International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 12, December 2016
www.ijates.com
ijates
ISSN 2348 - 7550

DESIGN IMPROVEMENT AND ANALYSIS OF CAR CHASSIS FOR STATIC AND DYNAMIC CHARACTERISTICS

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ABSTRACT

Chassis is one of the major and important part of an automobile field. The major function of chassis included supporting the body and hold the various part of the vehicle, apart from this chassis should have enough strength to resist shock, twisting, vibration and other stresses. Other than stress the torsional stiffness and natural frequency are important parameters which are to be taken into consideration while designing the chassis. So in this research, we concentrate on investigation of static and dynamic characteristic like Torsional stiffness and natural frequency of car chassis, the analysis has been completed by Finite Element Method and Experimental approach. According to that some modification has suggested on existing chassis. Base on that one modified chassis have been modeled which undergo the static structural analysis, modal analysis and experimental analysis. The existing and suggested chassis have been made by using modeling software PRO-E. Then the commercial finite element package ANSYS 14.5 and RADIOSS is used for further analysis. Torsional stiffness analysis is done by experimentally. Obtain results from the analysis, it can be observed that modified chassis having enhanced Torsional stiffness and natural frequency.

Keyword: Analysis, ANSYS 14.5, Chassis frame, Design, PRO-E, RADIOSS.

I. INTRODUCTION

Almost every year, each vehicle manufacture produces new design of their vehicles to compete with others manufactures. It means the vehicles become important in nowadays lifestyle. The function of this vehicle is used to transfer or move people from one place to other places with safe and comfortable. These two are the prime criteria implement in the every manufacturing of the car.In automobile field the chassis is one of the important part of the vehicle which usually placed in the lower body of the vehicle, including the tires, engine, frame, transmission line and suspension. Chassis provides necessary support to the vehicle components placed on it. When Ford makes his first car, the car chassis was made from wood. After that, on about 1910's steel and aluminum was using as the chassis material in the automotive field effected by industrial revolution and the early of this year start use woods and steel as the material of chassis. On 1930's created the technology that can improve the steel type and it come to modify the chassis structure in term of the increase the stiffness, torsion and reduction of vibration. It was the reason that the chassis was fully made from steel. Also the chassis frame should be enough strong to withstand shock, twist, vibrations and other stresses. The chassis frame consists of side members attached with a series of cross members. Along with the strength, stiffness is also one of the important considerations in the chassis design. Adequate torsional stiffness is required to have good handling characteristics. The chassis also receives the vibration and force produce from the car externally and internally. The road bumping, the load of passenger, the vibration of the vehicle engine and others can be the source of the external and internal force and it can be failure of the structure when the excitation of it coincides with the natural frequencies of the chassis which create resonant. Since the material is almost same for different chassis and differ for each chassis is come from its chassis design. Normally the chassis design is based on strength and stiffness. In the conventional design procedure the design is based on the strength and focus is then given to increase the stiffness of the chassis

II. LITERATURE REVIEW

[1] M. Ibrahim, et.al. had conducted a study on the effect of frame flexibility on the ride vibration of trucks. The aim of the study was to analyze the vehicle dynamic responses to external factors. The spectral analysis technique was used in the problem study. Other than that, the driver acceleration response has been weighted according to the ISO ride comfort techniques. From the author point of view, the excessive levels of vibration in commercial vehicles were due to excitation from the road irregularities which led to ride discomfort, ride safety problems, road holding problems and to cargo damage or destruction. Also, it has been found that the frame structure vibrations due to flexibility have a similar deleterious effect on the vehicle dynamic behavior.

[2] Lonny L. Thomson, et. al., had presented his paper on the twist fixture which can measure directly the torsion stiffness of the truck chassis. The fixture was relatively light weight and portable with the ability to be transported and set-up by one person.

