration characteristics. New suggested material helps to reduce weight of A-Pole without deviating from its natural frequencies extracted from base model.

B. Objective

Objective of the current research work is,

1. To reduce weight of A-Pole.
2. To Change Material from Mild steel to composite of Glass fiber with Aluminium reinforced
3. To Compare and reach the base line targets calculated for base material for Natural frequency
4. Validating CAE results with Experimental results.

C. Scope of Work

1. A-Pole of Jeep SUV is considered for this research work.
2. Normal mode analysis is performed to check the effect of material change on natural frequency and mode shape for first three modes.
3. Weight reduction and effect of using Aluminium with reinforced glass fiber is the use of research.

II. RELATED WORK

A. B. Deshmukh, S.V. Chaitanya, Sachin Wagh [1] given an idea about trend change in Automotive market. Today customers are more interested in a compact and efficient designed vehicle with an affordable cost. This is challenge to engineers and globally OEMs has accepted this. A vehicle design and development is mostly driven by crash and safety norms and regulations. Simultaneously NVH is also gaining an equal importance though it is raised from customer point of view. For this reason, globally manufacturers have ensured that the advantages of a significant weight saving are achieved with appropriate vibro-acoustics performance. This Paper study explains a good use of multilayer damping material in Body in White for controlling structure born noise and vibration. The research work uses with the design parameters for sandwich Panels and how an optimization target is met by using CAE tools and same is correlated with prototype test results. NVH performance is estimated utilizing a dedicated experimental setup for the vibro-acoustic characterization of sandwich panels. The design improvement predicted by CAE results in NVH characteristics of vehicle are study for further execution in BIW design.

Shaobo Young [2], has presented a vehicle development process and technologies which explains about the methodologies and the technical concepts used in analyzing automotive NVH concepts and also gives a detailed overview on the terminologies used in automotive industry to identify issues related to the vibration, noise and harshness and also provided a guide to address these issues by FEA methodology and experimental setup. It also explains the types of inputs for noise and vibration issues like structure born and air born noise and vibration. It also gives an brief idea about target cascading process and NVH development process.

Fard, M. and Liu, Z.,[3] explained in there paper on Automotive Body Concept Modeling Method for the NVH Performance Optimization regarding use of CAE (computer aided engineering) at concept phase of the vehicle development process. Same NVH results extracted at concept phase model from CAE has good correlation with results extracted from a detailed FE model analysis at intermediate and developed stage of the vehicle and also with experimental test output in low frequency range. This paper gives a good recommendation to proceed for developing a concept model with the help of beam and shell elements when a matured CAD data is not available. An interaction between BIW and seat mode, both are considered for poor seat vibration and same is resolved by optimizing seat mounting locations with the help of optimization and sensitivity analysis of the structure.

Ying Yanga, Guangyao Zhaoa, Dongbo Mab and Xiaobin Xua [4], achieved the modal analysis of a BIW both with finite element method and experimental test. The finite element model is established with considering the special characteristics of welding points because the boundary conditions will change the modes sensitively. Comparing with the calculated modes predicated on FEM to those of the tested of the BIW, it is shown that the natural frequencies and vibration shapes correspond to each other. These results will provide the substructure for ameliorating and optimizing the design of a car body. The dynamic parameters of a car body in white (BIW) are paramount during an incipient car developing. Predicated on the finite element method, the model of a BIW is developed in which the welding points are treated specially as an incipient element type and the vibration modes of it are calculated.

Ion DINCĂ, Adriana ŞTEFAN, Ana STAN [5], given an idea about use of hybrid material and its affect on mechanical properties. The metal/fibre hybrid laminates consist of an alternation of 0.2 ÷ 0.5 mm metallic sheets (Aluminum or Titanium in Aeronautical Engineering) and pre-pregs composed of unidirectional carbon or aramid or glass fibre or of the two-dimensional fabric of these materials, bonded by a polymer adhesive (epoxy, especially). Compared with the monolithic metal foils, the essential quality of these hybrid laminates are their superior resistance to fatigue, impact and crack propagation (existing or made by notches). The paper presents some results regarding hybrid laminates Aluminium-carbon fibre and aluminum-glass fibre achieved in the CEEX project X1C05.

