A Journal on "Design and Optimization of Vehicle Chassis for Harsh Road Conditions"

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Abstract -*The chassis, one of the most important sections of a vehicle, is the structural backbone of commercial vehicles. According to a groundbreaking study, chassis are subjected to high loads, which can lead to undesirable behavior such as cracks or severe failure. Furthermore, although not particularly explored, The impact of specific materials on chassis behaviour when subjected to stress has piqued researchers' interest. Based on the findings of these studies, it is possible to conclude that more chassis research is needed to generate data for future consideration in the evaluation & development of vehicle chassis designs.The chassis' main purpose is to support the components and cargo that are attached to it..When building a big truck chassis, many factors were taken into account, including material selection, strength, stiffness, and weight. This study focuses on the static and dynamic properties of a utility vehicle prototype ladder frame chassis. The chassis was created using the modeling software Autodesk Fusion 360, and the analysis was also carried out using Autodesk Fusion 360. To complete the chassis meshing, the auto meshing feature will be used.*

Key Words: *Ladder frame chassis, Step up Chassis, Fusion 360, Stress analysis, Displacement testing, structural analysis.*

1. INTRODUCTION

A developing tendency is for cars to be more efficient in their tasks and to be recognised for it. Automobiles and SUVs that are used for transportation, as well as Jeeps and pickup trucks that are used for utility, are examples of such vehicles. Vehicles, both personal and mass transportation, are in high demand in the twenty-first century. The large-scale job of one tonne of coal or nickel distribution from one continent to another will be used to illustrate the importance of transportation. The distribution of goods islimited by the inaccessibility of ships as a mode of sea transportation and trucks as a mode of land transportation. In 2018, their square in the world depicted in Fig. 1[1] contains a minimum of 380 million industrial vehicles and roughly 1.2 million passenger autos. This type was supposed to last until the new decade, at which point it would be over. It's impossible to picture a world without automobiles, especially cars, which are ubiquitous around the globe.

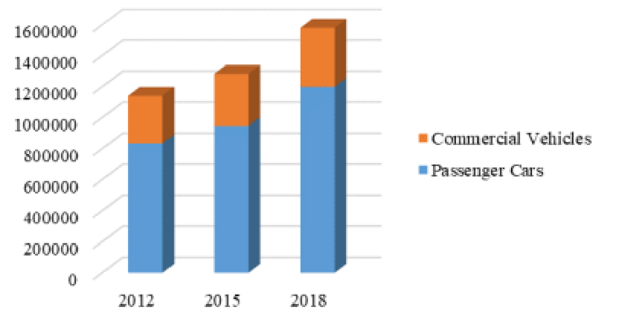


Figure 1: shows the number of passenger and commercial cars in use around the world [1].

Many manufacturers have gone so far as to include features that allow a vehicle to perform activities that it was not designed to perform. As a result, several vehicles had failed in the market due to poor reliability and unreliable chassis, resulting in imbalanced riding and unavoidable accidents.. This led to certain vehicles failing in the market because of its poor reliability and unstable chassis which led to unbalanced riding and inevitable accidents.

Additionally, the market has been building vehicles which are faster to manufacture and are of low loss, getting rid of the desires of pleasant inspection accordingly. We see numerous vehicles that are not made for street use and produce car autos must overcome. It has been discovered that the car chassis must have sufficient mechanical performance and be light in weight[3]. The goal is to achieve adequate mechanical performance so that the vehicle chassis does not deform when receiving loads, whether they are from the driving force, the engine, the body, or other elements. Because of faulty alignmthey get its passengers right into a fatal crash. To be able to challenge such narration and to build an excellent chassis keeping in mind the price and usability, we have constructed a chassis that is used for load carrying conditions and is specially for transportation of goods and manners. To accomplish that, we've carried out various kinds and makes use of chassis and underlined the various makes use of each and narrowed it right down to one kind. Then there has been the design component, which appeared to be the most critical part of growing a chassis and so, the hunt for current chassis gave us clean information on how and why chassis became created and built that manner. a lot of such chassis had been of the Mahindra Scorpio, Balero, Tata Yodha Pickup, and many others.

A big diameter thin-wall tube is defined as a perfect chassis. The term chassis comes from the French language, and it was originally used to refer to the vehicle's frame and basic structure. The two basic aims of an automobile chassis can be defined as follows:

- To support the components' weight.
- While moving, the suspension components must be held together rigidly. [2]

Nicolaus-Joseph Cugnot developed the first widely known car in 1769, and Charles and Frank Duryea discovered the first vehicle chassis. A vehicle, such as a car, must have at least three main components: a chassis, a body, and an engine. The chassis is the body that guides the uses of a vehicle, as well as supporting other elements such as the body, engine, passenger, and other automobile components.The body of a vehicle is the outermost section, and the engine is the driving part, but the chassis is the body that guides the uses of a vehicle, as well as supporting other parts such as the body, engine, passenger, and other automobile components. [1].

