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Modelling and Structural Analysis of Automobile Lorry Chassis

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Abstract:
A chassis consists of an internal vehicle frame that supports an artificial object in its construction and use, can also provide protection for some internal parts. An example of a chassis is the under part of a motor vehicle, consisting of the frame (on which the body is mounted). If the running gear such as wheels and transmission, and sometimes even the driver's seat, are included, then the assembly is described as a rolling chassis. The automobile is divided into two parts, body and chassis. The chassis is basic structure of a vehicle. It contains all the engine parts and power systems but the frame is the main portion of chassis which do not contain any other assemblies like engine parts. Its principle function is to safely carry the maximum load for all designed operating conditions. This paper describes modeling and structural analysis of conventional type heavy lorry vehicle frame. In the present work, the dimensions of an existing heavy lorry chassis of a vehicle is called reverse engineering is taken for modeling and analysis with four different materials subjected to the same conditions of the steel chassis. The four material used for the chassis are grey cast iron, AISI 4130 alloy steel, AISI A 514 GRADE B alloy steel, A709M GRADE 345 W alloy steel. A three dimensional solid Model was built in the CAE software CATIA V5 parametric and the analysis was done in ANSYS WORKBENCH 17.0.

Keywords: Grey cast iron, AISI A514 GRADE Alloy steel, a 709M GRADE 345W structural steel, AISI 4130 Alloy steel, physical Properties, Chemical properties.

I.INTRODUCTION

ROLE OF CHASSIS IN AUTOMOTIVES

Every vehicle body consists of two parts; chassis and bodywork or superstructure. The chassis is the framework of any vehicle**.** Its principal function is to safely carry the maximum load for all designed operating conditions**.** It must also absorb engine and driveline torque, endure shock loading and accommodate twisting on uneven road surfaces**.** The chassis receives the reaction forces of the wheels during acceleration and braking and also absorbs aerodynamic wind forces and road shocks through the suspension. So the chassis should be engineered and built to maximize payload capability and to provide versatility, durability as well as adequate performance. To achieve a satisfactory performance, the construction of a heavy vehicle chassis is the result of careful design and rigorous testing.

TYPES OF FRAME:

1. Ladder frame
2. Conventional chassis frame
3. Sub-type frame
4. Unit body construction
5. Space frame construction
6. Perimeter frame
7. Frameless chassis (integral chassis frame and body)

(1) Ladder frame

This is a common type of frame, in which all the transverse (lateral) connecting members are straight across in the plan view. In this type, the frame resembles a ladder as the name implies.

(2)Perimeter frame

A perimeter frame consists of welded or riveted or bolted frame members around the entire perimeter of the body. In this, the frame members are provided underneath the sides, as well as for the suspension and related components.

(3) Sub-type frame

A sub-type frame is a partial frame often used on unit-body vehicles to support the power train and suspension components. Normally the various components are bolted directly to the main frame. But many a times, these components are mounted on a separate frame called sub-frame.

(4) Unit body construction

Unit body construction is a design that combines the body and the structure of the frame. In this, the body itself supports the engine and driveline components. In this type of construction, heavy side members used in conventional construction are eliminated and the floor is strengthened by cross-members and the body, all welded together. In some cases the sub-frames are also used along with this type of construction.

(5) Space frame construction

Space frame construction consists of formed sheet used to construct a framework for the entire vehicle. This vehicle is also drivable without a body.

(6) CONVENTIONAL CHASSIS FRAME

Steel pressing of channel or box section form the side frame members. They are connected together by means of cross members (made of channel or box sections) so as to form a rigid but light frame work.