[3] Michael Broad and Terry Gilbert provides a thorough overview of the design and development considerations for a SAE Formula Hybrid chassis using the 2009 entry from North Carolina State University, codenamed NCSUFH.09, as a case study in his paper. The proper design methodology for the development of a series-hybrid vehicle chassis is explored. Next, several loading scenarios are investigated in order to understand the substantially increased forces that must be communicated through the chassis and suspension components due to the added mass of hybrid apparatus such as electric motors and battery arrays. Material selection will also be considered. Utilizing Solid Works 3-D modeling software, several design iterations are run in order to determine the best compromise between vehicles mass, component packaging, and weight distribution while still ensuring driver safety. Finally, Finite Element Analysis is implemented using the ANSYS design software. A loading model is examined in order to determine the efficiency of the structure in resisting torsional loads, as these are most critical in determining overall vehicle performance.

[4] Mr. William B. Riley as a member of the 1999 Cornell University Formula SAE Team and discuss several of the concepts and methods of frame design, with an emphasis on their applicability to FSAE cars. The paper introduces several of the key concepts of frame design both analytical and experimental. The different loading conditions and requirements of the vehicle frame are first discussed focusing on road inputs and load paths within the structure.

[5] Dr. R. Rajappan and M.Vivekanan dhan had conduct the vibration, natural frequency and mode shape by using finite element method. Modal updating of truck chassis model will be done by adjusting the selective properties such as mass density and Poisson’s ratio. Predicted natural frequency and mode shape will be validated against previously published result. Finally, the modifications of the updated FE truck chassis model will be proposed study to analyzed static and dynamic load characteristics using FE models. In this paper author identifying location of high stress area, analyzing to reduce the vibration, improve the strength, and optimize the weight of the truck chassis.[5]

[7] Dr. Mohammed A. Elhaddad and Abdel rahman M. M. You ssef is made Finite element model for space frame of a single seated race vehicle, the model was developed to evaluate the torsional stiffness of the frame. Also, the paper shows a design of a test rig to measure the torsional stiffness of the space frame. The Measured data was used for the model validation. The deflection and the twist angle of the frame was measured by the test rig to validate the result obtain from FEA.

[9] Goolla Murali, et. al. had conducted the research to made design improvements to improve the load carrying capacity of the structure on the basis of thickness. They determine torsion stiffness and bending stiffness of the truck chassis by using torsion analysis and bending analysis using finite element method. Then he makes some changes in the geometrical dimension and structural properties to improve the stiffness of the truck chassis. Hyper Mesh and OptiStruct solver has been used for the FE calculations. The modification on the chassis model was done and then analyzed in order to determine improve strength as well as reducing in vibration for the modifications, the existing truck chassis were added stiffener. Initially the thickness of the model, where the maximum deflection occurs in bending analysis was increased to certain value with acceptable limit. Then again the analysis is done in Hyper Mesh and OptiStruct.

2.1 Methodology

1. Simulation and analysis on the existing car chassis
2. Improvement of car chassis characteristic by changing the geometry and structure without changing functional dimension of the existing model by trial and error method.
3. Simulation and analysis on the new car chassis
4. Make experimental set-up for torsional stiffness calculation.
5. Experimental analysis of torsional stiffness for existing car chassis.
6. Experimental analysis of torsional stiffness for new car chassis
7. Comparison of result and conclusion.

2.2 Specification of Car Chassis

Overall Length = 2775 mm

Overall Width = 990 mm

Overall Height = 200 mm

2.3 Basic Calculation for Car Chassis

Capacity of car = Weight per passenger × No. of Passengers

= 75kg × 8 = 600 kg

Capacity of car with 1.25% = 750 kg

Total load acting on car chassis

= Gross vehicle weight + Weight of Passengers

= 800 kg + 750 kg = 1550 kg = 15205.5 N

Chassis has two longitudinal members so load will be acted upon these two longitudinal members. Therefore, load acting on each member will be half of the total load acting on chassis.