Until date, there have been four different types of lattice utilized in auto diligence, including Monocoque, Tubular lattice, Lattice Backbone, and Graduation Frame. Monocoque refers to a chassis in which the body and chassis shapes are merged together[2]. Ladder frames are a type of chassis that get their name from their shape, which resembles a ladder. This chassis is the oldest of all chassis types, and it's used in big motors and trucks. It's having a hard time keeping up with the increased demands for higher overall performance and lighter weight in order to meet fuel economy criteria. Shaped blocks are commonly utilized to construct this chassis, which can then be linked together via rivet or weld connections[4]. In another research of vehicle design, there are obstacles for chassis that those who want to ent geometry and various mechanical issues, if the automobile chassis deforms or bends, it will result in bad handling / uneven handling. Excessive torque can be applied to driveline components, and body part spacing is inconsistent. The theory behind the lighter chassis concept is that if the vehicle's weight is reduced while maintaining the same strength, the vehicle will naturally save more gasoline. The theory behind the lighter chassis concept is that if the vehicle's weight is reduced while maintaining the same strength, the vehicle will naturally save more gasoline.

1.2 Chassis Development

The chassis determined for the study is that of a Ladder chassis, as they are most normally used, since the fact that it is the chassis selected for most of the heavy loading situations and heavy transportation. Being the oldest form of chassis, it received its name from the fact that it is formed as a ladder. The most satisfactory part of the chassis is that it's less complicated to fabricate and use. From the start of the car, era touching on the uses and designing of chassis became not at all complex and due to its multi-fuction, became used in big numbers.

The Advantages is that being less difficult to assemble as components can be without problems put in, the construction method makes it quite tough, easier to fix as elements aren't permanently attached.The worst part is that the chassis has a weak torsional stiffness, making it difficult to corner. Because of its weight, it is not suitable for sports vehicles or hatchbacks.

When it comes to selecting materials for vehicle chassis assembly,It is necessary to consider factors such as safety and weight. The value of resources is enormous.. As a result, recyclable materials should be used. While absorbing impact energy, the material will have to ensure passenger safety also. The overall weight of the chassis is lowered by using lightweight materials in the chassis, which also helps to reduce fuel consumption. Optimizing and balancing solutions will allow for successful design. In the near future, societal and legal demands, such as the desire to maintain the natural environment and use resources wisely, will almost certainly be a major driver of change[10].

Requirements on Automotive Industry	Reaction of Automotive Industry	Significance of Materials Engineering
Care of Ressources Care of Environment	Consumption Reduction Weight Reduction	Light Weight Materials Materials with Higher Efficiency / Weight Ratio Low-Friction Material Combinations
	Reduction of Pollutant Emission - of Vehicles - in the Production Process	Non-Toxic Materials Low Emission Processes
	Closed Material Cycles	Recyclable Materials Application of Recycled Polymers Application of Renewable Organic Materials
Price Reduction	Cost Reduction in Development and Production	Low-Price Materials Low-Cost Processes

Table 1: Requirement of Automotive Industry

The following are the most significant criteria that a material must meet for vehicle manufacturers:

- Lightweight: Given the great priority placed on greenhouse gas reductions, emissions reductions, and improved fuel efficiency, his requirement for an automotive industry.
- Economic effectiveness: They are doing so with the understanding that one of the most important consumer-driven criteria in the automotive industry is cost, which decides whether a novel material has a chance to be chosen for a car component.
- Safety:The criteria take into account the ability to absorb impacting energy through regulated failure modes and systems, as well as the passengers' ability to survive.
- Recyclability of their products and Life cycle: Its main issues in the automotive industry are resource conservation and recycling options, which include R&D strategies focused on recycling processes and the creation of more easily recyclable materials, as well as their inclusion into vehicles and their constituent components.

Aluminum, steel, carbon fibers, composites, and other materials are commonly used. Automobile manufacturers use steel and its alloys as their main choice for chassis construction. Steel is the most popular material because of its resistance, temperature resistance, and durability. As a result of research and development, steel materials have improved in strength, stiffness, and lightness. Steel and its alloys are used in a wide range of automobiles because of their material properties. Steel, especially 'A36' steel, is a ductile material that is commonly used in chassis building. Connecting two A36 steel components can be done via welding and bolting. The material characteristics of A36 steel can be observed.

Property	Values of steel A36
Density	7.85 g/cm^3
Modulus of Elasticity	200 GPa
Poisson's Ratio	0.26
Yield strength	250 MPa
Ultimate Tensile strength	500 MPa
Thermal Conductivity	0.045 W/(mmC)
Thermal Expansion Coefficient	1.17 E-05 / C

Table 2: Properties of Steel A36

2. DESIGN METHODOLOGY

The Central Motor Vehicles Rules apply to all automobiles in India (CMVR). According to the CMVR's 93rd rule in chapter 5, construction equipment and maintenance of motor vehicles, "The entire width of the vehicle shall not exceed 2.6 metres when measured between the perpendicular planes of the vehicle axis at right angles," says the manufacturer. And "The vehicle's entire length shall not exceed 6.5 metres, and there should be no more than two axles. "This only applies to vehicles that do not fall under the category of transportation." [19]

The ladder chassis is utilized for the MUV vehicle. The design's layout resembles a ladder, as the name implies. The chassis' design space will be a rectangle, according to the dimensions. The two longitudinal rails appear on the rectangle's longest side in the design space. These rails are joined by cross-members, which are a type of support member.