III. Methodology

Geometrical information is accumulated from the components available in the market and a CAD model is developed by using CATIA. A STEP file exported from CATIA is imported into HM for Meshing and applying boundary conditions. CQUAD4, CQUAD3 and CHEXA elements are used to develop a FE model in Hyper Mesh. These elements types are supported for Optistruct solver. This model is developed for Modal and FRF analysis. A final FE Model with applied material and boundary conditions is processed using Optistruct and a post processing of the output results is done in Hyper View and Hypergraph. A Target values are obtained from this set of results which is a base line for the further iterations. A same model is used with different boundary conditions to perform a static linear analysis to calculate displacement of A-Pole and processed using solver ABAQUS and results are post-processed using Hyper View.

A same CAD model with different representation of FE model to represent a new Aluminium with reinforced Glass fiber is developed and with same boundary conditions used in base run analysis a new analysis is performed and results are post-processed. By equivalence results with base line model, different iterations are performed and a final model is developed which meats base line target values. A prototype is developed from the inputs received from CAE and same is validated through prototype testing. A flow chart for methodology is shown below.

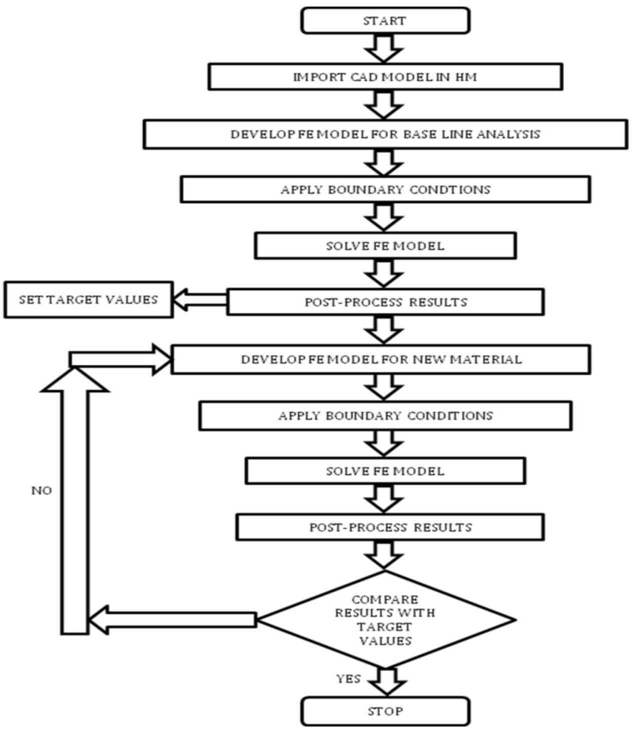


Fig 2. Methodology Flow chart

IV. Geometry Details and Tools Used

Below Table shows the thickness and martial utilized for the CAE analysis.

Table 1.

Geometry Details

Material	Thickness(mm)
Mild Steel	1.5
Aluminium	2.5
Glass Fiber	1

Table 2

Tools Used

Tools	Function
CATIA	3D CAD Model
ANSA/Hyper mesh	Meshing and BC
Hyper Work	Analysis and post processing

A. FE Model Preparation for Sheet metal and Aluminiun reinforced with Glass Fiber

A sheet metal parts are meshed with 2D shell element and connected by spot welds. Below table and figures shows details of FE Model.

Table 3

FE Model Details

Element Type	CQUAD4, CQUAD3, CHEXA, RBE3
Connection Type	Spot Weld, Adhesive
Connection Element	RBE3-HEXA-RBE3
Constrained	SPC1
Force	CLOAD

