Normal Mode Analysis of Automotive Car Body in White

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Abstract: **Body in White is the all welded structure made of different grades of steels to which all the other sub-systems like seats, steering, engine etc., are attached to form a complete car. The body-in-white, the backbone of a vehicle has to fulfill many functional requirements. Among these requirements are passive safety, service life, stiffness and acoustics. Besides increased body in white functionality, the relentless demand for fuel efficiency and improved driving behavior has contributed to a newer focus on body in white solutions. Body in white solutions can be grouped into engineering, manufacturing and materials solutions. Engineering defines a homogeneous load path in an optimized package, manufacturing focuses on methods such as sophisticated joining technologies, and the implementation of modern materials such as multiphase steel grades. BIW modal analysis is an important study in which the natural frequency of the structure is identified. The modal analysis is carried out on the car body using HyperMesh as preprocessor, optistruct as solver and hyperview as postprocessor. Steel with young's modulus 210 GPa is used for base model. By increases in thickness of some component of base modal, first frequency also increases. By adopting high grade steel material with different young's modulus for few components of car body in white, there is an increase in frequency. Iterations have been carried out to get highest first frequency, which will give better stiffness. The stiffer the body structure lesser the vibration while riding. Increased stiffness also improves handling capabilities.**

Keywords: HyperMesh, Finite Element Analysis, Body White, Natural frequency, LS-Dyna, Vibration Isolation

1. Introduction

BIW refers to the stage in automotive design or automobile manufacturing in which the car body sheet metal (including doors, hoods, and deck lids) has been assembled or designed but before the components (chassis, motor) and trim (windshields, seats, upholstery, electronics, etc.) have been added. In car design, the Body in White phase refers to the phase in which the final contours of the car body are worked out, in preparation for ordering of the expensive production stamping die. Main function of the BIW is to protect the occupants in case of roll-over accidents. Extensive computer simulations of crash worthiness, manufacturability, and automotive aerodynamics are required before a clay model from the design studio can be converted into a Body in White ready for production. It involves Normal mode, Modal analysis, Vibration Analysis, Eigen value and Eigenvector, Modal Analysis using FEM in this paper.

1) Methodology and Approach

A) Pre-processing: HYPERMESH
- Build the various components of the model
- Assign properties to the components
- To assemble them together in the proper location
- To simulate the connections between various components
- Boundary conditions (Frequency and load set up)

B) Processing: OPTISTRUCT
- Computing vibration analysis.
- To find the natural frequency of car body in white.

C) Post-processing: HYPERVIEW
- The analysis results in hyperview
- Thinking to improve the result.

In Hypermesh, Model set up is carried out in preprocessing and the model of SUV (BIW) is imported from Catia v5 software in IGES format. The imported model of BIW is further discredited into finite elements and all the elements need to pass the quality check. Assembly of various components into a single fit to form the BIW is done and welds are represented by using rigid body connectors -RBD2 and each individual part is assigned the requisite thickness and material property .The BIW assembly model is then solved using OptiStruct Software. The Results are analyzed using Hyperview software.

The various steps involved in the preprocessing are as follows. The suitable design is determined using an iterative procedure.

Results are obtained from post processing unit. Natural frequency and mode shapes are obtained from analysis. In base model, all components are made up of steel with young's modulus 210GPa. Fig shows the base model of the car BIW.

Table-1
Material used in Iteration-1(Base Model)

Material Name	Youngs Modulus in Gpa	Poisson's Ratio	Density in Kg/mm^3
Steel	210	0.3	7.89E-09