Channel sections, tube sections, and box sections are the most common longitudinal rail sections. It's worth noting that the box portion resists torsion and bending better than the channel and tubular sections. As a result, the longitudinal rails are made of a box section. There are two types of portions in the box section. One is square hollow portion, while the other is rectangle hollow section.

Because the rectangular hollow section has a high moment of inertia, it has a high resistance to transverse and lateral loading. As a result, the beam with higher depth is more powerful. As a result, for longitudinal rails, a rectangular hollow section is chosen. Cross-members join longitudinal rails together. The engine, transmission system, suspension system, and axles are all supported by these cross members. They contribute to the chassis' rigidity. Adding a few cross-members to the chassis can improve its strength, according to standard design procedures. The cross-member should be added properly. Simply, placing a cross-member at any location is not needed. As a result, a cross-member must be introduced so that the stress and displacement values are decreased. The cross-member design should be stiffened to further reduce stress and displacement at that position. As a result, it would be able to withstand the load while also reducing displacement and stress. Finally, each cross-members must be positioned correctly. Cross-members should also be rigid enough to minimize total chassis stress and displacement.

Additions and alterations to the chassis in terms of cross members can be made based on the following variables.

1.Strength: Stability requires substantial strength in the chassis. It should be able to handle the weight of components as well as other loading situations. A few cross-members can be added to the chassis to boost its strength.

2. **Stiffness:** refers to a person's resistance to being deflected. As described an automotive chassis should have high torsional and bending stiffness, therefore cross-members can be added to improve the rigidity of the chassis.

3. **Weight**: If cross-members are used to improve chassis performance, the weight of the chassis will eventually increase. The vehicle's performance may suffer as a result of this. The cross members must be light-weight as a preventative measure. Instead of using many cross-members in that area, a single stiffened cross-member should be used.

4. **Cost:** If the material cost is expensive, make sure that the material picked is strong enough while being light. Removing unnecessary material from the chassis might also save money.

5. **Space Constraints**: The appropriate room and provision for mounting the engine, transmission system, suspension system, and axles should be made while constructing cross-members for a chassis. [20]

Cross-member thicknesses should be less than longitudinal rail thicknesses.

1. If the cross-member thickness is greater than the longitudinal rail thickness, they cause strains at their connection locations between the cross-member and longitudinal rail.

2. If the cross-member weight exceeds that of the longitudinal rails, the complete chassis model will bend or crush[2].

The ladder chassis must be built in such a way that,

1. The chassis' front end is small to provide superior steering lock and a tighter turning radius.

2. The rear end of the chassis is large and somewhat raised upwards to allow rear axle movement when going over difficult terrain.

The type of cross-member is chosen based on the needed strength at that point. Cross-member placements are determined after a series of design iterations. Modifications to the cross members are made once the position has been chosen in order to improve strength in that area. This can be accomplished by increasing the thickness of the cross-member or redesigning it with a different shape. Because increasing thickness would result in the concerns mentioned before, cross-members are given support in such circumstances.

3. 3D MODEL

The CAD model of the ladder chassis was created using Autodesk Fusion 360 software. The model is designed by following the Design Methodology guidelines. The initial concept is for a longitudinal single rail with a rectangular box shape. Thedrawn longitudinal rail is thin at the front end and broad at the back end, as shown in Figure 1. Bends are sketched near the position where the wheels are installed. The design extrude is done using the 'extrude' option with the length of the MUV specified once it has been designed in Sketcher. The Shell command' is used, together with a thickness of 6mm, to make it a 'box-section.' The longitudinal rail is built with the necessary brackets and holds for future use. When the mirror' option is selected, another longitudinal rail is formed at a distance equal to the MUV's width. [21]

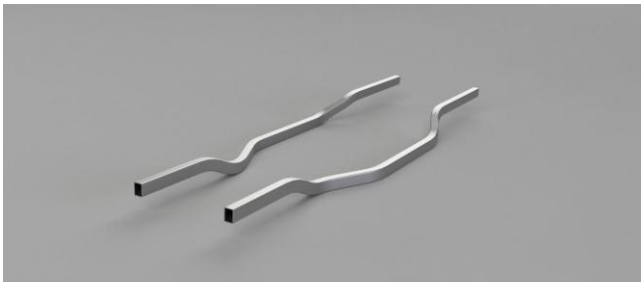
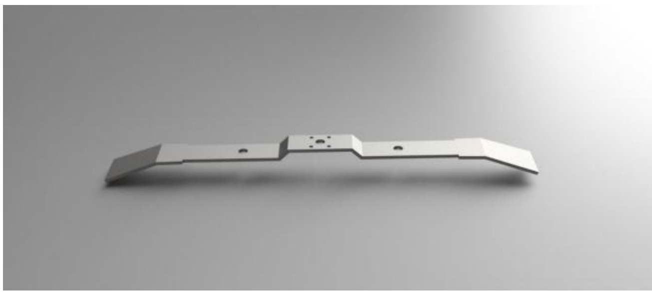


