JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

DESIGN AND NUMERICAL ANALYSIS OF A CHASSIS STRUCTURAL MEMBER FOR STRESS AND DEFORMATION AND VALIDATION BY CALCULATION APPROACH

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ABSTRACT

A current scenario an automotive industry facing a challenges like structural failure and fatigue failure of a chassis. The frame structure is a backbone of an on-road vehicles. A chassis carried complete powertrain system which includes radiator, engine, and propeller shaft, rear axle. Sprung mass and unsprung mass loads to be carried out by chassis structure. Chassis failure due to dynamic load conditions such as loosening of fasteners, tearing of welded and riveted joints due to vibration of a chassis. So the main objectives are to design, modelling and primary finite element bending and torsional analysis of chassis and validate through calculations and determine the prediction of life of a chassis.

1. INTRODUCTION

All the vehicles, chassis is one of the main structure to carry entire system. Chassis consists of a many different cross sections such as L, C, Z and I sections. Normally, on-road vehicles are either C section or box section channels used and welded. The most effective section is C channel and withstand critical loads. A chassis should be rigid stuff, more strength and stiffness. The dynamic features of chassis analysis like natural frequency, mode shapes to be determined by finite element method. The important factor like safely to be carry the maximum load for operating conditions. Frame structure receives wheels reaction forces during acceleration, braking and aero dynamic forces. The vehicle chassis loaded by static and dynamic vibration.

2. LITERATURE REVIEW

Many of the researchers discussed about an automotive vehicle chassis and its developments and technology incorporation in the system.

Alireza Arab Solghar, Zeinab Arsalanloo (2013) were studied about chassis of hyundai Cruz Minibus. Abacus Software used for modelling and simulation. Self-weight of the chassis is considered for static analysis and Acceleration, Braking and Road Roughness were considered for dynamic analysis. M. Ravichandra, S. Srinivasalu, Syed altaf Hussain (2012) have discussed about an alternate material for chassis. They study and analysed Carbon or Epoxy as chassis material in various cross sections like C, I and Box Section. Roslan Abd Rahman, Mohd Nasir Tamin, Ojo Kurdi (2008) has used FEM software and determine stress as an opening data for fatigue life prediction. Teo Han Fui, Roslan Abd. Rahman (2007) have explained about the 4.5 Ton truck chassis against road irregularity and excitations. Vibration induced by Road Irregularity and excitation by the vibrating workings mounted on chassis were studied.

3. PROBLEM STATEMENT

The vehicle performance based on gross vehicle weight and engine power, when the vehicle speed increases directional proportional to vibration increases. Therefore, chassis should be high strength with suitable segment is required to minimize the failure and factor of safety should be greater than one. The objective of this work is to minimize the stress and maximize the life of a chassis.

4. METHODOLOGY

A three dimensional solid model of chassis with loading points and mounting brackets are created by using Creo. The same model imported to hyper mesh for meshing and pre – processing activity for acting finite element analysis. In pre – processing stage model definition, it includes define the symmetrical field of the problem, factual properties of an elements, the geometric properties of an elements like length, area and nodes. The element connectivity must be inter connection between nodes, physical constraints with boundary conditions and the lateral, longitudinal and vertical loadings.

In result phase, the leading equations in the form of matrix assembled and the unknown values of the primary field variables are computed. The calculated results are used by substitution to determine variables like reaction forces, element stresses and frequencies. The features of steps such as matrix guidance, mathematical combination and equation solving are carried out automatically by CAE software and finally analysis and evaluation of the results.