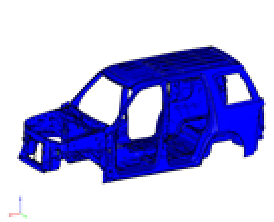

Fig. 1. Iteration-1: Base model

2. Different Bending of Car Body in White Designs

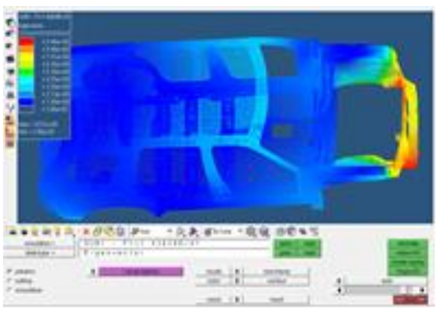

Fig. 2. The obtained frequency of mode-1 is 14.3628Hz

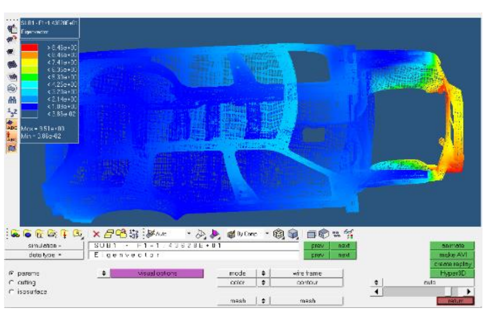

Fig. 3. The obtained frequency of mode-2 is 19.2474Hz

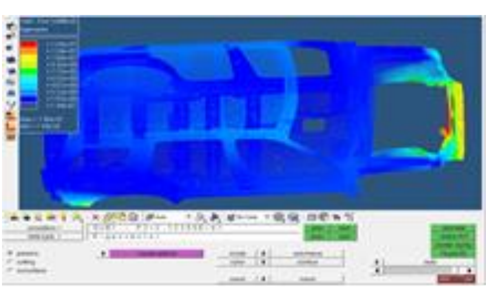

Fig. 4. The obtained frequency of mode-3 is 21.2355Hz

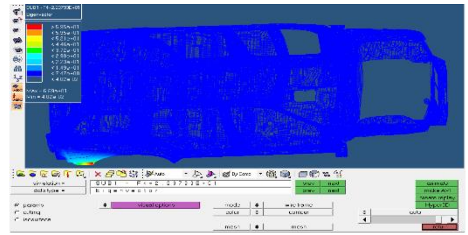

Fig. 5. The obtained frequency of mode-4 is 22.3793Hz

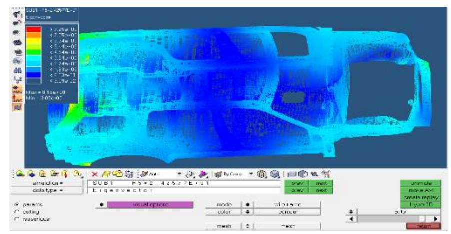

Fig. 6. The obtained frequency of mode-5 is 24.2577Hz

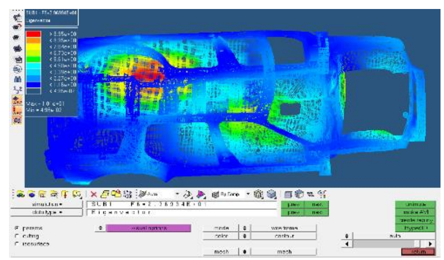

Fig. 7. The obtained frequency of mode-6 is 29.6994Hz

Table-2
Details of different modes with frequency of iteration

Iteration-1	
Mode-1 (Hz)	14.3628
Mode-2 (Hz)	19.2474
Mode-3 (Hz)	21.2355
Mode-4 (Hz)	22.3793
Mode-5 (Hz)	24.2577
Mode-6 (Hz)	29.6994
Mass (Kg)	250.6

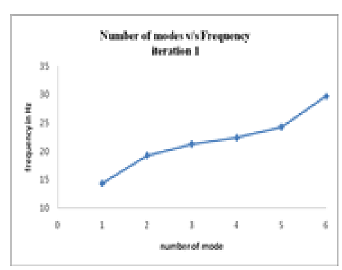

Fig. 8. Mode vs. Frequency of iteration-1

The Fig. 8, shows the mode v/s frequency of iteration-1. As the mode increases natural frequency also increases.

3. Results and Discussion

1. Iteration-1: Thickness of some components changed to 1.2mm in base model

Thickness of some components changed to 1.2 mm and thickness of remaining components remains same as that of the base model. Out of 123 components, nine components thickness has changed. All components are made of steel material with young's modulus 210GPa. Fig shows the thickness of components changed in base model.