Fig 2: Longitudinal rails

The same tools are used to design the cross-member (as shown in Figure). These are designed to give ladder chassis strength. A 'pocket' tool is used to make holes. All of the other components are built in the same way. The filet tool is used to smooth the sharp edge



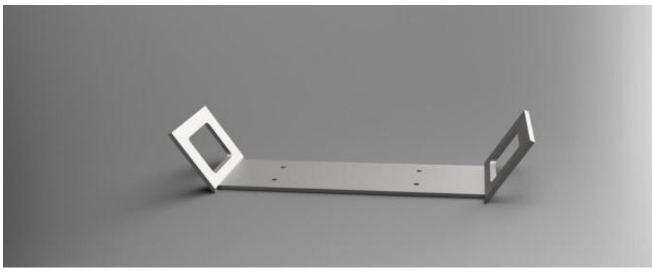


Figure 3: Cross Members

The Manipulation tool,' 'coincidence constraint,' and 'offset' tools are used to put all of the pieces together. The above-mentioned tools are used once the component has been imported into the assembly section. The component is manipulated into the desired place using a manipulation tool. When necessary, the offset tool is utilized to maintain a fixed spacing between the components. All other components are assembled using the same method.

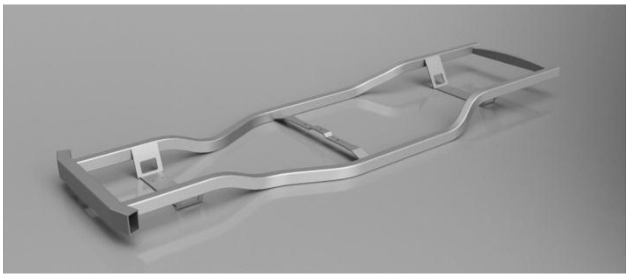


Figure 4: 3-D model of chassis designed

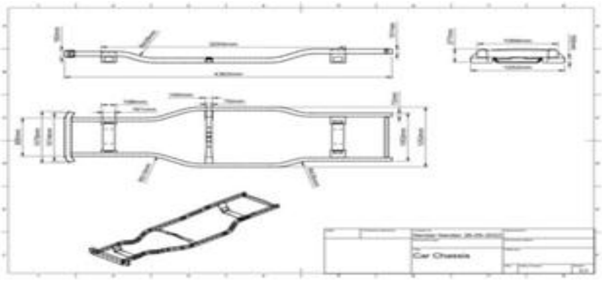


Figure 5: 2-D sketch of chassis designed

The designed chassis model is now analyzed for its structural testing, as in testing for Minimum Factor Of Safety(FOS), Maximum Displacement simulation testing, Maximum Stress testing for First Principle, Third Principle and Von Mises, also Maximum Strain testing. The following results are then compared with pre-existing urban chassis of two different structural designs and tabulated.

4. RESULTS AND DISCUSSION

As indicated in the figures below, the obtained outcomes are the physical behavior of the chassis after applying the stated parameters, namely the value of the minimum factor of safety, max stress, max displacement, & max strain. When the thinnest material's safety factor values are taken into account, the carbon steel chassis is determined to be the strongest among all offered materials based on the overall data. The observed stress and strain values support this trend, demonstrating that the structure can withstand larger stress levels while thechassis suffers less strain values, depending on the loading conditions.