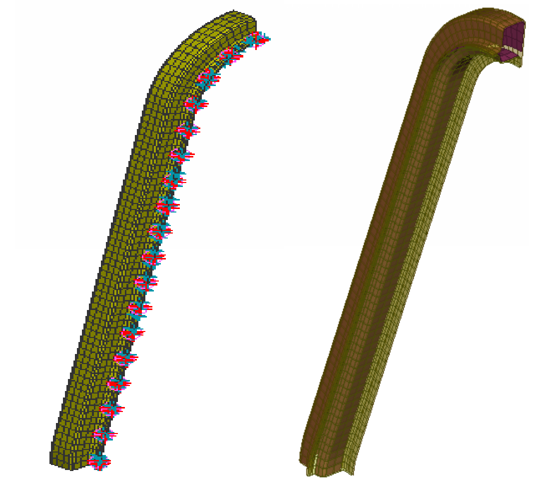


Fig.3 FE Model for Steel and aluminum material

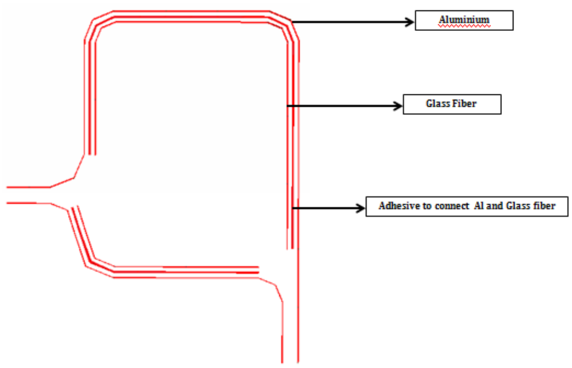


Fig.4 C/S for Reinforced Glass fiber Aluminium

B. Material Properties for Mild Steel, Aluminium and Glass Fiber

Below table shows material details used for FE analysis.

Table 4
Steel Material

Property	Value
Young's Modulus, E	200 GPa
Poisson's Ratio, ν	0.29
Density, ρ	8000 kg/m^3
Yield Stress, σ_{yield}	215 MPa
Ultimate Tensile Stress, σ_{uts}	505 MPa

Table 5
Aluminium Material

Property	Value
Young's Modulus, E	68.9 GPa
Poisson's Ratio, ν	0.33
Density, ρ	2700 kg/m^3
Yield Stress, σ_{yield}	214 MPa
Ultimate Tensile Stress, σ_{uts}	241 MPa

Table 6
Glass Fiber Material

Property	Value
Young's modulus in x-direction, Ex	40300 MPa
Young's modulus in y-direction, Ey	6210 MPa
Young's modulus in z-direction, Ez	40300 MPa
Poisson's Ratio, ν	0.2
Density, ρ	1900 Kg/m^3
Shear modulus in XY plane, G_{xy}	3070 MPa
Shear modulus in YZ plane, G_{yz}	2390 MPa
Shear modulus in ZX plane, G_{zx}	1550 MPa

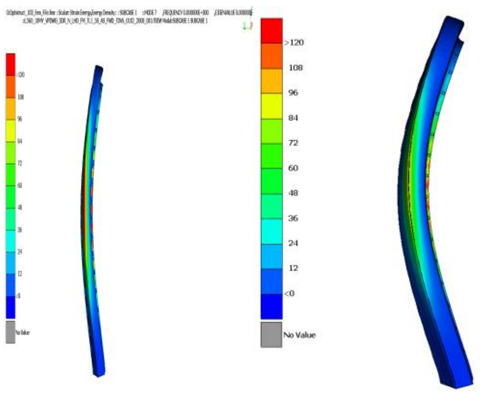
V. CAE RESULT COMPARISON

A. Modal Analysis

A free-free normal mode analysis is performed using NASTRAN to check the connectivity of the model and to calculate its natural frequencies and mode shapes for both base model as well as the model with modified material properties. Below table shows the values for the natural frequencies and figure shows relative mode shapes.

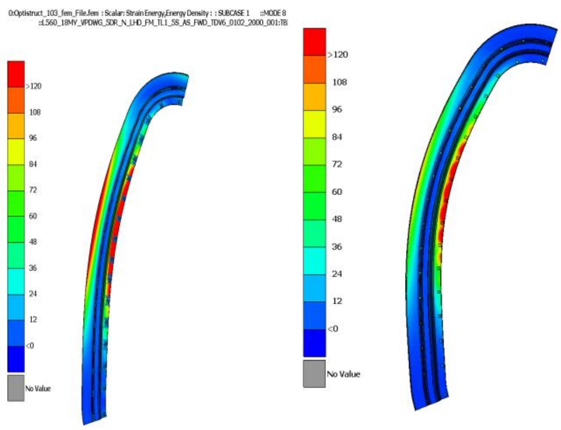
TABLE 6.
NATURAL FREQUENCY VALUES

Mode Number	Mode Shape	Frequency Value For Steel	Frequency Value For Al-GF
1st Mode	Lateral Bending	55.3 Hz	54.8 Hz
2nd Mode	Vertical Bending	65.4 Hz	64.9Hz
3rd Mode	Torsion	103.1 Hz	105.1Hz



