Finite Element Analysis of Car Structure for Bending and Torsional Stiffness

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Abstract - *Automotive design engineers face the thought-provoking problem of developing products in highly competitive markets. Vehicle skeleton is vital to confirm the load of varied elements and loads applied throughout vehicle operational area unit adequately supported while not vital deflection. The structure is likewise in charge of securing occupants and payloads amid crashes. The present research paper is around to check the stiffness (Bending and Torsional) of Body in White structure as it takes up the whole vehicle self-weight alongside the inhabitant's weight under thought. In this research work BIW structure is modelled as two models which is of different materials and compared for the percentage increase in stiffness of the structure.*

Keywords: Body In White(BIW), Stiffness

1. INTRODUCTION

The overall market opening and automotive production capacity increment stimulate the automotive plants competitiveness. In the car business the quality is reflected through the consumer loyalty's in connection to the items and offered administrations. Current auto economic situations and forthcoming government guidelines not just authorize carmakers to lesser the fuel utilization and cost for their vehicles yet in addition upgrade different attributes of their items, for example, inhabitant security, taking care of value, ride solace and client's recognition. The client's view of the vehicle is characterized by putting it progressively more 'strong' street feel just as recuperating the basic low-recurrence issues like seat quake and guiding segment wobble. For the most part, view of strength and NVH execution are identified with the solidness of the vehicle body structure. Dealing with nature of vehicle is straightforwardly influenced by suspension structure and relies upon the little versatile distortions in respect to the vehicle focal point of mass, and little ill-shapen are portrayed via vehicle body stiffness. These days car division is driven by light weighting key to cutting edge item advancement utilizing savvy elective material like aluminium, composite materials in top end vehicles because of their few points of interest. BIW accounts at half weight of vehicle and having a degree to diminish the weight by methods for elective materials. Steel is constantly supported via car businesses because of its

effortlessness in creation, yet in most recent quite a while fuel costs are rising and reusing guidelines are coming into power in this manner it progresses toward becoming need to diminish weight of vehicle. Car producing process is essentially in three phases; first stage is the manufacture of a sheltered, light weight and basically stable vehicle body in the Body shop, the second stage is putting the defensive and enhancing coats on the vehicle body in the process plant called Paint shop, lastly the fitting of Trims and Chassis materials in the Assembly shop.

During the conceptual design stage, when changes to the design are easiest to implement and have lower impact on overall project cost, the weight and structural characteristics are mostly unknown since detailed vehicle information is unavailable at this early stage, This lack of knowledge about the design problem can be seen below in Figure 1.1, However, even with insufficient information, the structural characteristics need to be considered and included in the design process from the outset of the conceptual stage. For the reasons given above the present research here focuses on the conceptual design stage of an automotive structure.

2. OBJECTIVES

The following of the objectives of my research are:

- Objective of the study is to minimizing the volume fraction that is to minimize the overall design space volume.
- To check dynamic behaviour of model BIW structure and to check connectivity of assembled model.
- Design response for torsional stiffness is displacements in Z translational directions measured at front shock tower which is then used as the responses.
- Design response for bending stiffness is displacements in Z translational directions measured at occupant position which is then used as the responses.

3. ANALYSIS OF A BIW STRUCUTRE

3.1 Meshing

The parts were imported one by one in HYPERMESH, then the each part was meshed with certain conditions, finer the mesh more approximate will be the results. As 2D shell meshing is used TRIA and QUAD elements are formed. As the elements are stiffer, more stress will be produced and it shows less deformation which will tend to fail the part. As their will be more stress near the holes, edges and on the corners. Tolerances were checked after meshing, as the degree of meshing is proportional to results, the links of the QUAD elements is tried to keep straight. The below figure 4.2 shows the complete meshed model of BIW structure. The main criterion that brings the results approaching to real values is the refinement of meshing influencing results very approximate to real values. Refinement of meshing should be an optimized one so that while solving it doesn't consume much time which directly affects cost.
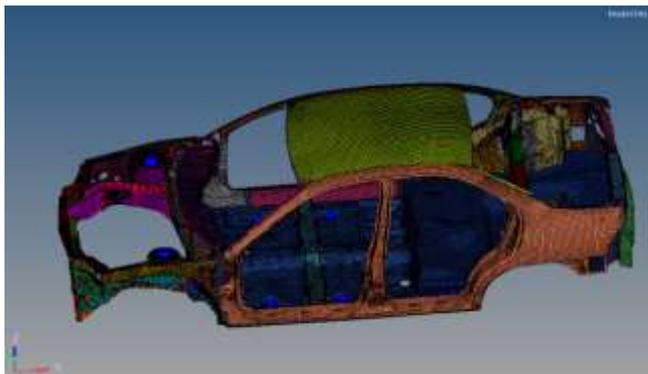
Fig -1: Meshed BIW Structure

