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Designing and Frequency Analysis on Bus Structure for Lynx and Stag

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Abstract:
The structural strength is a fundamental concern. Unnecessary weight of the bus structure leads to reduction in overall performance of bus. The designing the whole frame with analysis by using solidwork software and reducing the capital spent on out sourcing as well as materials. The perfect chassis is a large diameter thin walled tube. In order to understand this we should have a solid grasp of statics and deflection. The Automotive chassis has two main goals, to hold the weight of the components and to rigidly fix the suspension components together when moving. The frame of the bus consists of five parts are roof, floor, sides, front, rear. Each frames are designed separately and is assembled together using weldment. The frame is a space frame structure made separately out of two types of cross sections that is rectangular tube and round tube. After the completion of the frame, stress deformation and frequency modes are analysed and results are obtained. As per the target of 5 hertz of minimum natural frequency, the model was designed and values more than the target is achieved in all the five modes which are detailed results in this report.
Keywords: *Body Structure, 3D-Modelling, Frequency, Stress, Displacement, Solidworks, Lightweight.*

1. Introduction

Firstly we shall know what stag and lynx mean here. Stag and Lynx are the two models of Bus series developed for Indian as well as South American markets such as Brazil. Both the series are meant for Indian use but the Lynx series is also meant to serve Brazil and is exported as CBU (Completely Built Unit). This mainly focuses on Chassis and the bus structure frame. This is basically about building and analysing a structural frame for a LYNX & STAG series bus chassis. The structure has to build strong enough as to withstand static and dynamic forces generated internally and externally but equally economic and light. The main work starts with the taking measurement constraints from the ladder frame. Then the chassis is designed and is analysed using software's. Presently the models are created indigenously and are manufactured in traditional way. The end result would help creating, analysing the model and hence saving the out-sourcing costs and time. Basically an automotive chassis is tasked with holding all the components together while driving, and transferring vertical and lateral loads, caused by accelerations, on the chassis through the suspension and to the wheels.

Manokruang and Butdee (2009) used a model based on beam elements, in which the transverse geometry of the tubular elements is summarized in the flexural and the 2nd approach of light weight design. Used expert system, to eliminate less priority parts and reduced the overall vehicle weight by maintaining the stress level below the allowable [2].

Lan et al. (2004) investigated medium-sized bus- body structure. By using computer-aided design (CAD) package for modeling and the analysis was made using finite element (FE) solver, ANSYS.Sensitivity analyses were carried out on body structural parameters with the objective of minimizing body weight while maintaining the required performance. Based on the sensitivity analyses, it was found the upper cross-beam of the chassis frame, the vertical middle posts, the bridging bars of the chassis frame and the lower cross-beam of the chassis frame are more sensitive to rigidity/weight and frequency/weight [4].

2. Vehicle Loading

The first step to designing a vehicle frame, or any structure, is to understand the different loads acting on the structure. The main deformation modes for an automotive chassis are given in as:
1. Longitudinal Torsion
2. Vertical Bending
3. Lateral Bending
4. Horizontal Lozenging

2.1 Longitudinal Torsion

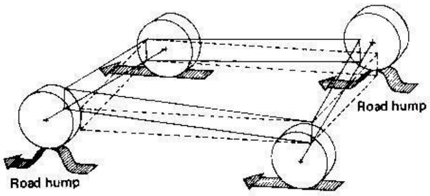

Figure 1: Longitudinal Torsion [10]

Torsion loads result from applied loads acting on one or two oppositely opposed corners of the bus. The frame can be thought of as a torsion spring connecting the two ends where the suspension loads act. Torsional loading and the accompanying deformation of the frame and suspension parts can affect the handling and performance of the bus. The resistance to torsional deformation is often quoted as stiffness in foot-pounds per degree. This is generally thought to be the primary determinant of frame performance.

2.2 Vertical Bending

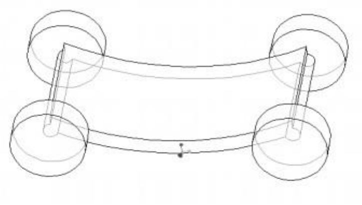

Figure 2: Vertical Bending [10]

The weight of the passengers and components mounted to the frame, such as the engine and other parts, are carried in bending through the bus frame. The reactions are taken up at the axles. Vertical accelerations can raise or lower the magnitude of these forces.