(7) Frameless Chassis (Integral Chassis Frame and Body)

Developments in the art of welding and pressing of large steels sheets into complex shapes, have allowed the integration of the frame structure and the body work as a single unit, so as to achieve a very light but a stiff structure for a given material content. This chassis cum body construction is also called as 'frameless chassis' Dave Anderson and Greg Schade[1] developed a Multi-Body Dynamic Model of the Tractor-Semitrailer for ride quality prediction. The studies involved representing the distributed mass and elasticity of the vehicle structures e.g. frame ladder, the non-linear behavior of shock absorbers, reproduce the fundamental system dynamics that influence ride and provide output of the acceleration, velocity and displacement measures needed to compute ride quality. There were three main factors contributed in this study. Firstly, the author had come out with the development of an ADAMS multi-body dynamics model for use as a predictive tool in evaluating ride quality design improvement. M. Ibrahim, et.al. [2] 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. Rossi Pinto Filho [3], who analyzed on the Automotive Frame Optimization. The objective of his study was basically to obtain an optimized chassis design for an off-road vehicle with the appropriate dynamic and structural behavior. The studies were consisted of three main steps. Firstly, the modeling of the chassis used in a commercial off-road vehicle using commercial software based on the finite elements method (FEM). Secondly, a series of testing were conducted to obtain information for modeling and validation. Finally, the validated model allowed the optimization of the structure seeking for higher torsion stiffness and maintenance of the total structure mass. Izzudin B. Zaman [4] has conducted a study on the application of dynamic correlation and model updating techniques. These techniques were used to develop a better refinement model of existing truck chassis with approximately 1 tone and also for verification of the FEA models of truck chassis. The dynamic characteristics of truck chassis such as natural frequency and mode shape were determined using finite element method. Lonny L. Thomson, et. al., [5] had presented his paper on the twist fixture which can measure directly the torsion stiffness of the truck chassis. The fixture was relatively lightweight and portable with the ability to be transported and set-up by one person. The extensive testing has been carried out to check on the accuracy of the fixture and was found to be within 6% accuracy. Murali M.R. Krishna [6] has presented his study on the Chassis Cross-Member Design Using Shape Optimization. The problem with the original chassis was that the fundamental frequency was only marginally higher than the maximum operating frequency of the transmission and drive shaft, which were mounted on these cross-members. The aim of this testing was to raise the cross-member frequency as high as possible (up to 190-200 Hz) so that there was no resonance and resulting fatigue damaged. Marco Antonio Alves [7] on the Avoiding Structural Failure via Fault Tolerance Control. There were two approaches or option used, firstly the structural modification and secondly by some active modification. In this case the author has chosen the second option only. The aims of study were to decrease the vibration on the truck and consequently increase life of the structure. The study used a Finite Element Model of a truck to represent the vibrations phenomena. Alireza Arab Solghar, Zeinab Arsalanloo[8] (2013) studied and analyzed the chassis of Hyundai Cruz Minibus. ABAQUS Software was used for modeling and simulation. Self weight of the chassis is considered for static analysis and Acceleration, Braking and Road Roughness were considered for dynamic analysis. It's observed that the stresses on chassis caused by braking were more compared with acceleration.

II. SPECIFICATION OF THE PROBLEM

The present work describes mainly about the modelling and structural analysis of a heavy lorry chassis with the present material and also different types of alloys ViZ., Grey cast iron, AISI A514 GRADE B Alloy steel, AISI 4130 Alloy steel. The solid model of the chassis was created in CATIA V5. Model was imported in ANSYS 17.0 for analysis by applying the existing load conditions. The model was tested for stress and deformation as the design constraints. After analysis a comparison is made between existing conventional steel chassis and other material heavy vehicle chassis viz., grey cast iron, AISI 4130 alloy, AISI A514 GRADE B Alloy steel. and also analysis in fatigue tool and after analysis life and damage comparison is made between the existing and other alloys.

III.CHASSIS MATERIALS

Currently the material used for the chassis is A709M Grade 345W Structural steel which is known as structure steel.

A 709M Grade 345W chemical composition

- Manganese (0.75-1.35)
- Phosphorus (up to 0.04)
- Silicon (0.15-0.40)
- Carbon (0.20)
- Sulphur (up to 0.05)
- Iron (97.5)

Grey cast iron- The composition of grey cast iron in terms of its entire constituent elements can be explained as follows:

- Carbon (up to 4%)
- Silicon (up to 3%)
- Manganese (0.8%)
- Sulphur (.07%)
- Phosphorus (0.2%)
- Molybdenum (up to 0.75%)
- Chromium (0.35%)
- Vanadium (0.15%)