4.1 Material properties and chassis specifications

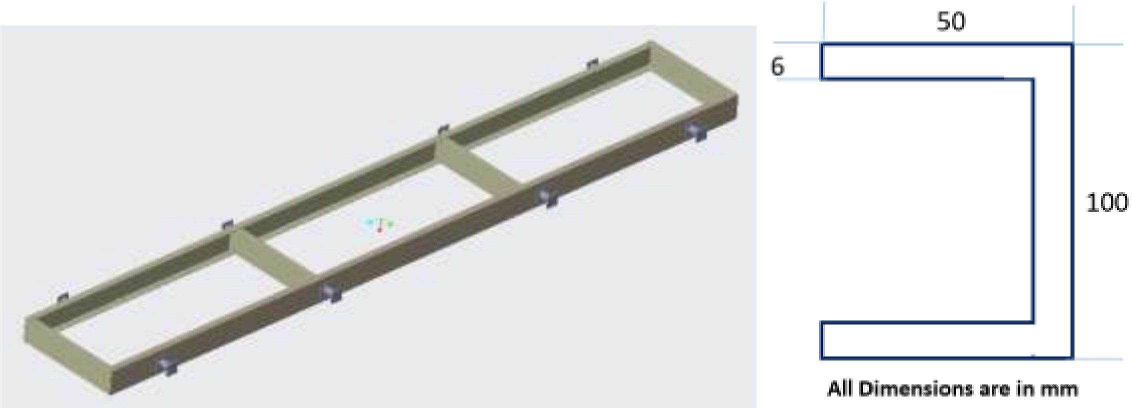
The material to be selected should have high strength structural steel and density to withstand bending and torsional loads and good ductility. The vehicle frame is formed by standard C – channel and horizontal beam type of the chassis. They are connected by bolted and welded joints. Ma

Material	High strength structured steel
Young's Modulus (E)	$2.e^5$ MPa
Poisson ratio (μ)	0.3
Bulk Modulus	$1.75e^5$ MPa
Yield Strength	Range 230 Mpa to 410 MPa
Ultimate Strength	460 MPa
Density	7.85e-006 kg mm^{-3}

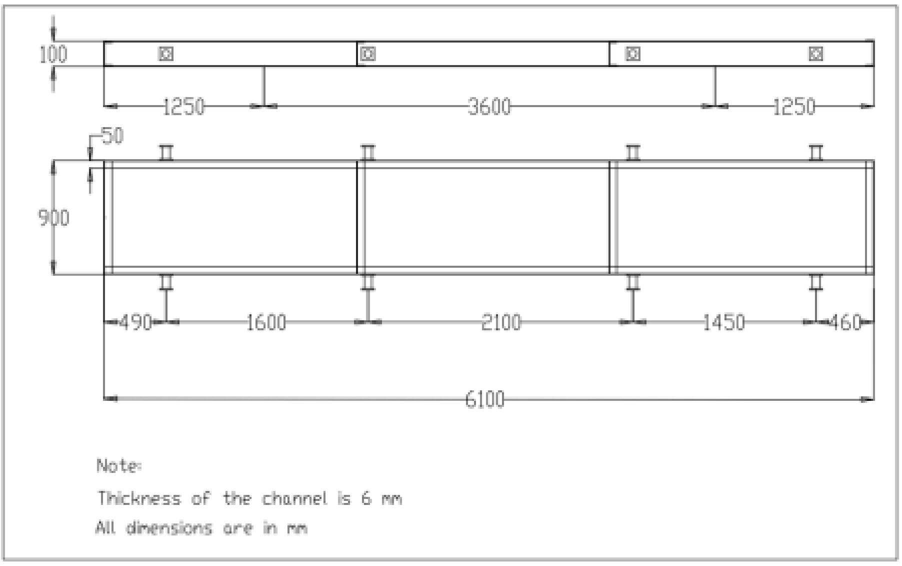
Net vehicle weight	6,090 kg	59,743 N
Payload	9,610 kg	94,274 N
Gross – vehicle weight	15,700 kg	1,54,017 N (15.4 Ton)
Cross - section	C - channel	
Material	High strength structured steel	Yield Strength : 360 Mpa

4.2 CAD Model

To made CAD model of the chassis with cross members and suspension mounting locations. The assembled frame according to the load distributions and load acting member. The model consists of approximately 30 components.