2.3 Lateral Bending

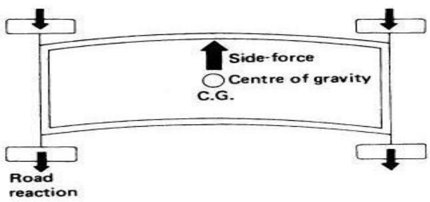

Figure 3: Lateral Bending [10]

Lateral bending loads are induced in the frame for various reasons, such as road camber, side wind loads and centrifugal forces caused by cornering. The sideways forces will act along the length of the bus and will be resisted at the tires. This causes a lateral load and resultant bending.

2.4 Horizontal Lozenging

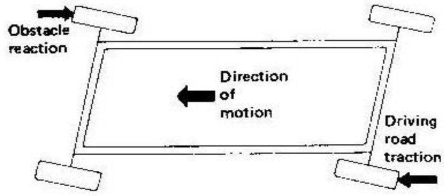

Figure 4: HorizontalLozenging [10]

Forward and backward forces applied at opposite wheels cause this deformation. These forces may be caused by vertical variations in the pavement or the reaction from the road driving the bus forward. These forces tend to distort the frame into a parallelogram shape as shown in the figure (4). It is generally thought that if torsional and vertical bending stiffness are satisfactory then the structure will generally be satisfactory. Torsional stiffness is generally the most important as the total cornering traction is a function of lateral weight transfer.

3. Methodology

The perfect chassis is a large diameter thin walled tube. In order to understand this you should have a solid grasp of statics and deflection.
The Automotive chassis has two main goals.

- Hold the weight of the components.
- To rigidly fix the suspension components together when moving.

The first item is an easy design solution and is also the basis of the original chassis designs that were taken from horse drawn carriages. One of the most effective shapes for supporting point loads fixed at two ends is an I-Beam, a box tube, or a C-Beam. One beam on either side so that a floor could be attached and even the smallest of I or C beams can hold tremendous weight. When cornering torques is applied to the chassis it causes it to twist. The engineering solution for this torsion problem is simply a tube and the stiffer the chassis the more cornering torque it can handle with less effect on suspension geometry. After brief the points from all points of view, rectangular cross-section is chosen with the material being steel 1045 cold rolled. After planning for body weight reduction and increased and optimized strength for better performance of our buses specific to Indian road conditions, Out of many trials, the first model is planned and designed by using solidwroks and frequency analysis is done on bus frame and obtained result are compared between rectangular tube and round tube.

4. Modeling and Solidworks Analysis

4.1 Model Development

- **Major Dimensions**
- TOTAL LENGHT- 7900MM
- TOTAL WIDTH-2300MM
- TOTAL HEIGHT-2360MM
- FRONT WINDSHEILD- 1200 X 2300MM (H X W)

- RADIATOR GRILLE-900 X 730MM (H X W)
- DOOR DRIVER -1000 X 800MM (H X W)
- DOOR PASSENGER -1600 X 750MM (H X W)
- WINDOW PANE-700 X 1140MM (H X W)
- VENTILATOR-500 X 1475MM (H X W)
- REAR EMERGENCY WINDOW-800 X 1830MM (H X W)
- BOOT-750 X 1400MM (H X W)
- BATTERY COMPARTMENT-640 X 750MM (H X W)

4.2 Component Specifications

Here two separate models are created; one with therectangular tube and other with round tube.
Rectangular tube specifications (in mm)

- 70 x 40 x 5
- 60 x 40 x 3.2
- 50 x 30 x 2.6

Tubular pipe (round c.s) (in mm)

- 42 x 4.0
- 33.7 x 4.0

4.3 Final Material and Type Selected

➢ **Material**

- AISI 1045 steel, cold drawn.

➢ **Type**

- Rectangular tube
- Round tube.

4.4 Tools / Software Used

Solidworks 2011 64bit,solidworks simulation included.

