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Reduction of passenger car weight(C-Pillar) by using reinforced composites (AL + GF)

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Abstract

The growing challenges on fuel economy improvement and greenhouse gas emission control have become the driving force for automakers to produce lightweight automobiles. Also, the weight reduction may contribute to superior recyclability and/or vehicle performance (e.g., improved driving economy, braking behaviors, and crashworthiness). One effective strategy is to develop and implement lightweight yet high-performance materials as alternative solutions for conventional automotive materials such as cast iron and steel. The work is carried out to reduce the weight of the Column C-Pillar reinforcement of a passenger car LVC class and to meet the Roof Crash requirement. A traditional material Mild Steel is replaced by Aluminum reinforced with Glass fiber. Paper executed in three stages. At the initial stage present geometry details like its dimensions and thickness. Continue by setting baseline targets for new material by FEA method for Linear analysis modal and FRF. Correlations of composite structure with different iterations with the help of tools like Hyper mesh and Opti Struct.
Keywords –lightweight, C-Pilar, FEA, Hymermesh, OptiStuct Modal analysis.

1. Introduction

Increase in automotive world competition with high expectations from customers' needs appropriate passenger car optimization with special importance to vehicle safety regulations. To enhance the safety of vehicles automobile manufacturers, use high-thickness steel metal panels and pillars but this results in additional weight for the vehicle.

Lightweight metals reduce the vehicle weight reduce emissions and advance vehicle performance, but lightweight materials lag in stiffness requirements, for stiffness requirements, like vibration analysis where composite materials play a big role.

Aluminum and Glass Fiber reduce the weight of the C-Piller without affecting its natural frequencies and mechanical strength.

Every year the use of strong materials by automakers takes life for so many people.

In this paper, a C- Pilar of LVC is considered for checking material swap and checking its strength with the help of natural frequency extraction and shaker test (FRF).

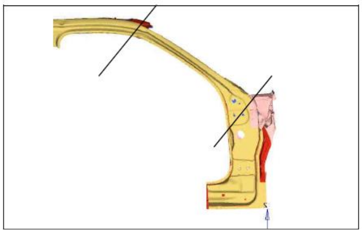

Fig.1 C-Pilar Assembly

2. Problem Statement

Weight reduction of the Body In White (BIW)(base material mild steel) of passenger cars is a main issue that has an added advantage on safety and emission norms. Heavy electrical battery equipment has been added to the standard vehicles. Stiffness characteristics of BIW because of change in mass and stiffness. C- Pillar of the BIW is considered for this research work to understand the effect of the use of alternative material on stiffness characteristics. The new suggested material helps to reduce the weight of Column C-Pillar without deviating from its stiffness natural frequency.

3. Objective

The objective of the current research work is,

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

4. Scope of Work

1. C-pilar of LVC 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 the first three modes.
3. Weight reduction and the effect of using Aluminium with reinforced glass fiber is the use of research.

5. Literature Survey

A paper presented by A. B. Deshmukh, S.V. Chaitanya, and Sachin Wagh [1] on a Case Study on Sandwich steel Application in Automotive BIW for

NVH Improvements gives an idea about trend change in the Automotive market. Today customers are more interested in a compact and efficiently designed vehicle with an affordable cost. This is a challenge to engineers and globally OEMs have accepted this. Vehicle design and development is mostly driven by crash and safety norms and regulations. Simultaneously NVH is also gaining equal importance though it is raised from a customer point of view. For this reason, globally manufacturers have ensured that the benefits of a major weight saving are met with appropriate vibro-acoustics performance. This Paper study explains a good use of constrained layer damping material in Body in White for target meeting of structure-born noise and vibration. The research work is used for the design parameters for sandwich panels and how an optimization target is met by using CAE tools and the same is correlated with prototype test results. Vibration, Harshness, and Noise performance are estimated utilizing a fixed experimental setup for the vibro-acoustics characterization of sandwich panels. The design improvement assessments by CAE end up in Vibration, Harshness, and Noise characteristics of automotive cars are studied for further execution in the body in white design.

Shaobo Young [2], has presented a vehicle development process and technologies that explain the methodologies and the technical concepts used in analyzing automotive NVH concepts and also gives a detailed overview of the terminologies used in the automotive industry to identify issues related to 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 a brief idea about the target cascading process and NVH development process.

