

Establishing Correlation between Torsional and Lateral Stiffness Parameters of BIW and Vehicle Handling Performance

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ABSTRACT

There are numerous parameters that affect the handling characteristics of ground vehicles. Among those, lateral and torsional body stiffness plays a major role. Increasing the body stiffness not only improves the handling characteristics, [1] but also other properties like crashworthiness, [6], Noise Vibration & Harshness [NVH], and durability, [2], [3]. But a body with high stiffness, demands a higher weight and cost because of the increased panel thickness required and reinforcement members. Car manufactures try to reduce the vehicle weight to improve the fuel efficiency, because this is one of the primary criteria based on which customers purchase vehicles. In the process of achieving a light weight body, the body stiffness may suffer. As a result of many earlier studies, it is known that increase in stiffness of the vehicle body improves the handling of the vehicle, [2]. But, there has been no attempt made to predict how much improvement in handling occurs for a particular increase in body stiffness. The objective of this project is to establish a Correlation between Torsional and Lateral Stiffness Parameters of Body-In-White [BIW] on Vehicle Handling Performance. The correlation obtained can be used in optimization of the initial design so that the handling of the vehicle may not suffer in the process of weight reduction.

The areas of the vehicle body that are susceptible to deformation during the static and dynamic conditions are identified using Computer Aided Engineering [CAE] Techniques. Based on the findings from CAE, various fixtures are fabricated according to the need to vary the stiffness parameters. The change in handling performance with the variation of torsional and lateral stiffness parameters is evaluated. After understanding the change in subjective

performance, objective data is measured for validation of the same. The objective evaluation of the vehicle is done through standard test procedures and the variation in the handling characteristics with reference to the standard vehicle is discussed.

INTRODUCTION

As discussed earlier, it has been widely accepted that the increase in stiffness of the vehicle body improves the handling and NVH behavior of the vehicle, [2]. In this project, an attempt has been made to predict how much improvement in handling occurs for a particular increase in body stiffness. Also, it is attempted to validate the results to check the accuracy of the study. The Computer Aided Design [CAD] model of the vehicle is made and is subjected to Finite Element Analysis [FEA]. Linear static stiffness analysis is done to measure the torsional and lateral stiffness of the BIW. A 95% correlation between the actual BIW stiffness and that measured using CAE is already established according to the company internal standards. Hence, the actual measurement of the BIW stiffness after each modification is avoided during the project.

Arresting the deformation of the BIW will increase stiffness. The various deformation modes are studied, and methods for arresting the deformation in torsional and lateral deformation modes are found out. The stiffness parameters are varied by welding pipes, such that they arrest the deformation of areas in torsional and lateral deflection modes. Seven iterations for increased torsional stiffness are obtained from modelling. Out of these, considering the time duration and ease of fabrication, three are selected. Two iterations are made for increased lateral stiffness. The modifications are then implemented on the prototype model.

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The prototype vehicle is then tested to evaluate the effect on handling performance. Subjective evaluation as well as objective measurement of the handling performance parameters is done on the base vehicle and also after each fabrication. The improvements in the results are studied and the correlation is obtained. Sinusoidal Steer Input test (Sine test), [4] is performed for objective measurement of handling performance parameters. Yaw gain and time lag are the parameters that are measured. The results are studied and the correlation is obtained. The correlation obtained is validated on another model to check the accuracy. The validation is done only for measuring the performance for improved torsional stiffness because of time constraints. Two iterations are performed on this model, one being the base vehicle and the other, with BIW torsional stiffness increase.