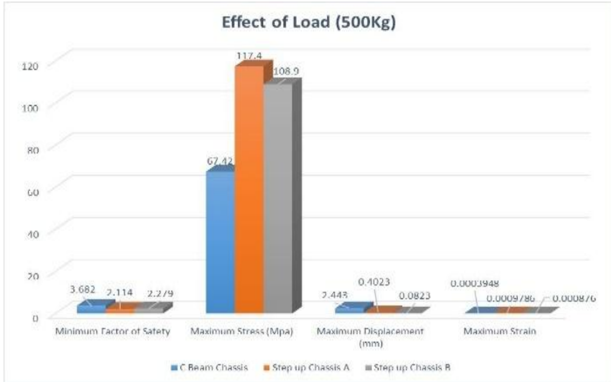


Figure 6.: Post simulation Comparison at 500kg load

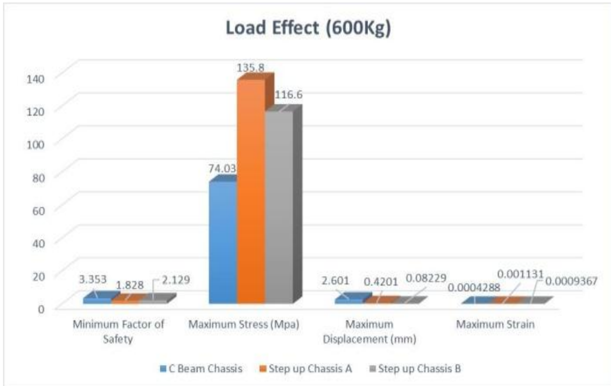


Figure 7: Post simulation Comparison at 600kg load

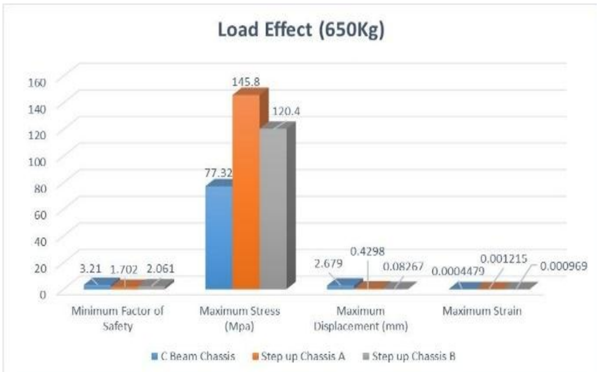


Figure 8: Post simulation Comparison at 650kg load

Since the testing is done for three loading conditions ie; at 500kg, 600kg and 650kg **we consider the results produced at 500kg and 650kg loading condition.**The Structural displacement in the models conducted are displayed in the figures below.

4.1 Displacement Simulation of C beam Chassis and Step-up Chassis for different Load Condition

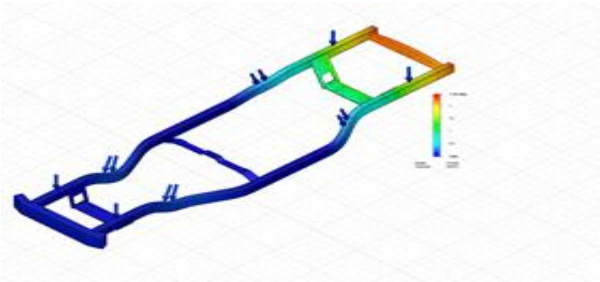


Figure 9.1: C beam Displacement at 500 kg

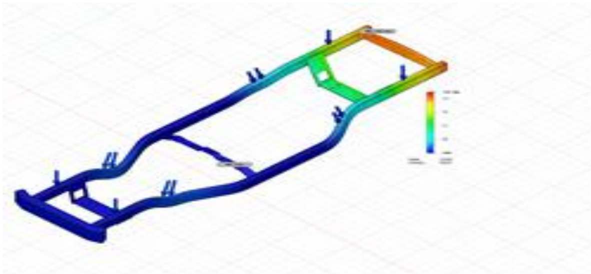


Figure 9.2:C beam Displacement at 650kg

After numerous specified loads are applied to the chassis, according to the simulation result in this scenario, different locations and values of maximum displacement occur. When load is 500kg, the max displacement value is 2.443mm, which is placed around the back of the chassis, and the other is 2.679mm, as illustrated in Figure, which is positioned on the back side of the largest force applied (650kg). The displacement value reflects how far the structure has moved from its initial location as a result of the imposed load.