3.2 Connections

In order to connect two parts permanently in a BIW structure spot welding or seam welding is used, for similar metals spot welding is used and for dissimilar metals seam welding is used. In ABAQUS connectors comes into a picture where in which node to node contact and node to surface contacts is used. In ABAQUS connectors comes into a picture where in which node to node contact and node to surface contacts is used. ABAQUS uses coupling kinematic (coup-kin) and kinematic coupling (kin-coup) for small distance which are 1D elements and for large distance DCOUP3D which is a hexa element. As shown in the below figure, yellow points represents weld points where the connectors are used like coup-kin and DCOUP3D depending on requirement and then realised.
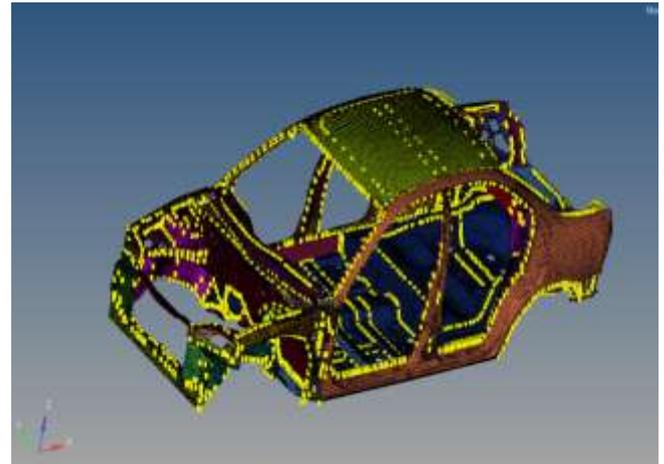
Fig -2: Connectors

3.3 Materials Used

As BIW structure is modelled as two types of models, one is basic model and another one altered one. First basic BIW model consist of SAE1045 with E=270000MPa, μ=0.3, ρ=7.85e^9 T/mm^3 and Al2024 with E=75000MPa, μ=0.3, ρ=2.7e^9 T/mm^3.

Where as the altered BIW model madeup of SAE1045 with E=270000MPa, μ=0.3, ρ=7.85e^9 T/mm^3 STEEL 420S45 with E=200000MPa, μ=0.3, ρ=7.78e^9 T/mm^3 and STEEL DP800 with E=210000MPa, μ=0.3, ρ=7.87e^9 T/mm^3.

3.4 Bending Stiffness

Stiffness is the property of a material defined as the resistance to deformation. Essentially it is the opposite of the flexibility. The harder it is to bend a material the greater the stiffness. Higher the stiffness of the member higher is the load carrying capacity, as the member can store high energy and lower the deflections. Bending stiffness is the ratio of bending moment to rotation or moment required to cause unit rotation. Static bending test was done to verify the firmness of the body on which the long-lasting of the entire car would depend car would depend of the body on which the long-lasting of the entire car would depend. Static bending test was done to verify the firmness of the body on which the long-lasting of the entire car would depend.

3.5 Torsional Stiffness

Torsional stiffness is the characteristic property of a material which signifies how rigid is that material, how much resistance it offers per degree change in its angle when twisted. In the area of mechanics of solids two equal and opposite couples acting about the axis of shaft gives rise to torsion. The unit of torsion is KN-m or N-m etc. Power is generally transmitted from motor to compressor, turbine to generator; motor to pump etc.

The angle of twist can be defined as the angle of twist in a shaft is the angle through which the section at the right side end rotates about the longitudinal axis and angle of twist is measured with reference to the section at the top side end or bottom side end of the shock tower .in which also the torsional strength is defined as the torque per unit maximum shear stress. Torsional shaft is also known as the efficiency of a shaft. Also torsional rigidity is defined as it is the torque required to produce a unit angle of twist in a specified length of the shaft.