AISI 4130 alloy steel- AISI stands for the American Iron and Steel Institute, has given the designation to the steel alloy with the particular composition of material like AISI 4130,AISI 4140. AISI 4130 is also known as the chrome-moly alloy steel which stands for chromium-molybdenum alloy steel. The chemical composition of the AISI 4130 steel alloy is given as follows:

- Carbon (0.28-0.33)
- Chromium (0.8-1.1)
- Iron (97.3-98.22)
- Manganese (0.4-0.6)
- Molybdenum (0.15-0.25)
- Phosphorus (up to 0.035)
- Sulphur (up to 0.04)
- Silicon (0.15-0.35)

The followings values show the chemical composition of AISI A514 GRADE B alloy steel.

- Iron 98%
- Manganese 0.85%
- Chromium 0.48%
- Silicon 0.28%
- Molybdenum 0.2%
- Titanium 0.02%
- Carbon 0.12-0.210%
- Vanadium 0.05%
- Boron 0.003

IV. SPECIFICATION OF EXISTING HEAVY VEHICLE CHASSIS

Table.1. Parameters of chassis

1	Total length of chassis	7322mm
2	Thickness of chassis	8mm
3	Width of chassis	80mm
4	Density of steel chassis	7850kg/cm^3
5	Back body chassis length	5290.7mm
6	Applying load	98066.5 N(10 ton)
7	Part bodies	257
8	Payload	10 tons
9	Young's modulus of steel chassis	2 e5 N/mm2
10	Front cabin chassis length	2559.3mm

Table.2. Physical properties of alloys

materials	Modulus of elasticity (GPA)	Density Kg/m^-3	Tensile strength (MPA)	Yield strength (MPA)
Grey cast iron	140	7200	450	280
AISI 4130 Alloy steel	190	7850	670	435
AISI A 514 GRADE B Alloy steel	210	7850	760	690
A 709M GRADE 345W structural steel	200	7850	460	260

V. MODELLING OF CHASSIS IN CATIA V5 R20

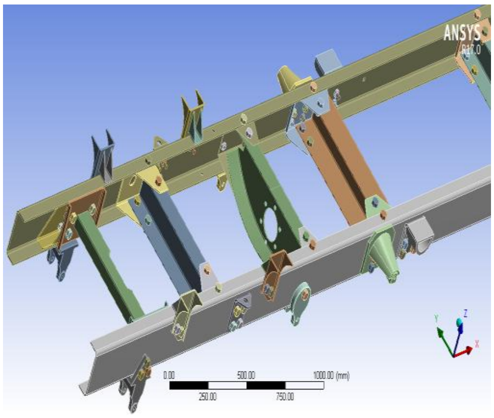


Figure.1. Assembly Design of chassis

VI. STRUCTURAL ANALYSIS OF HEAVY VEHICLE CHASSIS

Start the ANSYS WORKBENCH 17.0 open the software and drag the structural analysis drop into the window and select the engineering data to apply the material to the design and click on to the geometry and the design modeler window opens and click on to the file and import the external file for the analysis and click on to the generate button and go back to the workbench window select the model and the mechanical window opens the model loaded on the screen and select the model to mesh and apply generate mesh and click on to the static analysis in outline box give the loads and the boundary conditions of the chassis and go to solution and select the stresses and deformation and click on to the solve button to Solve the model.