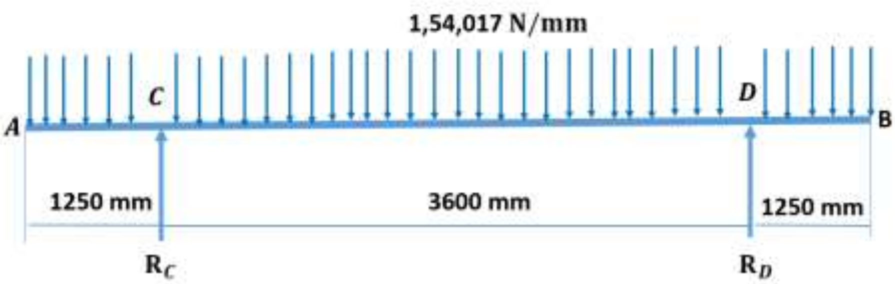


3D CAD model of the chassis (Isometric view and channel section)



4.3 Design Calculations

The specification of chassis, young's modulus, moment of inertia, bending and torsional equations. According to the equilibrium condition of equation, the bending and torsion left ramp and right ramp loads were calculated manually and calculate the deflection, section modulus, chassis thickness and tire reaction forces for FE analysis.



Free body diagram of a chassis

Rendering to the packing conditions of the beam has care of two axles A and B. Total load acting on the chassis has been shown in the figure. The reactions R_C and R_D with the load acting on the beam have been shown in the figure. A section has been considered in span DB at a distance x from A. Taking moment of all forces

$$R_C + R_D = 939 * 10^6\ N$$

$$M_{CD} = R_B * 6100 = 939 * 10^6 * 3600$$

$$R_C = R_D = 554 * 10^6\ N$$

Maximum allowable deflection in beam = $\frac{\text{OVERALL LENGTH}}{\text{GROUND CLERANCE}} = \frac{6100}{350} = 17.4$ mm

Selection of ‘C ‘channels for high strength structural steel AISI 1015.

The vehicle chassis has two longitudinal members with cross sectional members. Generally, C – channels are used in most of the vehicle structures available in this particular type of variant in the market.

The C channel has been selected on the basis of bending stress induced in the structure. Deflection produced in the structure for structural steel AISI 1015.

Where, h = 100 mm and b = 50 mm

$t - Thicknes$ Thickness of flange, $t = 6\ mm$

$$I_{CD} = 150828000\ mm^4$$

Selection modules $Z_{XX} = \frac{I}{y}$

$$Z_{CD} = 42500\ mm^3$$

$$M_{max} = 69360000\ Nmm$$

$$E = 205\ Gpa = 205\ kN/mm^2$$

Yield strength = 360 Mpa

Permissible stress = $\frac{\text{Yield strength}}{\text{Factor of safety}} = \frac{360}{2} = 180\ N/mm^2$

According to the bending equation,

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Stress produced in the beam,

$$\sigma = \frac{M_{max}}{Z_{max}}; \qquad \sigma = \frac{69360000}{42500}$$

$$\sigma = 163.2\ N/mm^2$$

Since σ is fewer than the permissible stress. Hence, the design is safe.

According to Macaulay’s Theorem the maximum deflection is produced in beam is

$$M_{CD} = EI\ \frac{d^2y}{dx^2}$$

$\int^{\text{ing}}$ with respect to x we get

$$M_{CD} = \text{EI}\ \frac{dy}{dx}$$

Again $\int^{\text{ing}}$ with deference to x we get

$$M_{CD} = \text{EI} * \text{y}$$

Therefore, maximum deflection is produced in beam

$$y_{max} = -\frac{410.96 * 10^9}{EI}$$

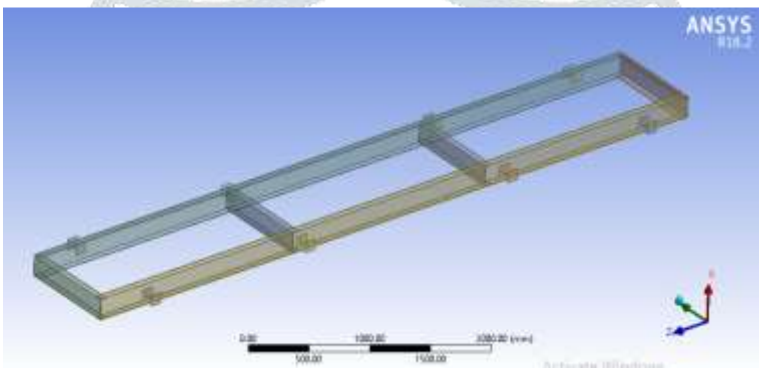
$$y_{max} = -\frac{410.96 * 10^9}{205 * 10^9 * 150828000}$$

$$y_{max} = 13.29\, mm\ (Tensile\ and\ compression)$$

Since 13.29 mm is less than the maximum allowable deflection 17.4 mm. Hence, the design is safe. Therefore, the chassis, young's modulus, moment of inertia, bending and torsional equations. According to the equilibrium condition of equation, the bending and torsion left ramp and right ramp loads were calculated and validate through FE analysis.