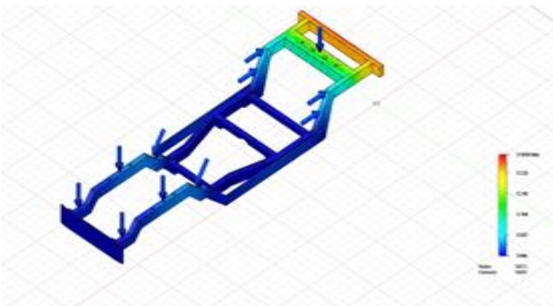


Figure 9.3: Step up chassis A displacement at 500kg

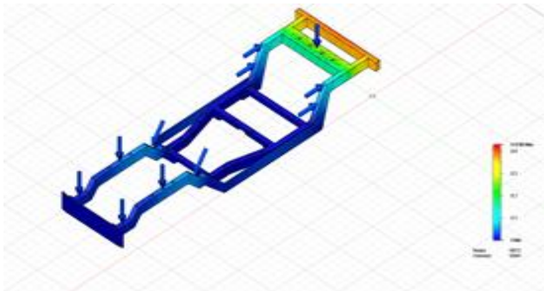


Figure 9.4: Step up chassis A displacement at 650 kg

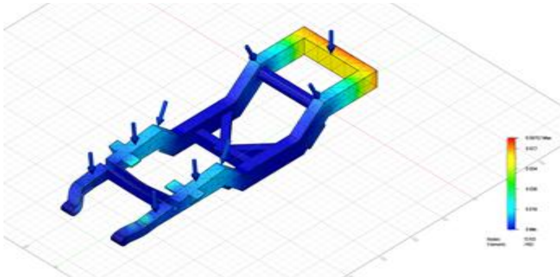


Figure 9.5: Step up chassis B displacement at 500kg

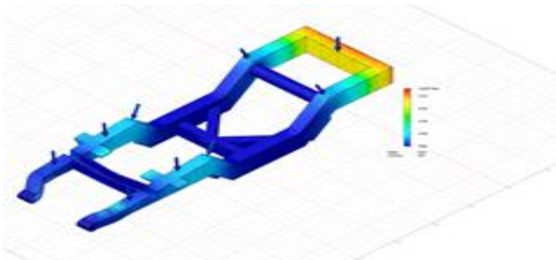


Figure 9.6: Step up chassis B displacement at 650kg

The following comparisons are made with the 'Step up Chassis A' and 'Step up Chassis B' versions, respectively. Using the Step up Chassis A model, defined loads are applied to the chassis, and different locations and values of maximum displacement occur based on the simulation results in this scenario. As indicated in Figure above, when load is 500kg, the max displacement value is 0.4023mm, which is located around the back of chassis, and the other is 0.4298mm, which will be located on the back side of the largest force applied (650kg). According to the simulation result in this scenario, when numerous specified loads are applied to the chassis, different locations and quantities of maximum displacement occur. When load is 500kg, the max displacement value is 0.0823mm, which is placed around the back of the chassis, and 0.08267mm, which will be located on the back side of the largest force applied (650kg), as shown in Figure. The developed chassis, in comparison to the Step up chassis types, exhibits a variety of behaviors connected to operational elements such as load combination and internal characteristics such as structural thickness and material. The type of material utilized has an influence that increases the value of the factor of safety and maximum stress while decreasing the value of max displacement and max strain.

4.2 Stress Simulation of C beam Chassis and Step-up Chassis for different Load Condition

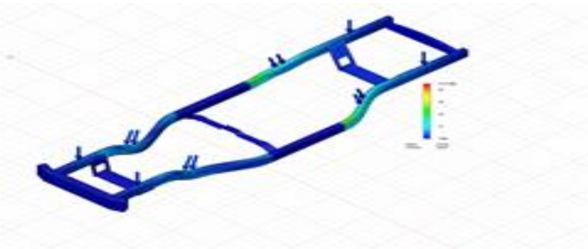


Figure 10.1: C beam Stress at 500 kg

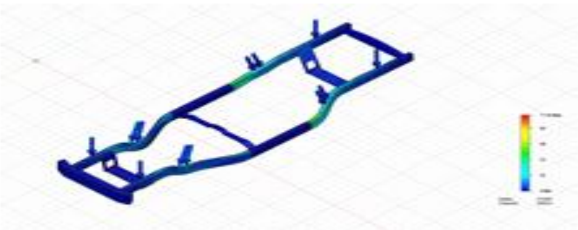


Figure 10.2: C beam Stress at 650kg.

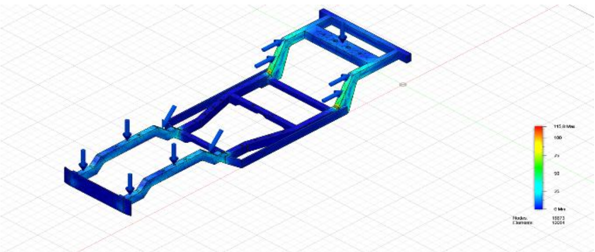


Figure 10.3: Step up chassis A Stress at 500kg

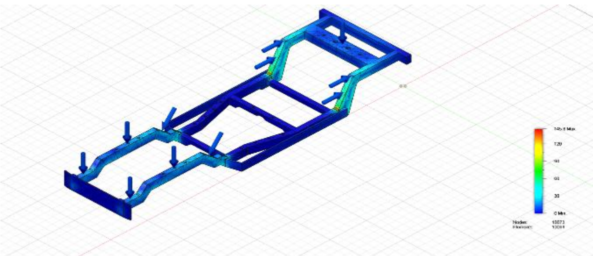


Figure 10.4: Step up chassis A Stress at 650kg

Based on the stress simulation result of these cases, different location And after many selected loads, that are applied to the chassis, the maximum stress value occurs.. When the Load is 500kg for the C beam chassis, the maximum stress is 77.99 MPa, while at 650kg the maximum stress is 89.42 MPa which will be located on the same side, of the largest force applied shown in Figure. Similarly for Step-up chassis A and B the maximum stress at 500kg load is 121.9 Mpa and 89.64Mpa, for 650kg load the maximum stress is 151.9 Mpa and 95.03 Mpa. The stress number indicates that a higher applied load causes the structure to shift more from its initial position. This has also been conducted for the following Models in comparison.