Load acting on one longitudinal member

= 15205.5 N ÷ 2= 7602.75 =7603N

2.4 Material Specification

Density = 7850 kg/m^3

Compressive Yield Strength = 250 MPa

Tensile Yield Strength = 250 MPa

Tensile Ultimate Strength = 460 MPa

Young's Modulus = 1250MPa

Poisson's Ratio = 0.3

2.5 Calculation of the Torsional Stiffness

The global twist angle of the chassis is a function of the vertical displacement between the two involved coil-over mounting points and their distance.

$$\theta f = \frac{2\delta}{Lf} \ (Radian)$$

Where;

Lf = Distancebetween the front dial indicators

δ= Total deflection of car chassis

Torque can be derived as:

$$T = (\frac{Fd}{2} + \frac{Fe}{2}) \times Ls$$

Where,

Fd = Force in the right front end of the structure

Fe = Force in the left front end of the structure

Ls = Traverse distance between the applied force application points

The torsion angle in the rear part of the structure, θt is determined from the measured

Displacements in the extremities of the longitudinal rails,

$$\theta t = \frac{(\delta d + \delta e)}{Lt}$$

Where;

δd and δe are the measured displacements in the dial indicators, separated laterally by a distance Lt.

The global torsion stiffness was measured between the ends of the chassis. For this load case torsion stiffness could be calculated by:

$$K = \frac{T}{\theta}\left({}^{Nm}/_{Rad}\right) \ and \ \theta = \theta f - \theta t$$

Where,

K = global torsion stiffness

T = Torque

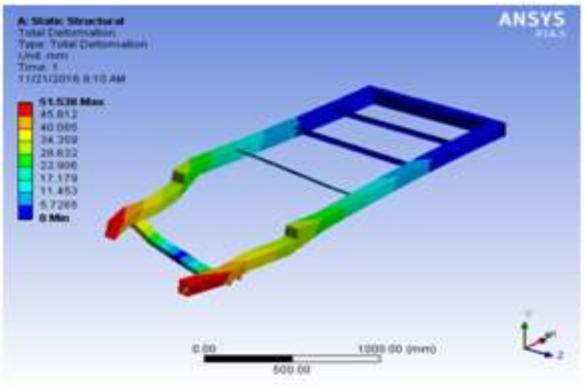
θf = front torsion angle of the structure

θt =rear torsion angle of the structure

2.6 Static Analysis of Chasis By ANSYS

This is based on the situation where one of the car's front wheel rest on a hump, which causing torsion to the car chassis

1. For Unmodified Chassis B. For Modified Chassis



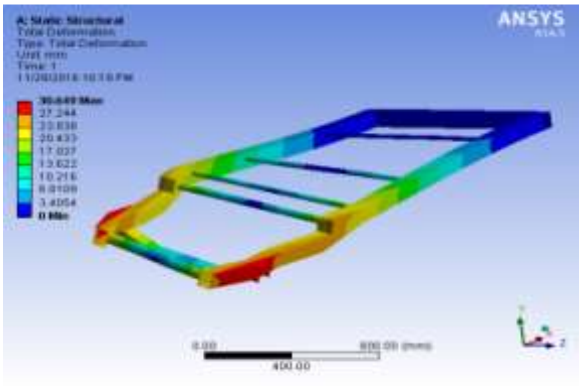
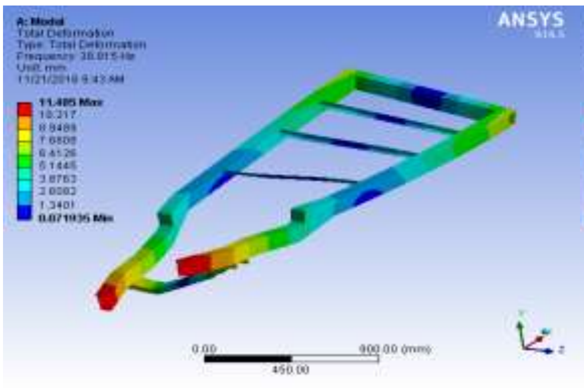