4.5 Modelling of Bus Structure

The bus frame consists of few sub-frames. They are listed below
(a) Floor
(b) Side
(c) Front
(d) Rear
(e) Roof.
Each sub-frame is made separately and isjoined together and each one has its own unique design and significance.

➢ **Complete frame assembly**

The sub-frames are joined together using welding to get a unified space frame.

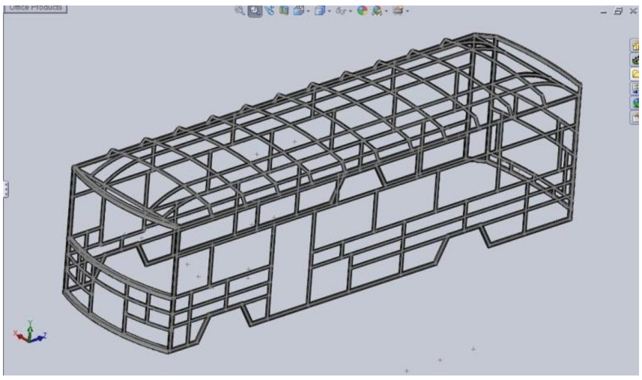

Figure 5: Solidwork model of bus structur

4.6 Model Analysis

➢ **Major Frequency Displacement Analysis**

Here we are analysising five modal by using Rectangular tube in that only one deformation of Roof Frame and Total Frame is shown below.

➢ **Rectangular Tube FrameFor Roof Only**

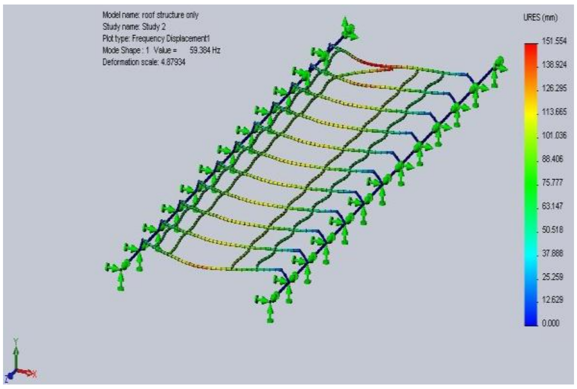

Figure 6:Roof Deformation

➢ **Total Frame For Rectangular Tube**

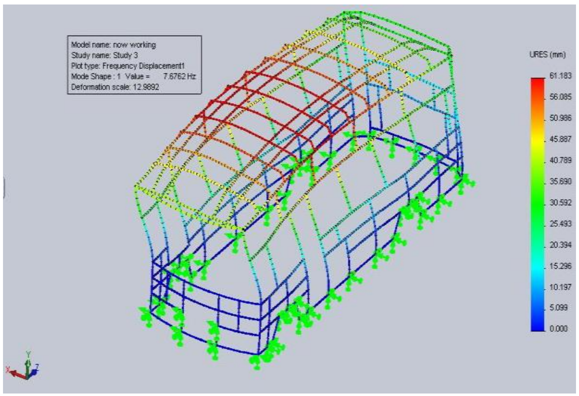

Figure 7: Total Frame Deformation

Here we are analysising five modal by using Round tube in that only one deformation of Roof Frame and Total Frame is shown below.