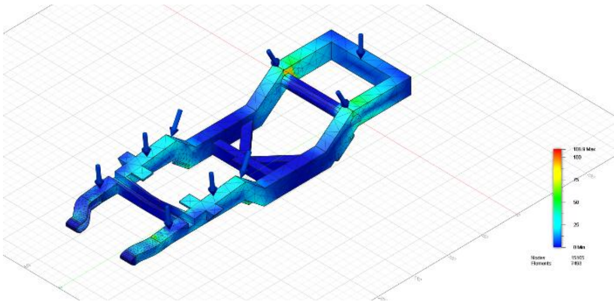


Figure 10.5: Step up chassis B Stress at 500kg

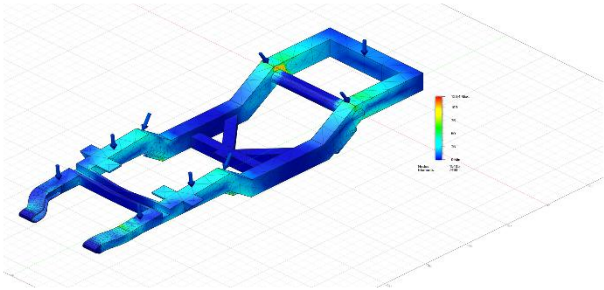


Figure 10.6: Step up chassis B Stress at 650kg

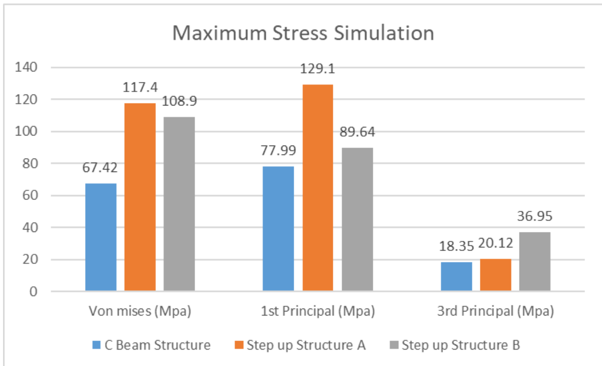


Figure 10.7: Maximum stresses at 500kg

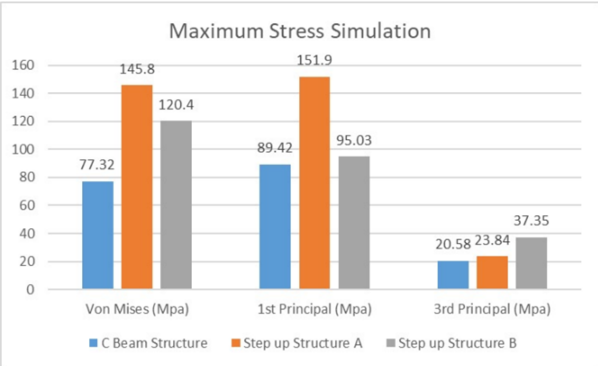


Figure 10.8: Maximum stresses at 650kg

4.3 Factor of Safety Simulation of C beam Chassis and Step-up Chassis for different Load Condition

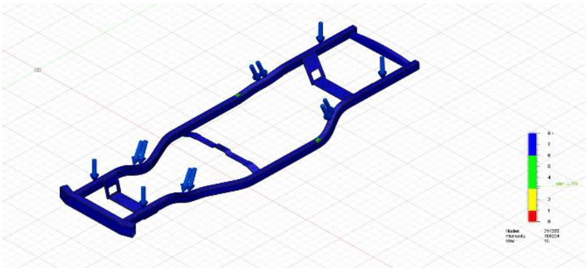


Figure 11.1: C beam FOS at 500kg

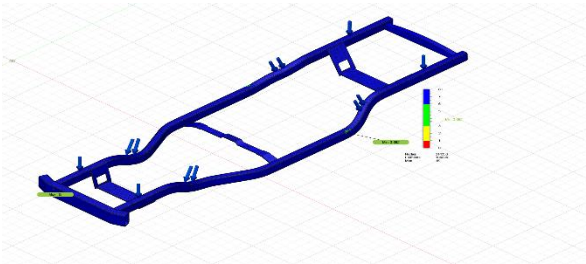


Figure 11.2: C beam FOS at 650kg

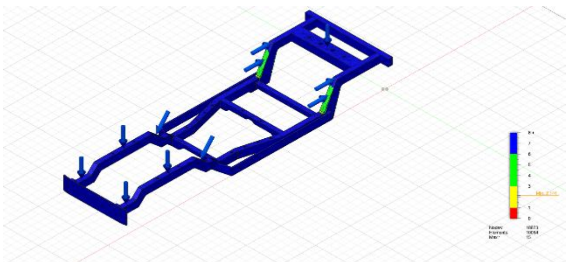


Figure 11.3: Step up Chassis A FOS at 500 kg

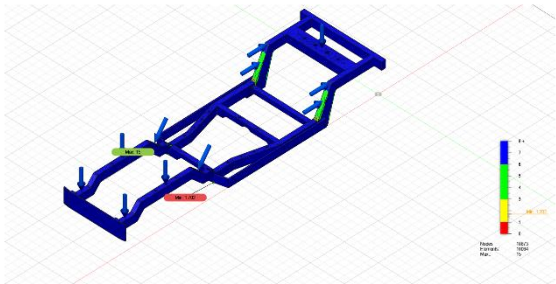


Figure 11.4: Step up Chassis A FOS at 650kg

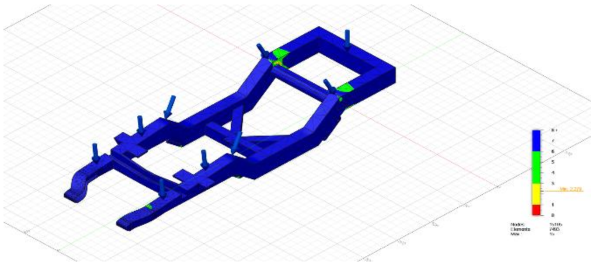


Figure 11.5: Step up Chassis B FOS at 500 kg

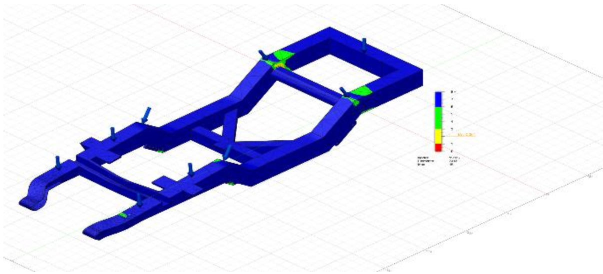


Figure 11.6: Step up Chassis B FOS at 650kg

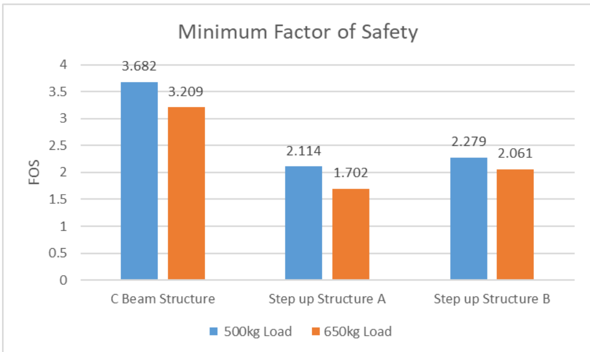


Figure 11.7: Minimum FOS at 500kg and 650kg

The simulation result for this case, is to verify the Factor of Safety for each model of Chassis. Load is applied along the regions of stress influence as, when the load is 500kg, the FOS value is 3.682 while the other one is 3.209 the highest force applied (650kg) shown in Figure. The FOS of the Step up chassis A model are 2.114 and 1.702 at min(500kg) and max(650kg) loading conditions, similarly for the Step up chassis B its 2.279 and 2.061 at 500kg loading condition and 650kg loading condition. The higher the value of FOS ie; above 3, the safer is the structure under loading and closer the value is to 1, the farer it is to being safe.

4. CONCLUSION

Based on the results obtained, due to operational And internal factors, many observations are made. The type of material used has an effect on the safety factor and maximum stress while lowering maximum displacement and maximum strain. Because a material with a higher yield strength, Low Carbon Steel A36, is used in this instance, the strength parameter increases. The influence of frame thickness is demonstrated by the increasing tendency of maximum stress, maximum displacement, and maximum strain, as well as the decreasing tendency of the safety factor with decreasing frame thickness. The tension will rise as thearea of the frame decreases, and