Fig.1 Total Deformation **Fig.2 Total Deformation**

2.7 Modal Analysis of Chasis By ANSYS

Modal analysis by using Finite Element Method (FEM) can be used to find natural frequencies and mode shapes. In this analysis, the modal analysis has been done by the finite element packaged ANSYS 14.5. After making finite element model of chassis and appropriate meshing, model has been analyzed and first 9 frequenciesthat play important role in dynamic behavior of chassis, have been analyzed.

2. For Unmodified Chassis



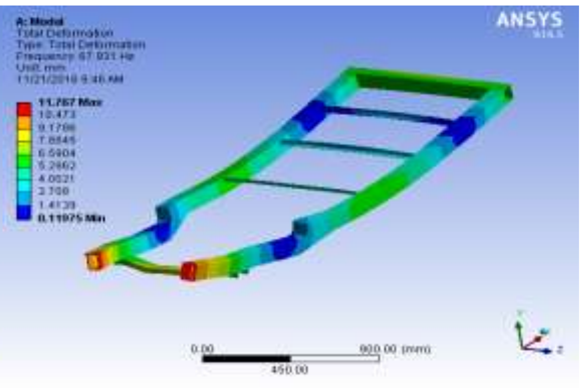


Fig.3 Natural Frequency (Torsional **Fig. 4 Natural Frequency (Bending Mode)**

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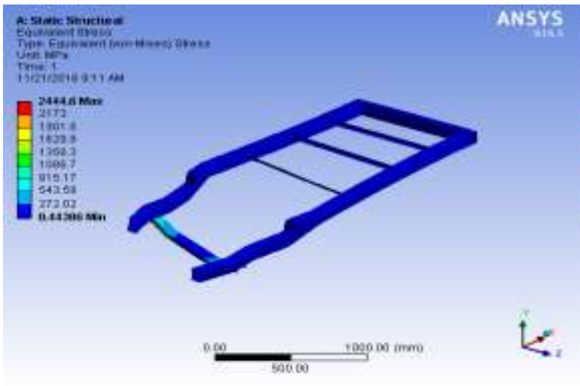
ISSN 2348 - 7550

3. For Modified Chassis



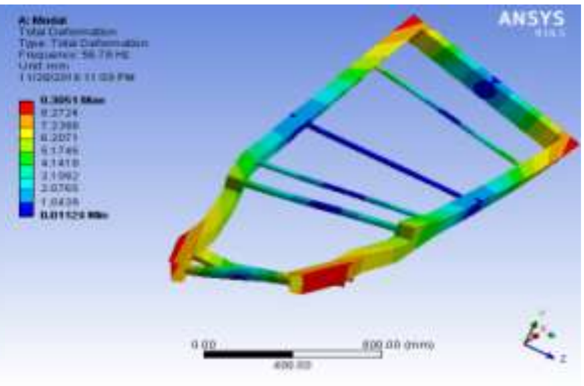
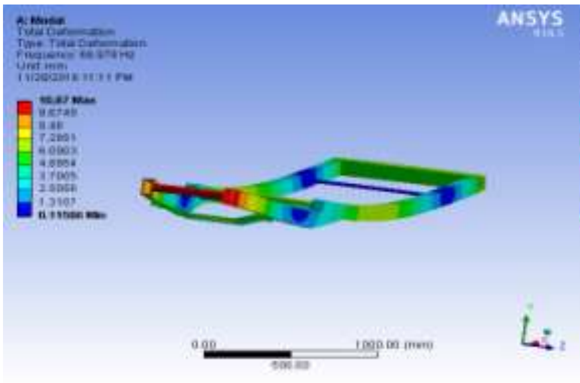