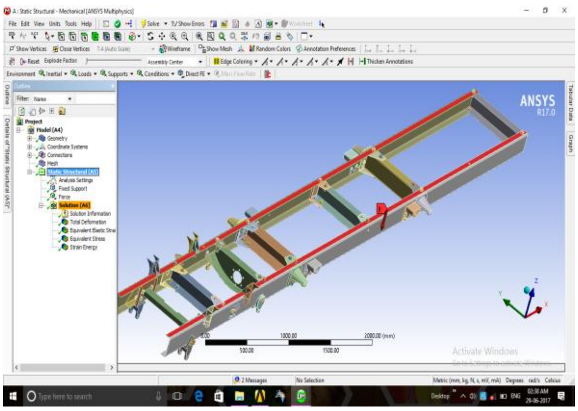


Figure.2.Boundary conditions of chassis

VII. RESULTS AND DISCUSSIONS

STRUCTURAL ANALYSIS OF CHASSIS

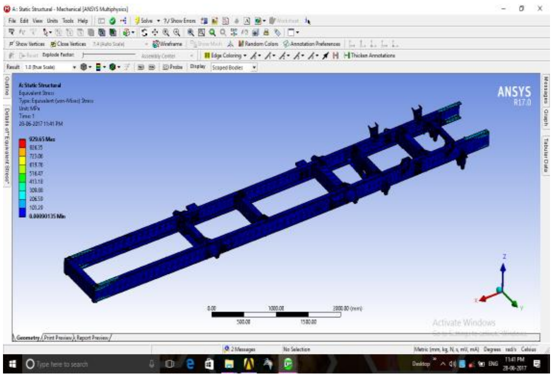


Figure.3. Stress distribution for grey cast iron

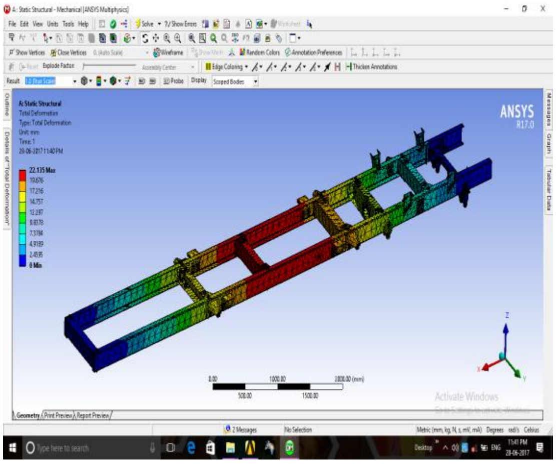


Figure.4. Displacement pattern for grey cast iron

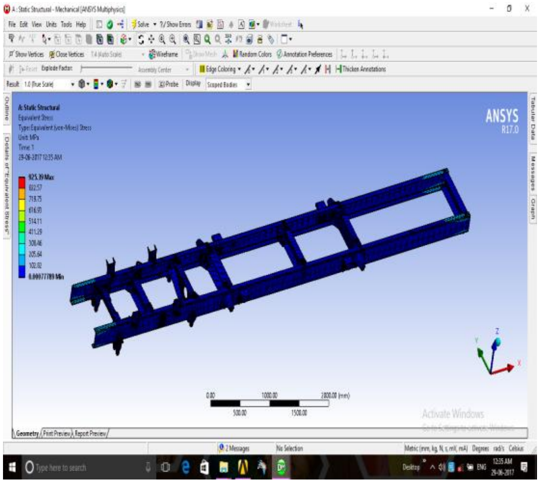


Figure.5. Stress distribution for AISI 4130 steel alloy

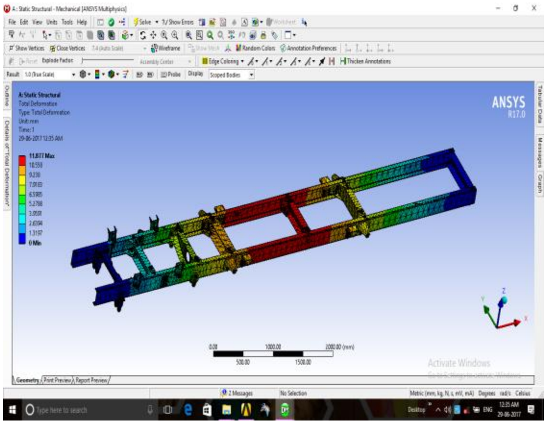


Figure.6. Displacement pattern for AISI 4130 Steel alloy

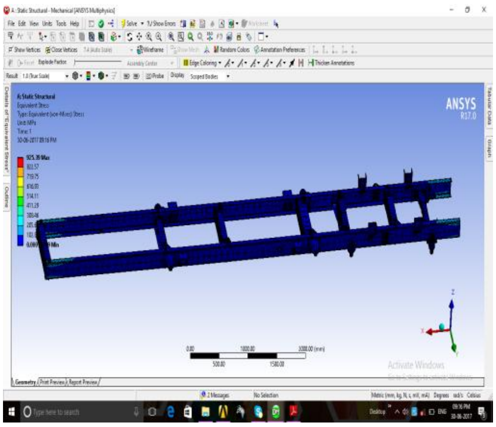