➢ **Round Tubular Frame For Roof Only**

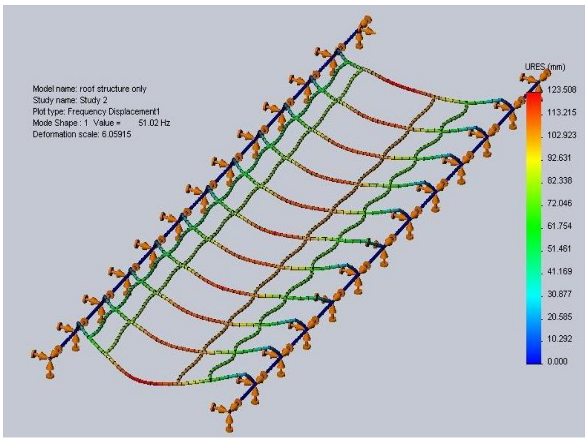

Figure 8: Roof Deformation

- **Total Frame For Round Tubular**

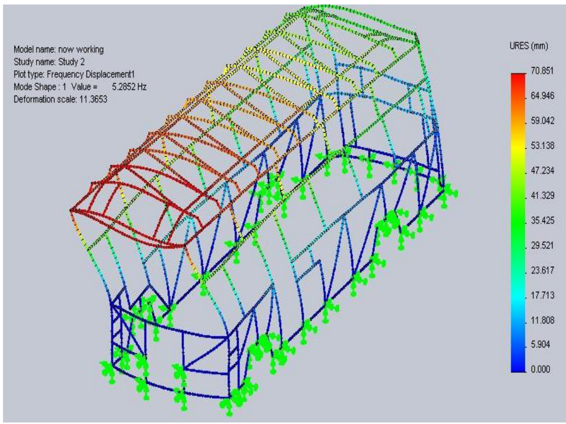

Figure 9: Total Frame Deformation

4.7 Results

All four tables and Comparision shown below.

Table1.Rectangular Tube For Roof

Mode No	Deformation scale	Frequency (Hertz)	Maximum Deflection (mm)	Min required (Hertz)
1	4.88	59.384	151.554	5
2	0.7825	73.132	1163.958	5
3	6.79022	80.775	129.137	5
4	0.6006	82.211	1342.995	5
5	4.90772	87.376	157.770	5

Table 2.Tectangular Tube For Total Frame

Mode No	Deformation scale	Frequency (Hertz)	Maximum Deflection (mm)	Min required (Hertz)
1	12.9892	7.6762	61.183	5
2	12.8438	12.5	61.893	5
3	14.9309	18.093	54.640	5
4	7.3398	19.579	108.269	5
5	6.46641	19.829	122.930	5

Table 3.Round Tube For Roof

Mode No	Deformation scale	Frequency (Hertz)	Maximum Deflection (mm)	Min required (Hertz)
1	6.05915	51.02	123.503	5
2	3.62696	52.178	210.341	5
3	5.09373	55.606	150.114	5
4	4.36413	58.19	173.664	5
5	2.8571	61.716	258.887	5

Table 4.Round Tube For Total Frame

Mode No	Deformation scale	Frequency (Hertz)	Maximum Deflection (mm)	Min required (Hertz)
1	11.3653	5.2852	70.851	5
2	9.05778	9.657	89.948	5
3	12.6499	12.103	64.031	5
4	6.74356	14.428	119.187	5
5	6.35815	16.956	126.536	5

4.8 Comparisons

Table 5.Comparision between Rectangular Tube and Round Tube

SL No	Rectangular Tube		Round Tube	
	Frequency (Hertz)	Max Deflection (mm)	Frequency (Hertz)	Max Deflection (mm)
1	7.6762	61.183	5.2852	70.851
2	12.5	61.893	9.657	89.948
3	18.093	54.640	12.103	64.031
4	19.579	108.269	14.428	119.187
5	19.829	122.930	16.956	126.536

By comparing the results of both the types of frames, it becomes visible that the rectangular frame scores over the round tubular frame in natural frequency and minimum displacements as well.Thus it becomes evitable that rectangular C.S frame offers better performance than its competitor. But cost-wise, round tubular frame proves out to be superior even if large diameter tubes are used to match the parameters achieved by its counterpart.The choice selection can be flexible. Glancing over some restriction of material availability, storage easiness and workability either of the frame type can be used.

5. Conclusions

As stated before the main aim was to design and develop a frame for STAG and LYNX series. It was also required to get frequency displacement data in several models and a rectangular cross-section as it was abundant in inventory and was used from long time and was also directed to use round tube along with that.Both the reports are created with all the corresponding values. A Comparision of both the cross-sections is also made and is tabulated side by side to get quick reference.The target of achieving 5Hertz of minimum natural frequency was gained in all the modes.

The Future scope will be that other materials can be possibly used. But with the selection of other superior materials, cost would significantly go up. If the customers are high end such as Volvo, Isuzu etc. they might require superior materials. Then the chances of getting this developed under those conditions would be the possible future plans. As the materials are getting limelight of priority such as carbonfibre, glassfibre and other composites, the very chances of working with those materials will be a milestone.

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