Fig.5 Equivalent (Von-Mises) Stress **Fig.6 Natural Frequency (Torsional Mode)**



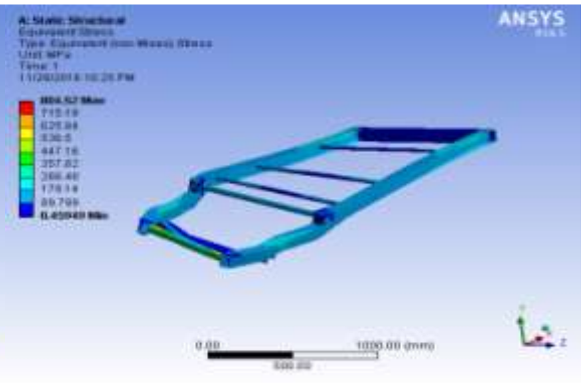
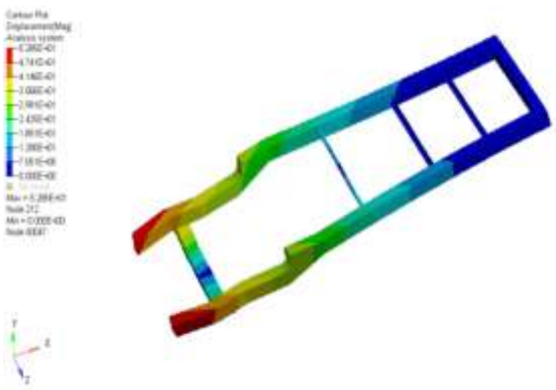


Fig.7 Natural Frequency (Bending Mode) **Fig.8 Equivalent (Von-Mises)Stress**

2.8 Static Analysis of Chasis By Radioss

4. For Unmodified ChassisB. For Modified Chassis



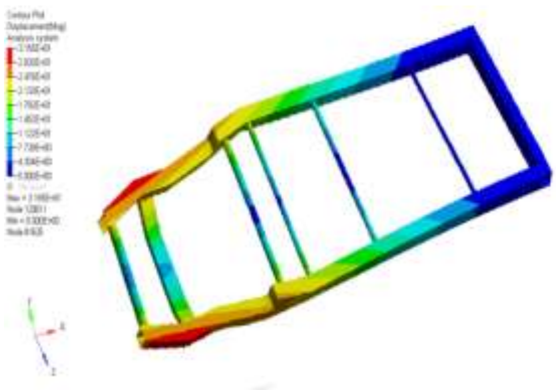


Fig.9 Total Deformation **Fig.10 Total Deformation**

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2.9 Modal Analysis of Chasis By Radioss