Fard, M. and Liu, Z.,[3] explained in their paper on the Automotive Body Concept Modeling Method for the NVH Performance Optimization regarding the use of CAE(computer-aided engineering) at the concept phase of the vehicle development process. The same NVH results extracted at the concept phase model from CAE have a good correlation with results extracted from a detailed FE model analysis at the intermediate and developed stage of the vehicle and also with experimental test output in a low-frequency range. This paper gives a good recommendation to proceed with developing a concept model with the help of beam and shell elements when matured CAD data is not available. An interaction between BIW and seat mode, both are considered for poor seat vibration, and the 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], In this paper, the modal analysis of a BIW is achieved both with finite element method and experimental test. The finite element model is established by considering the special characteristics of welding points because the boundary conditions will change the modes sensitively. Comparing the calculated modes predicated on FEM to those of the tested 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 development. 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 are calculated.

Ion DINCĂ, Adriana ŞTEFAN, Ana STAN [5], This paper gives an idea about the use of hybrid material and its effect on mechanical properties. The metal/fiber 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 fiber or of the two-dimensional fabric of these materials, bonded by a polymer adhesive (epoxy, especially). Compared with monolithic metal foils, the essential quality of these hybrid laminates is 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 fiber achieved in the CEEX project X1C05.

6. 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 element types are supported by the 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 value is obtained from this set of results which is a baseline for further iterations. The same model is used with different boundary conditions to perform

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static linear analysis to calculate the displacement of C- Pilar and processed using solver ABAQUS and results are post-processed using Hyper View.

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

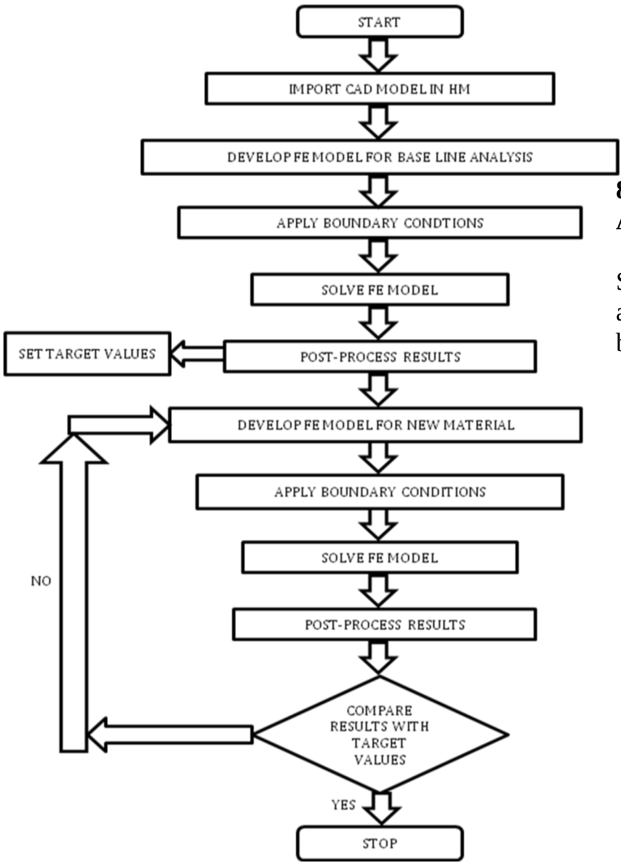

Fig 2. Methodology Flow chart

7. Geometry Details and Tools Used

The below Table shows the thickness and martial utilized for the CAE analysis.

Table 1. CAD Details

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

Table 1.1 Tools Used

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

8. FE Model Preparation for Sheet metal and Aluminum reinforced with Glass Fiber

Sheet metal parts are meshed with a 2D shell element and connected by spot welds. Below table and figures below show details of the FE Model.