3.6 Equations Used

- For calculating bending stiffness

$$K_{Bending} = \frac{F}{\delta} \quad (1)$$

Here, F= total Force applied at occupants position in N

δ = Deflection in mm

- For calculating torsional stiffness

$$K_{Torsion} = \frac{T}{\Theta} \quad (2)$$

Here, T= torsional load in N

Θ= Angular deflection in deg

= $\tan^{-1}\frac{2z}{w}$

z= deflection in mm

w= length of a car in mm=4086mm

3.7 Finite Element Analysis

FE Modelling is done in HYPERMESH V13.0 software since It is dedicated software for complete pre-processing activity such as meshing of complex geometry, material properties assigning, sectional properties assigning & applying boundary conditions etc. can done with greater ease. BIW structure consist of 174335 elements and 176356 nodes.

3.7.1 Analysis for static Bending stiffness

As far as bending stiffness analysis the body in white structure of both basic and altered models the average weight of a occupant is applied at the four occupants position of 1962N i.e 490.5N is applied at each seating position in z-direction and front and rear shock towers are constrained in all degrees of freedom such that four point bending occurs.
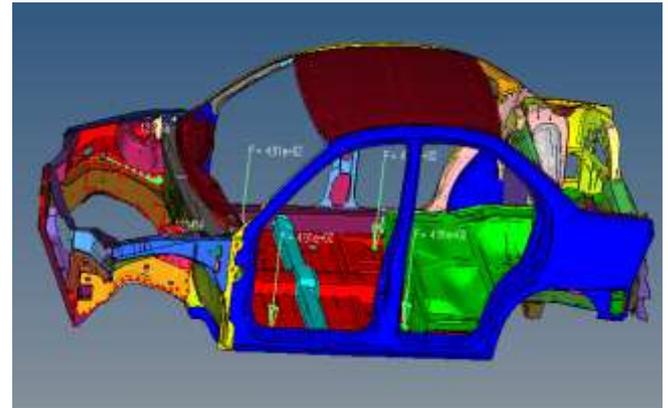

Fig -3: Bending load applied to BIW structure

3.7.2 Analysis for static torsional stiffness

Here load of 2000N is applied to front shock towers but in opposite direction and rear shock towers are constrained in all degrees of freedom. Solved in ABAQUS for result. Deflection is measured and angle of twist is calculated that is used to calculate torsional stiffness.
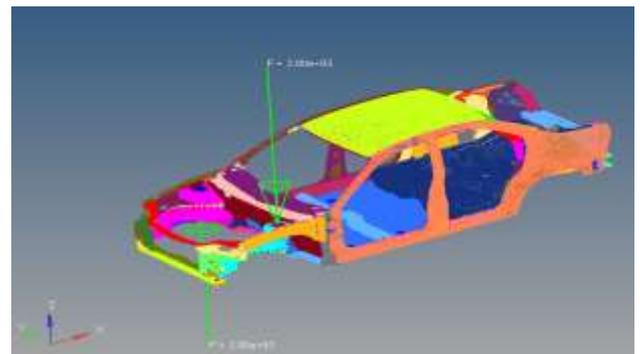

Fig -4: Torsional load

4. RESULTS

4.1. For bending stiffness analysis

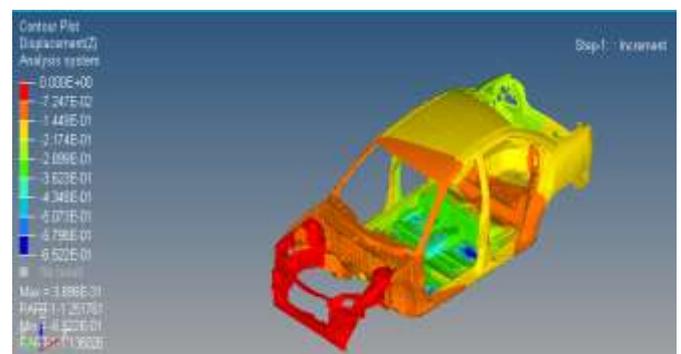For basic body in white structure, deflection is found to be 0.072mm

Fig -5: Maximum displacement for bending loading in basic BIW structure

$$K_{Bending} = \frac{F}{\delta}$$

$$K_{Bending} = \frac{1962}{0.072}$$

$$K_{Bending} = \frac{27250N}{mm}$$

For altered body in white structure, deflection is found to be 0.049mm

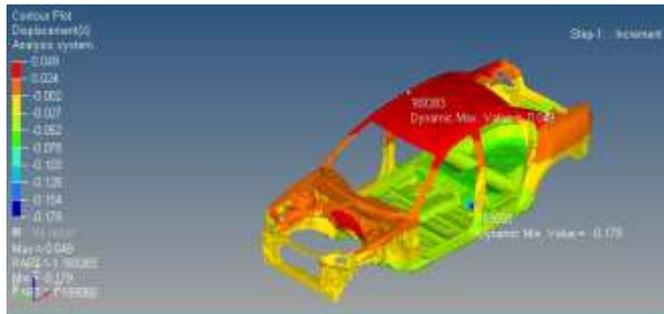**Fig -6:** Maximum displacement for bending loading in altered BIW structure