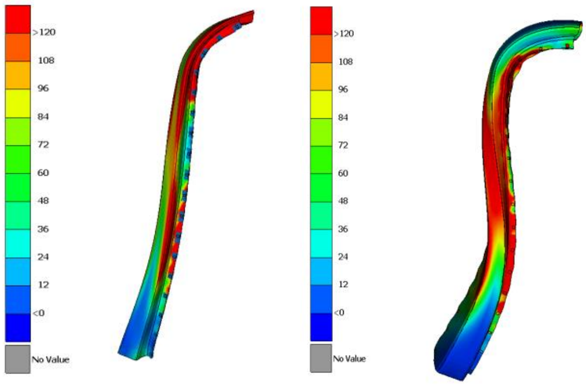
Steel-55.3 Hz AL-GF-54.8 Hz

Fig 5. 1st Mode Shape - Lateral Bending



Steel-65.4 Hz AL-GF-64.9 Hz

Fig 6. 2nd Mode Shape - Vertical Bending



Steel-103.1 Hz AL-GF-105.1 Hz

Fig 7. 3rd Mode Shape - Torsion

B. FRF Analysis

A frequency response analysis is performed using NASTRAN to check and confirm the natural frequencies and relative mode shapes extracted from normal mode analysis. Below figures shows the graphs compared for 1st three modes for Frequency Vs Displacement.

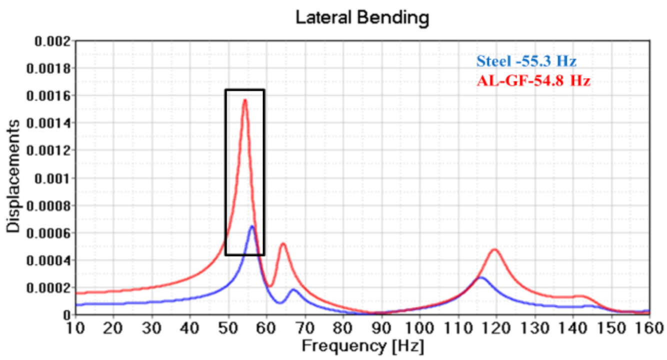


Fig 8. Lateral Bending Mode

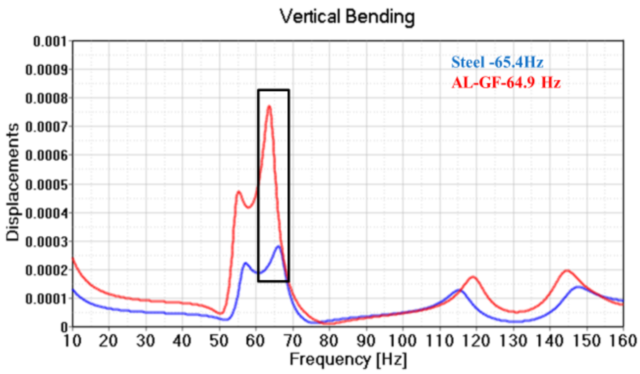


Fig 9. Vertical Bending Mode

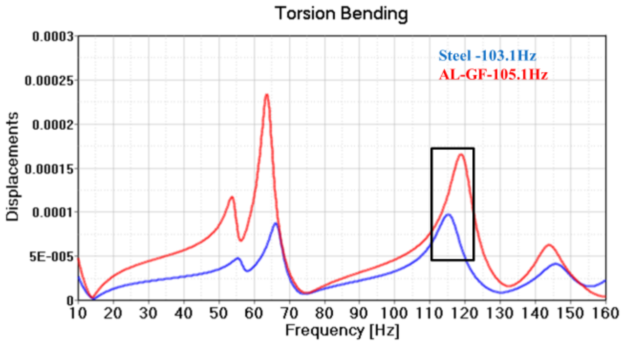


Fig 9. Torsion Mode

C. Weight Comparison

Below table shows the comparison between the mass of the both model and the geometrical properties used for a model.

TABLE 8.

GEOMETRY AND MASS COMPARISON

Model	Material	Thickness (mm)	Mass (Kg)
1	Mild Steel	1.5	1.53
2	Aluminium	2.5	1.08
	Glass Fiber	1	
Difference			0.45

D. CAE Result Summary

Below table gives a brief information about comparison between CAE results of two different materials.

TABLE 9

RESULT SUMMARY

Parameters	Material	
	Mild Steel	Al with Glass Fiber
Natural Frequency Hz	55.3 Hz	54.8 Hz
	65.4 Hz	64.9 Hz
	103.1 Hz	105.1Hz

VI. CONCLUSION

From the above two tables, it is observed that Aluminium with reinforced Glass Fiber has benefits over the Mild steel and reduces the weight of the A-Pole by approximate 30%. A result summary table shows that reinforced Glass fiber helps to reduce the mass and gives a good damping effect and also adds stiffness to the structure. A future work can be done to study its strength for nonlinear analysis.

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