Figure.7. Stress distribution of A790M GRADE 345W alloy steel

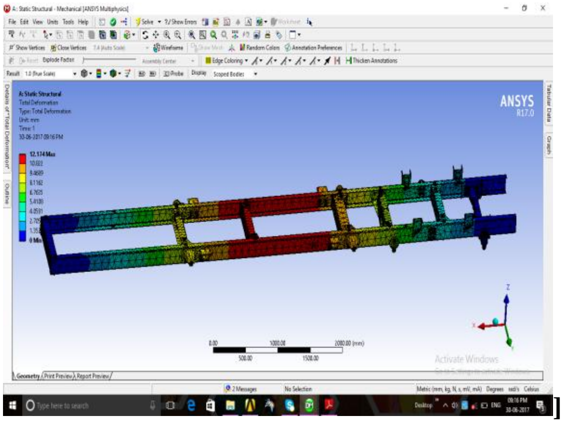


Figure.8. Displacement distribution of A790M GRADE 345W alloy steel

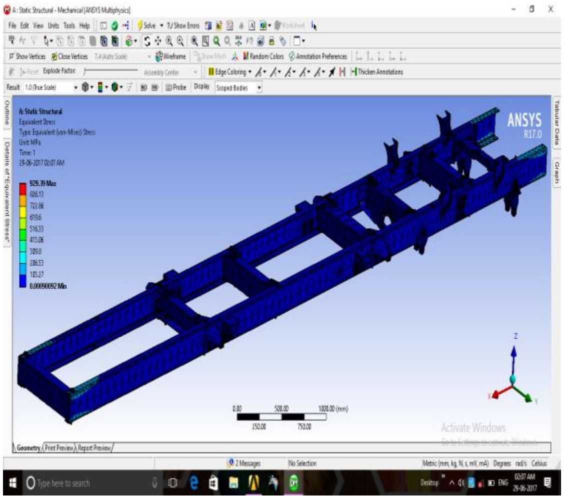


Figure.9. Stress distribution for AISI A514 GRADE B Alloy Steel

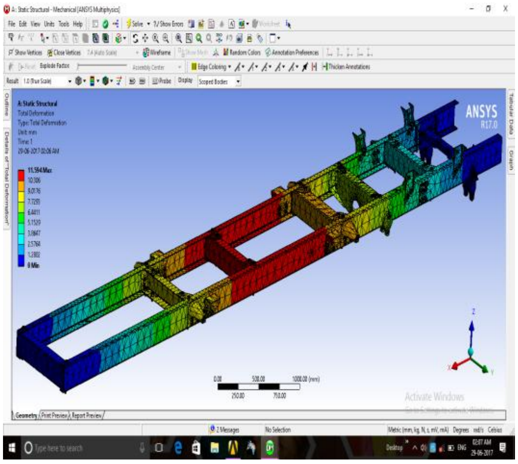


Fig10. Displacement distribution for AISI A514 GRADE B Alloy Steel

FATIGUE ANALYSIS OF CHASSIS:

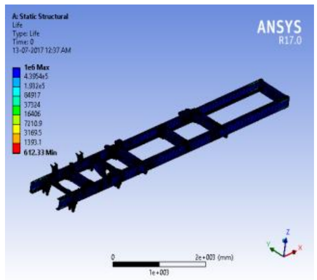


Figure.11. Life for AISI A514 GRADE B

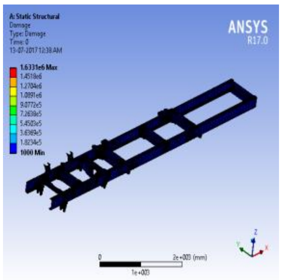
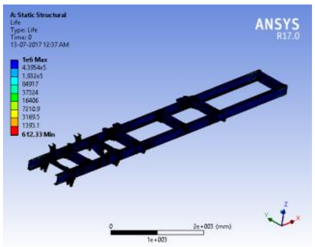