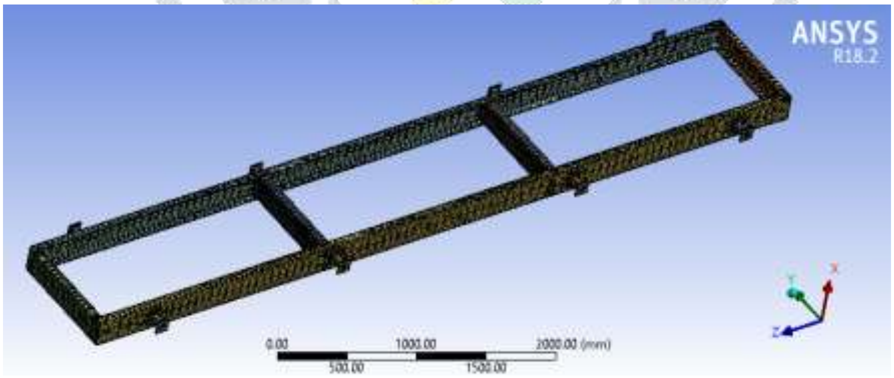
5. STRUCTURAL ANALYSIS OF CHASSIS

A geometric model of the chassis import to an ansys pre-processing setting to create the FE model required in the analyses. To import as an igs file format.



3D CAD model

To mesh the given model in 3D with terra elements. Defeaturing the fillets with help of surface fillet. Check the quality parameters which is more than the given maximum element size and number of nodes 9587 and number of elements 12045 as shown in the figure.



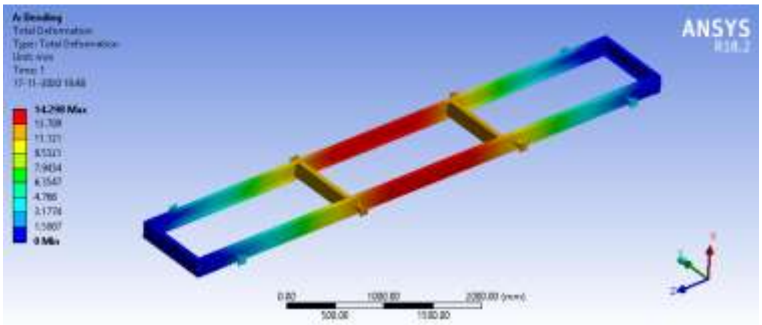
MESH Model

5.1 Boundary conditions

Bending and torsion load cases have been assessed as for the maximum load cases. The load applied to the FE model chosen according to the loading range used during the vertical load acting on the chassis for the bending and torsion analysis, body weight and payload can be practical on the top of the body and tire reaction load can be applied on the suspension mounting points to satisfy the equation of steadiness conditions.

5.2 Total deformation of chassis

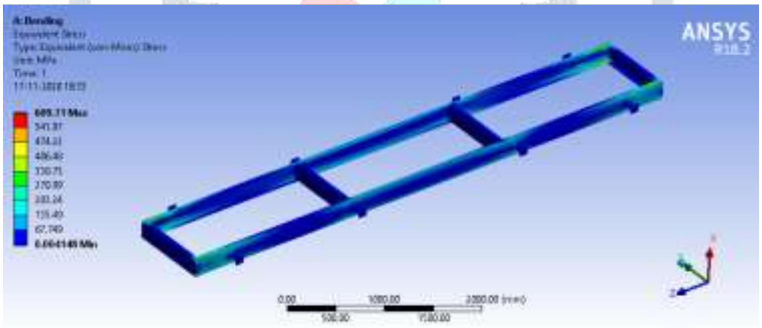
The total bending of the chassis indicates clearly that the deformation is maximum at the middle of the chassis. The maximum value of deformation is 14.2 mm. Color distribution of the plot gradually was found to be decreased from middle of the chassis to front and back, maximum level to the minimum level throughout the chassis. Gradient distribution in the direction of vertical.