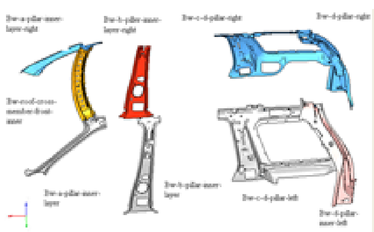

Fig. 9. Components

Table-3
Details of different modes with frequency of iteration-1

Iteration-1	
Mode-1 (Hz)	14.4047
Mode-2 (Hz)	19.3856
Mode-3 (Hz)	21.3808
Mode-4 (Hz)	22.4760
Mode-5 (Hz)	24.5374
Mode-6 (Hz)	29.9912
Mass (Kg)	255.0

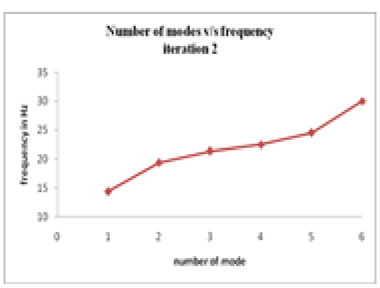

Fig. 10. Mode vs. Frequency of iteration

2. Iteration-2: Material of some components changed to High Strength Grade Steel-310GPa in base model

SAEJ2340-310 is high strength grade steel with young's modulus 310GPa. J2340-hot rolled steel. Material of some components changed to SAEJ2340 with young's modulus 310GPa and other components material remains same as base material (i.e. steel with young's modulus 210GPa).Out of 123 components, 22 components material has changed. Thickness of all components remains same as that of base model. Components of material (steel with young's modulus 310GPa) changed in base model.

Table-4
Details of different modes with frequency of iteration-2

Iteration-2	
Mode-1 (Hz)	14.7419
Mode-2 (Hz)	20.5543
Mode-3 (Hz)	22.5363
Mode-4 (Hz)	25.2185
Mode-5 (Hz)	26.4143
Mode-6 (Hz)	32.2525

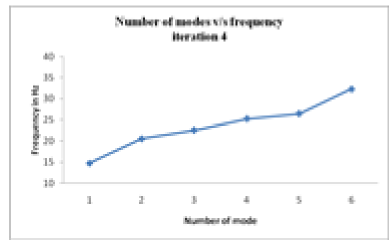

Fig. 11. Mode vs. Frequency of iteration

3. Iteration-3: Material of some components changed to High Strength Grade Steel -328GPa in base model

SAEJ2340-328 is high strength grade steel with young's modulus 328GPa and J2340-Hot rolled steel. Material of some components changed to high grade steel with young's modulus 328GPa and material of remaining components remains same as that of base model (steel with young's modulus 210GPa). Out of 123 components, 22 components material has changed. Thickness of all components remains same as that of base model components of material (steel with young's modulus is 328GPa) changed in base model.

Table-5
Details of different modes with frequency of iteration-3

Iteration-3	
Mode-1 (Hz)	14.7905
Mode-2 (Hz)	20.6751
Mode-3 (Hz)	22.8163
Mode-4 (Hz)	25.6634
Mode-5 (Hz)	26.7519
Mode-6 (Hz)	32.6362

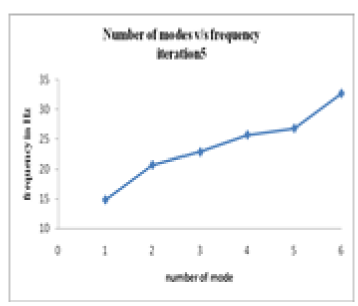

Fig. 12. Mode vs. Frequency of iteration

4. Iteration-4: Material of some components changed to High Strength Grade Steel -350GPa in base model

SAEJ2340-350 is high strength grade steel with young's modulus 350GPa. J2340-Hot rolled steel. Material of some components changed to SAEJ2340 with young's modulus 350GPa and material of remaining components remains same as that of base model (steel with young's modulus 210GPa). Out of 123 components, 22 components material has changed. Thickness of all components remains same as that of base model. The components of material (steel with young's modulus 350GPa) changed in base model.