Figure. 12. Damage for AISI A514 GRADE B



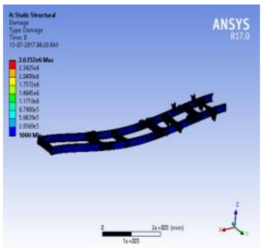
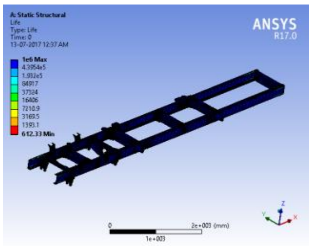


Figure.13. Life for Grey cast iron Grey

Figure.14. Damage for Cast iron



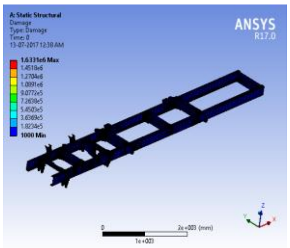


Figure.15. Life for A 709M GRADE 345W

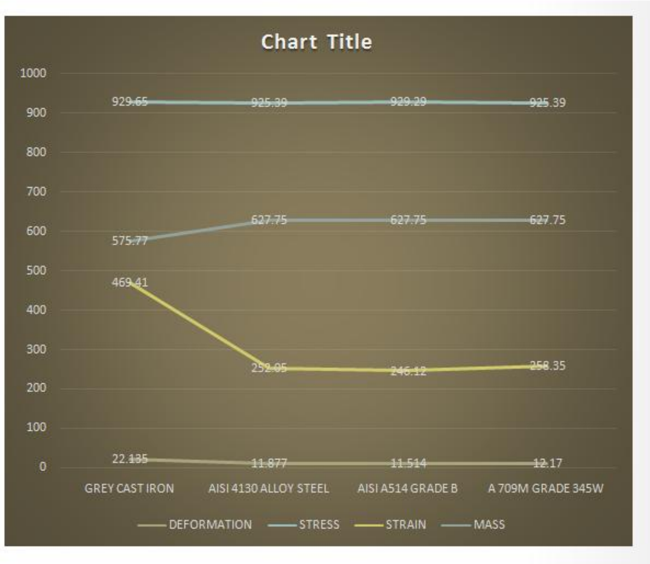
Figure.16. Damage for A 709M GRADE 345W

Table3. Comparative analysis of structure steel vehicle chassis and other alloy steel chassis

materials	Grey cast iron	AISI 4130 alloy steel	A 709M GRADE 345W alloy steel	AISI A 514 GRADE B alloy steel
STRESS (mpa)	929.65 mpa	925.39	925.39	929.29
DEFORMATION (mm)	22.135mm	11.877	12.17	11.514
STRAIN ENERGY (mJ)	469.41mJ	252.05	258.35	246.12
MASS (kg)	575.77kg	627.75	627.75	627.75

Table.4.Comparative Fatigue Analysis of Structural Steel Chassis over Other Alloy Steels

SLNO	FATIGUE	AISI A514 GRADE B ALLOY STEEL	GREY CAST IRON	A 709M GRADE B ALLOY
1	LIFE	1e6 min	1e6 min	1e6 Min
2	DAMAGE	1.6114e6 min	2.635e6 min	1.6331e6 min



Graph.1. Comparative analysis of structural steel chassis and other alloy steels

VIII. CONCLUSION

The results show that for all of the materials that have been tested in this text, AISI A514 GRADE B steel alloy shows better performance than all of the other metal alloys. It is seen that the material for the chassis i.e. A709M GRADE 345W alloy steel shows strength lower to the AISI A 514 GRADE B steel alloy and also in case of the deformation AISI A 514 GRADE B alloy is superior to structure steel, and also Life is equal for all the materials and damage is lower than all materials. From the result it can also be considered that the AISI A 514 GRADE B alloy is lighter than all of the alloys and on the same side providing the strength as well.

IX. SCOPE FOR FUTURE WORK

There is a high scope for further research in chassis using the composite materials replacing steel alloys to increase strength and weight reduction, but these are cost effective.

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