$$K_{Bending} = \frac{F}{\delta}$$

$$K_{Bending} = \frac{1962}{0.049}$$

$$K_{Bending} = 40040.8163 \text{ N/mm}$$

Table -1: Comparison of bending stiffness

Description	Base Model	Upgraded Model	%Increase in stiffness
Bending stiffness	27250 N/mm	40040.816N /mm	31.94%

4.3 For Torsional stiffness analysis

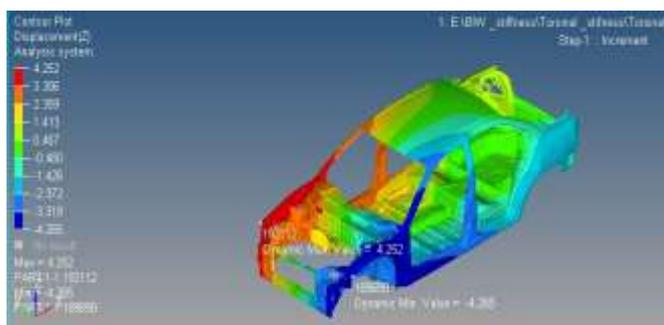For basic body in white structure, deflection is found to be 4.252mm.

Fig -7: Maximum displacement for torsional loading in basic BIW structure

$$K_{Torsion} = \frac{T}{\Theta}$$

$$\theta = \tan^{-1}\left(\frac{2z}{w}\right)$$

$$\theta = \tan^{-1}\left(\frac{2*4.252}{4086}\right) = 0.1192 deg$$

$$\theta = 0.1192 deg$$

$$K_{Torsion} = \frac{T}{\theta} = \frac{2000}{0.1192} = 16778.52 N/deg$$

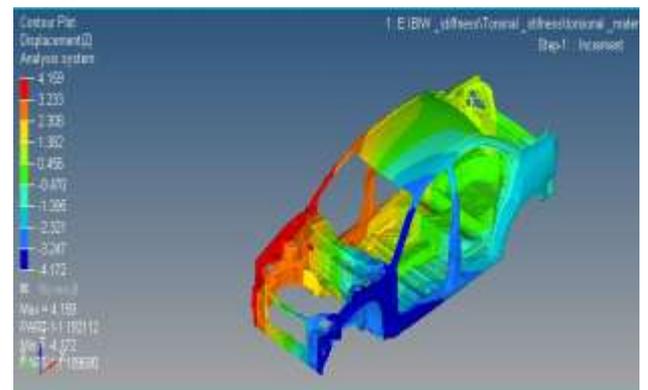For altered body in white structure, deflection is found to be 4.159mm

Fig -8: Maximum displacement for torsional loading in altered BIW structure

$$K_{Torsion} = \frac{T}{\Theta}$$

$$\Theta = \tan^{-1}\left(\frac{2z}{w}\right)$$

$$\Theta = \tan^{-1}\left(\frac{2*4.159}{4086}\right)$$

$$\Theta = 0.1166 deg$$

$$K_{Torsion} = \frac{T}{\Theta} = \frac{2000}{0.1166} = 17152.66 N/deg$$

Table -2: Comparison of torsional stiffness

Description	Base Model	Upgraded Model	%Increase in stiffness
Torsional stiffness	16775.252	17152.66	2.18%

5. CONCLUSIONS

In the presented research, two different approaches for BIW modelling were introduced and investigated. Obtained results were compared and

evaluated in details. Based on the finite element analysis studies, the following conclusion were drawn

- From the finite element analysis the Upgraded model has increased in bending stiffness i.e., 40040.16 N/mm from Base model of 27250 N/mm, 31.94% increase.

- The Upgraded model has increased in Torsional stiffness i.e., 17152.66Nm/degree from Base model of 16778.52 Nm/degree, 2.18% increase.

- The base model has a mass of 284kg and the upgraded has a mass of 309kg, which is approximately 8% increases, and which in turn doesn't affect the vehicle performance

- The stress and deflection are within the limit, thus concluded.

6. REFRENCES

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