A. For Unmodified Chassis **B. For modified Chassis**

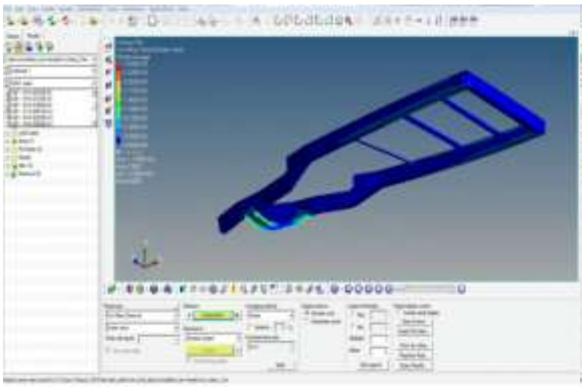

Fig.11 Natural Frequency and Von-Misesstress

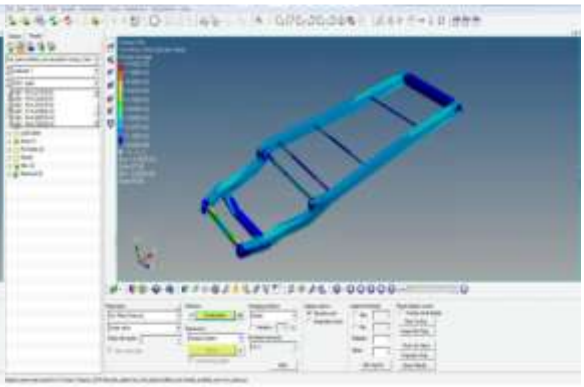

Fig.12 Natural Frequency and Von-Mises Stress

III. EXPERIMENTAL SET-UP

PRO-E was used to design the test rig which is shown in the fig 13 and fig. 14 .The test rig consists of mainly 2 parts, the front part and the rear part, this test rig is use to test any wheelbase chassis as the front part is not attached to the rear part The rear end of chassis is fixed on rear part of test rig, and front end is fixed on lever of front part which is pivoted at center. The lever arm of front part is extended at one end to apply twisting torque.

To measure the torsional stiffness, two dial indicators will be used at front end to measure the opposite resultant vertical deflection at the left and right front knuckles and two at rear end. The load was added at load point A to avoid the tilting of test rig and fixed the rear part of test rig. .The chassis is twisted in increments by loading masses at load point B in steps with deflection data recorded by using dial indicator at each step at front and rear side. After adding the load equal to require torque final deflection is measure and then the twist angle is reversed until reaching zero by unloading masses in steps.

Fig.13 CAD model of torsional test rig.

Fig.14 Actual model of torsional test rig.

3.1 Tools and Measuring Equipment

The test rig itself does not require many tools due to its tool less design, however for attaching the rig to the chassis U clamp or especially design clamp will be used. Also for dissembling the rear suspension and replacing the front struts a set of tools may be used depend on suspension and vehicle type. Weights will be needed to do the experiments about 750 kg depend on the amount needed to fix the rear rig and the amount needed to twist the chassis by given torque and dial indicator was used to measure deflection

3.2 Measuring the Twist Angle by Experimentally

For torsional stiffness measurement we require to find out twist angle and require torque.

The twist angle is calculated from following equation

$$\theta f = \frac{\delta_R + \delta_L}{L}$$

Where,

θf = Front twist angle

δ_R = Deflection in right side

δ_L=Deflection in left side

L = Distance between two dial indicator at front side

$$\theta t = \frac{\delta_d + \delta_e}{Lt}$$

Where,

θf =Rear twist angle

δ_d = Deflection in right side

δ_e =Deflection in left side

Lt = Distance between two dial indicator at rear side

And torque is calculated from following equation

$$T = L_A \times F$$

Where,

T = Applied Torque

L_A= Torque arm length

F = Applied force

Result Table I

Analysis	Before modification		
	ANSYS 14.5	**RADIOSS**	**EXPERIMENTAL**
Natural Frequency (Hz)	38.815	36.95	----
Torsional stiffness (Nm/rad)	30223.11	29454.72	27138.43
Total deflection (mm)	51.53	52.85	57.38
Von-mises stress (MPa)	2444.6	2555	-----

Result Table II

Analysis	After modification		
	ANSYS 14.5	**RADIOSS**	**EXPERIMENTAL**
Natural Frequency (Hz)	56.79	54.39	----
Torsional stiffness (kNm/rad)	50803.09	49350.1	45264.37
Total deflection (mm)	30.649	31.55	34.4
Von-mises stress (MPa)	804.52	828.2	-----

IV. CONCLUSION

The modification of the chassis against the existing chassis has been carried out by iterating on various design modifications. There are several modifications done in existing chassis based on trial and error method. Out of which one modification is finalized on the basis of result obtain from ANSYS. Then this modified chassis is analyzed by FEM i.e. RADIOSS for Natural Frequency and Equivalent stresses and torsional stiffness validation is done Experimentally.it is observed from above analysis that there is a improvement in Natural frequency by 46.30 %, the Equivalent stresses is reduce by 67.08 %, Torsional stiffness is increase by 66.79 %. and the total deflection is reducing by 40.04 %. The error is found up to 12 %

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