Table-6
Details of different modes with frequency of iteration-4

Iteration-4	
Mode-1 (Hz)	14.8449
Mode-2 (Hz)	20.7967
Mode-3 (Hz)	23.1628
Mode-4 (Hz)	26.1858
Mode-5 (Hz)	27.1491
Mode-6 (Hz)	33.0821

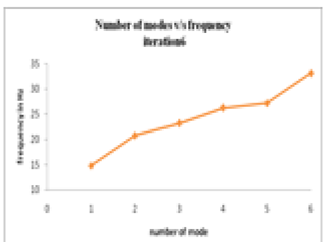

Fig. 13. Mode vs. Frequency of iteration

5. Iteration-5: Material of some components changed to High Strength Grade Steel -407GPa in base model

SAEJ2340-407 is high strength grade steel with young's modulus is 407GPa, J2340-hot rolled steel. The material of some components changed to SAJ2340-407 with young's modules 407GPa and material of remaining components remains same as that of base model (steel with young's modules 210GPa). Out of 123 components, 22 components material has changed. Thickness of all components remains same as that of base model. The components of material (steel with young's modulus 407GPa) changed in base model.

Table-7
Details of different modes with frequency of iteration-4

Iteration-5	
Mode-1 (Hz)	14.8449
Mode-2 (Hz)	20.7967
Mode-3 (Hz)	23.1628
Mode-4 (Hz)	26.1858
Mode-5 (Hz)	27.1491
Mode-6 (Hz)	33.0821

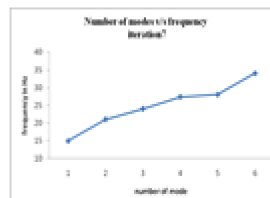

Fig. 14. Mode vs. Frequency of iteration

Table-8
Details of different modes with frequency of all iterations

Iterations	Mode-1 (Hz)	Mode-2 (Hz)	Mode-3 (Hz)	Mode-4 (Hz)	Mode-5 (Hz)	Mode-6 (Hz)	Mass (Kg)
Base model	14.3628	19.2474	21.2355	22.3793	24.2777	29.6994	250.6
Thickness of some components changed to1.2mm in base model	14.4047	19.3856	21.3808	22.4760	24.5374	29.9912	255.0
Material of Some components changed to high strength grade steel - 310GPa in base model	14.7419	20.5543	22.5363	25.2185	26.4143	32.2525	250.6
Material of Some components changed to high strength grade steel - 328GPa in base model	14.7905	20.6751	22.8163	25.6634	26.7519	32.6362	250.6
Material of Some components changed to high strength grade steel -350GPa in base model	14.8449	20.7967	23.1628	26.1858	27.1491	33.0821	250.6
Material of Some components changed to high strength grade steel -407GPa in base model	14.9655	21.0271	24.0489	27.4448	28.1129	34.1373	250.6

4. Conclusion

During the study of the current BIW through seven different iterations, we have reached a natural frequency of 14.9655Hz as the highest first frequency. The series of study have improved the first frequency of the BIW from 14.3638Hz to 14.9655Hz. This has been achieved by using high strength grade steel SAEJ2340 (young's modulus is 407GPa) for important structural members of the BIW which give stiffness to the structure. Following inferences can be drawn from the study conducted.

- The natural frequency of the structure increases with the increase of young's modulus of the material.
- Bending of the structure as the first mode and then the twisting modes.
- The natural frequency contour gives an insight into the weakest portions (regions highlighted in red) on the structure. This is of great importance for design of the structure. The natural frequency of the structure can be influenced by changing the design of these portions of the total structure.
- The use of high strength material for the BIW structure also helps for better performance of the vehicle in the crash scenario.
- The high strength material will also help in achieving better durability of the structure.

The natural frequency of 14.9655Hz is largely satisfying from the structural performance and non-resonance purposes for the current configurations of the BIW. This is achieved by the use of high strength SAEJ2340 steel with young's modulus 407GPa for the important structural members of BIW.

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