Table 2. FE Model Details

Element Type	CQUAD4, CQUAD3, CHEXA, RBE3
Connection Type	Spot Weld, Adhesive
Connection Element	RBE3-HEXA-RBE3
Constrained	SPC
Force	Eigen Modes

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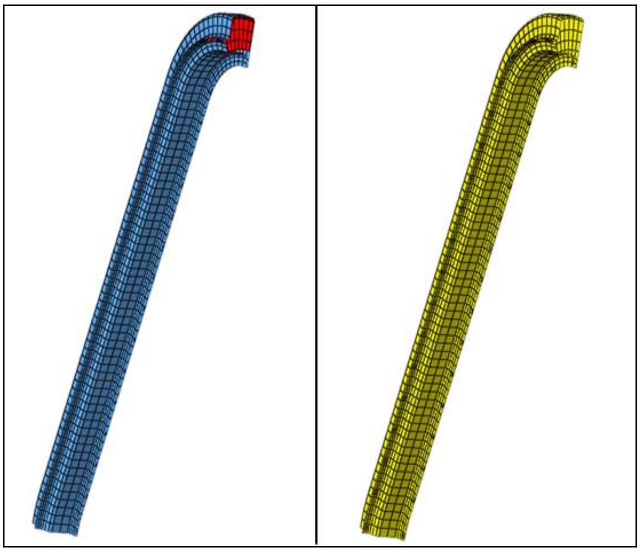

Fig.3 FE Model-Steel FE Model-Aluminium

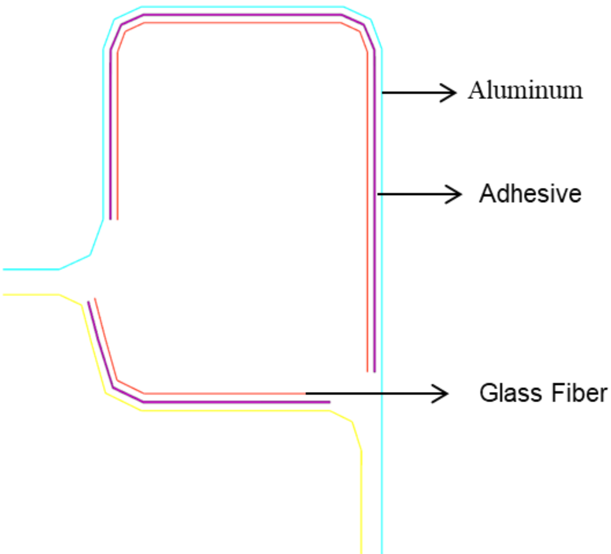

Fig.4 C/S for Reinforced Glass Fiber Aluminum

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

The below table shows the material details used for FE analysis.

Table 3. 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 4. Aluminum 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 5. Glass Fiber Material

Property	Value
Young's modulus in the 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

10. CAE Result Comparison

10.1 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 the base model as well as the model with modified material properties. The below table

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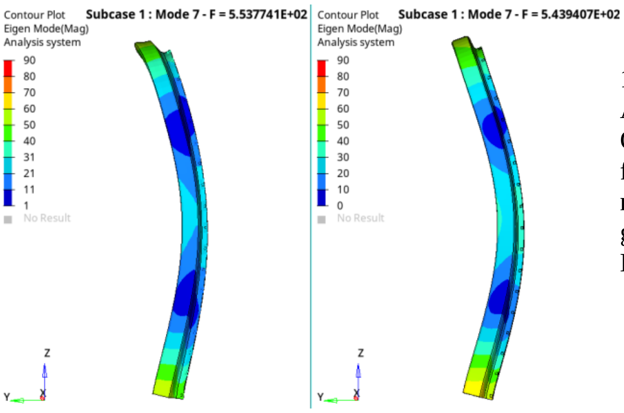
shows the values for the natural frequencies and the figure shows relative mode shapes.