METHODOLOGY

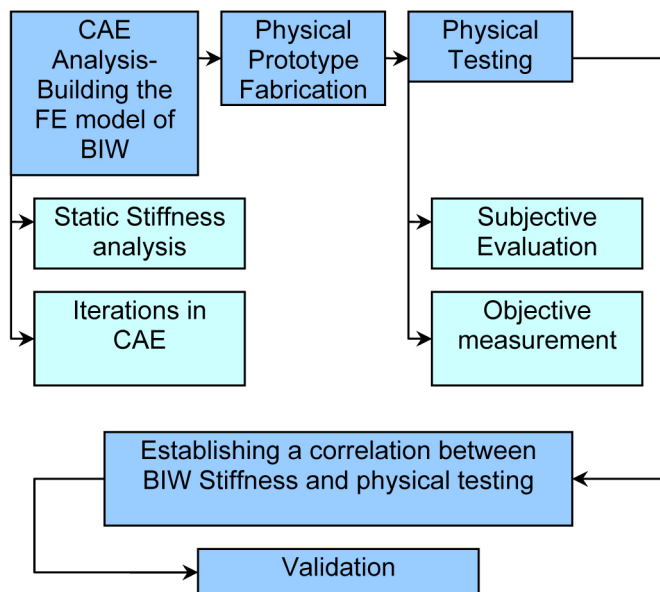


Fig 1. Process flow

CAE ANALYSIS

STATIC STIFFNESS ANALYSIS

The BIW of the project prototype as well as the validation model are created in CAD. They are then meshed for Finite element analysis. The mesh elements selected are two dimensional and are either triangular or quadrilateral in shape. These shapes are selected because meshing is done on sheet metal surface and also facilitate proper meshing at irregular boundaries. Modifications done for subsequent iterations to alter the stiffness are performed in CAE. The meshed model is then imported for finite element analysis. Normal mode analysis is done to check the integration and

correctness of the model. The different modes of vibration and the strain energy dissipation contour are also studied through normal mode analysis.

The main parameter that is to be considered is the modal shape that occurs at a particular frequency. These modes show the deformation pattern of the BIW. Out of the different body modes that are obtained, torsional and lateral vibration modes are considered for this study. The strain energy dissipation contour gives a clear idea of the area on the BIW which are prone to deflection. Since stiffness is resistance to deformation, arresting the deflection of these areas increases the stiffness. Linear static stiffness analysis is used to quantitatively measure the global body torsional and lateral stiffness of the attachment points of the models. The method of actual measurement of the stiffness is simulated in this process. The following are the important stiffness measured on the vehicle body

- 1). Torsional Stiffness
- 2). Lateral Stiffness

Measurement of torsional stiffness

For measurement of global body torsional Stiffness, the BIW is first constrained at rear strut attachment points on the body. Torsional load is applied at the front strut attachment points and the deflections at different nodal points on the body specified according to the standards are measured. From these deflections, the angular displacement of each node is measured and averaged using least square method. The torque required to produce unit angular displacement gives the torsional stiffness. The basis for calculating torsional stiffness is the relation between torque and rotation angle.