Total deformation in bending

5.3 Bending stress distribution

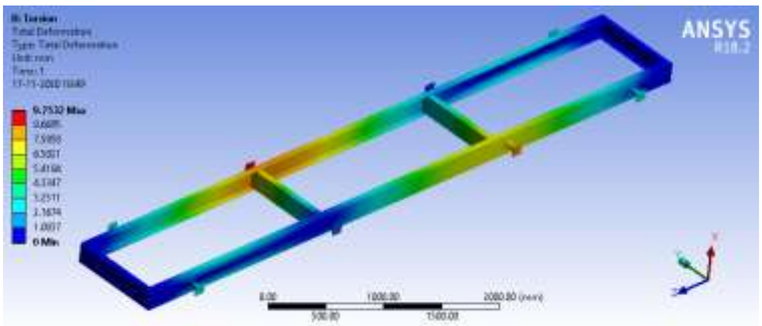
A von-misses stress in the behavior which can be obtained for the vertical direction in the bending case. Bending stresses indicates for both front and rear gets move up and downward direction. Average bending stress distribution on the chassis structure 203.24 Mpa and will be within the recommended value as shown in the figure below.



Von-misses stress

5.4 Torsional deformation

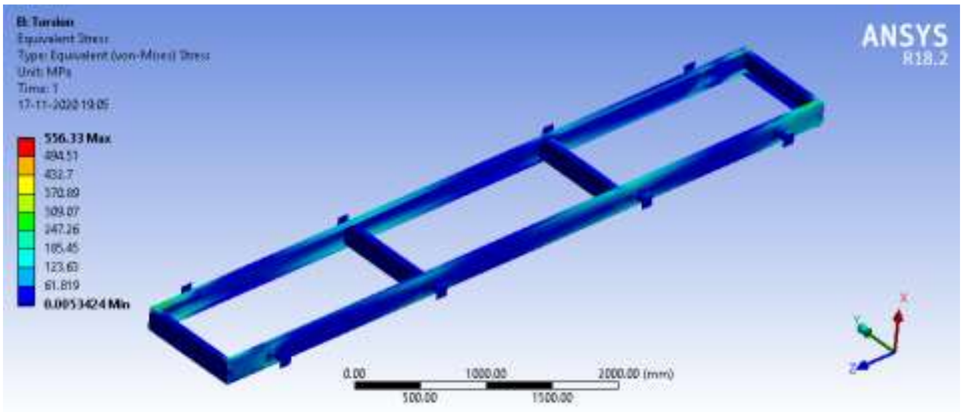
Torsional analysis of the stress produced while applying the twisting moment to the both the end of the shaft about its centre axis. Torsion is the twisting of an object due to an applied torque and it is also called as left ramp load condition and right ramp load condition. The figure shows that the total deformation 9.75 mm on the left and right side of the chassis.



Total deformation in torsion

5.5 Torsional stress

The von-misses stress in the behavior can be obtained lateral and longitudinal direction in the torsion case. Torsional stress indicate for both front and rear gets move up and downward direction. Average torsional stress distribution on the chassis structure 185.45 MPa within the suggested value as shown in figure.



6. RESULTS COMPARISON

To compare calculated results and FEM results:

Sl.No	Parameters	Calculated value	FEM - Bending	FEM - Torsion
1	Stress	163.2 N/mm^2	203.24 N/mm^2	185.45 N/mm^2
2	Deformation	13.29 mm	14.2 mm	9.75 mm

7. CONCLUSION

An automotive chassis is analyzed by using CAE simulation software. From this analysis the maximum deformation and maximum stress distribution with in the standard and recommended value. The deformation at the middle of the structure. The generated vertical longitudinal deformation and von misses stress will be within the permissible and recommended value. The results compared within the safety zone. Therefore, the proposed chassis structure design will be safe.

Further will improve strength and increase the stiffness by adding gussets and supports in future scope of work and do the modal and vibration analysis of a chassis.

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