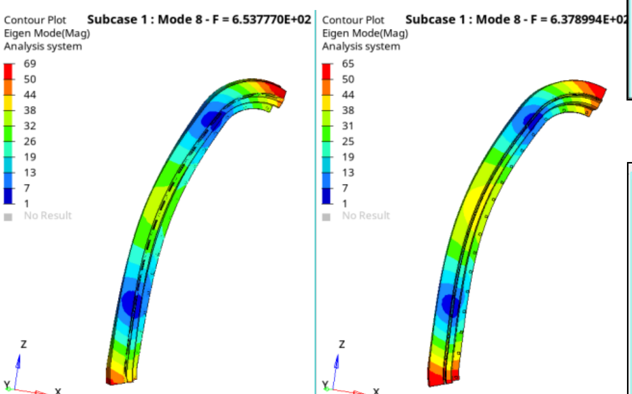
Table 6. Natural Frequency Values

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



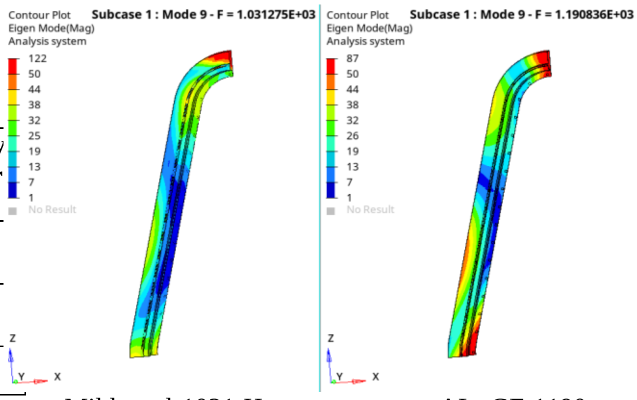
Mild steel-553 Hz AL-GF+544 Hz

Fig 5. 1st Mode Shape - Lateral Bending



Mild steel -654 Hz AL+GF-638 Hz

Fig 6. 2nd Mode Shape - Vertical Bending



Mild steel-1031 Hz AL+GF-1190 Hz

Fig 7. 3rd Mode Shape - Torsion

10.2 FRF Analysis

A frequency response analysis is performed using OptiStruct to check and confirm the natural frequencies and relative mode shapes extracted from normal mode analysis. The below figures show the graphs comparing 1st three modes for Frequency Vs Displacement.

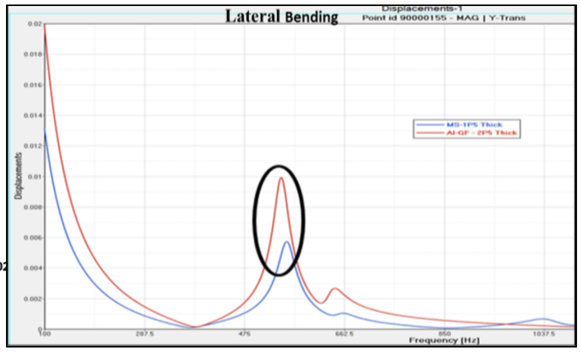


Fig 8. Lateral Bending Mode

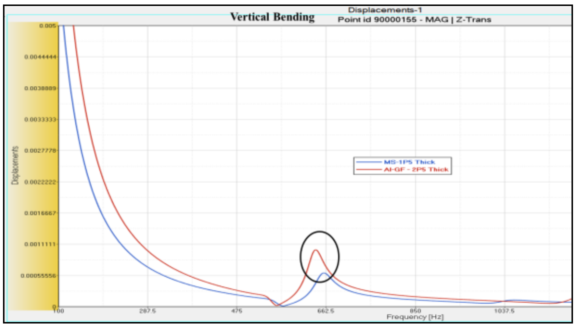


Fig 9. Vertical Bending Mode

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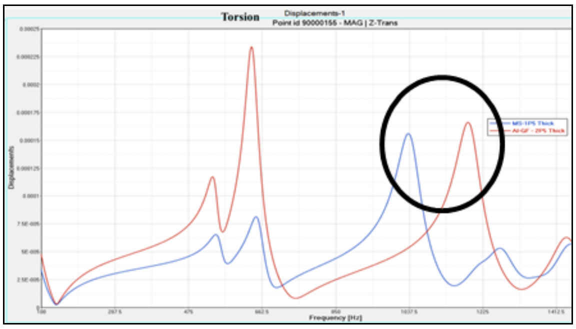

Fig 9. Torsion Mode

11. Weight Comparison

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

Table 7. Geometry and mass comparison

Model	Material	Thickness (mm)	Mass (Kg)
1	Mild Steel	1.5	1.53
2	Aluminium	2.5	1.09
	Glass Fiber	1	
Difference			0.44

12. CAE Result Summary

The below table gives a brief information about the comparison between the CAE results of two different materials.

Table 8. Result Summary

Parameters	Material	
	Mild Steel	Al with Glass Fiber
Natural Frequency Hz	553 Hz	544 Hz
	654 Hz	638 Hz
	1031 Hz	1190Hz

13. Conclusion

1-From the above Table 7 geometry and mass comparison, it is observed that Aluminium with reinforced Glass Fiber has benefits over Mild steel and reduces the weight of the C- Pilar by approximately 30%.
2- From above table 8 a result summary table shows that reinforced Glass fiber helps to reduce the mass gives a good damping effect and also adds stiffness to the structure.

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