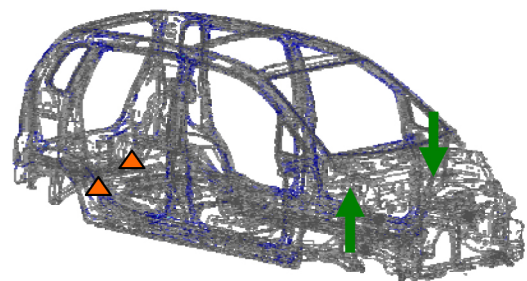


Fig 2. Load & boundary condition for static torsional stiffness evaluation

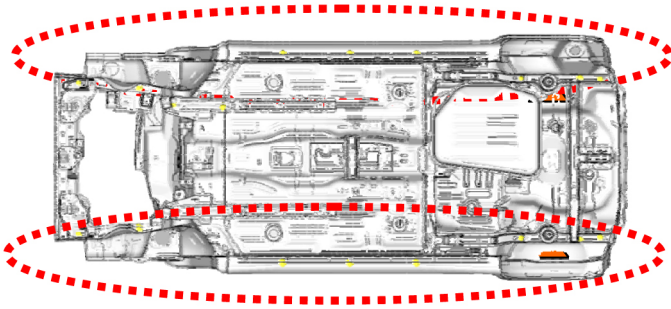


Fig 3. Measurement locations for torsional stiffness evaluation

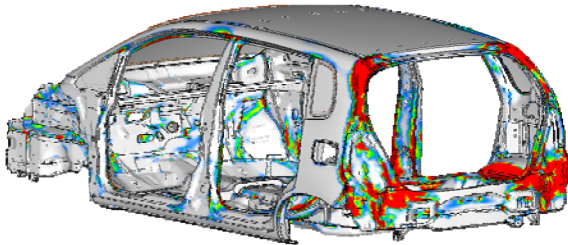


Fig 4. Strain energy contour

Models developed in CAE having increased torsional stiffness

The Stiffness parameters are varied by making modifications in the CAE model of the BIW. Steel pipes are used to modify the stiffness parameters. Torsional vibration modes of the body are analyzed and areas prone to maximum deflection are identified. The areas prone to maximum deflection are arrested to increase stiffness. Seven iterations for increased torsional stiffness are obtained by CAE modeling. From these, three are selected for fabrication, considering ease of fabrication.

Table 1. Iterations done in CAE

SL. No	Model	% Increase in Torsional Stiffness
1	B000	base
2	B001	22
3	B002	33
4	B003	36.88
5	B004	40.50
6	B005	54.8
7	B006	61
8	B007	80.88

Iteration-1

Iteration 1 is the base vehicle B000 in the table. Stiffness values of all the other models are taken as an increment in percentage from the stiffness of B000.

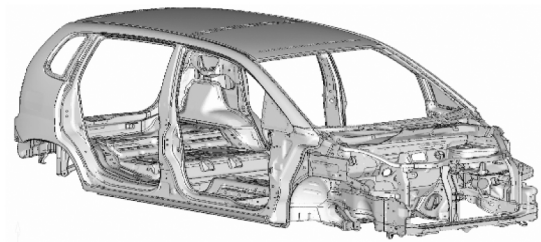


Fig 5. Base Model - B000

Iteration-2

This is the model named B001 in the table. In this iteration the torsional stiffness is increased by 22%. When the body modes are analyzed, it is found that rear door opening has the largest torsional deflection. This deflection is arrested by welding pipes as shown in the figure. The total length of pipe used is 2.95m

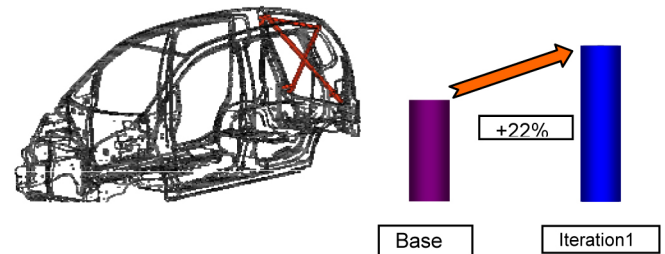


Fig 6. Iteration 2 - Model B001

Iteration-3

This is the model named B002 in the table. In this iteration, the cage like structure that is fabricated as shown in the figure increases the torsional stiffness by 33%. The total length of pipe used is 14.20m

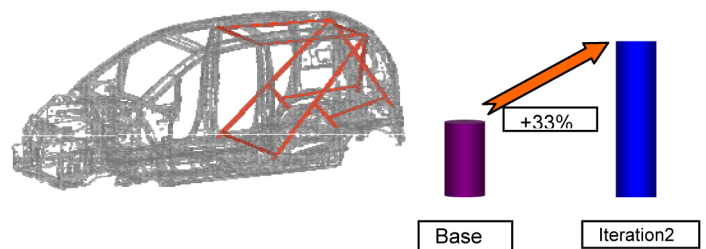


Fig 7. Iteration 3 - Model B002

Iteration-4

This is model named B006 in the table. In this iteration, torsional stiffness is increased by 61%. This is the final iteration with modification for improved torsional stiffness. The total length of the pipe used is around 17.76m.