the displacement will rise as the thin frame will have less material to carry the load. Thin frames also shorten the chassis, increasing strain while lowering the safety factor. The result of applied loading on the specified vehicle chassis is an increase in maximum stress, maximum displacement, and maximum strain, while the safety factor value falls as the load increases. the frame of the vehicle. The simulations conducted have been tabulated to indicate that the C beam chassis tends to give favorable results in comparison to the other Step up chassis models. The conclusion that can be drawn from this is that the designed model is the better and safer structure to bear the weight of the vehicle throughout its functional use. Future structural optimization research is highly encouraged to be carried out. The simulation data from this study is a good starting point for determining the best chassis construction combination.

5. REFERENCES

1. Kalghatgi, G. (2018). Is it really the end of internal combustion engines and petroleum in transport?. Applied Energy, 225, 965-974.
2. Design and Analysis of A Ladder Frame Chassis for Static andDynamic Characteristics – Obed Lungmuana Darlong, Assoc. Prof. Byra Reddy, Assoc. Prof. Dadapeer B – Assistant Professor, Mechanical Engineering Department, RMD Sinhgad School of Engineering, Maharashtra, India
3. Structural Assessment Of Alternative Urban Vehicle Chassis Subjected To Loading And Internal Parameters Using Finite Element Analysis Angga K. Ary, Aditya R. Prabowo, FitrianImaduddin, Department of Mechanical Engineering, UniversitasSebelasMaret, Jl. Ir. Sutami 36A, Surakarta, Central Java 57126, Indonesia
4. Design and Crash Analysis of Ladder Chassis - Monica Muthyala.
5. Structural Analysis Of A Ladder Chassis Frame – Vijay Patel, LDRP Institute of Technology and Research, Ruhulamin Patel Government Engineering College, Dahod – April 2012
6. Structural Analysis Of Chassis: A Review – Suraj B Patil – M.E, Mechanical Engineering Department, RMD Sinhgad School of Engineering, Maharashtra, India, Dinesh G Joshi – Assistant Professor, Mechanical Engineering Department, RMD Sinhgad School of Engineering, Maharashtra, India
7. Stress analysis of a truck chassis with riveted joints by Cicek Karaoglu*, N. Sefa Kuralay, 2002.Department of Mechanical Engineering, DEU Faculty of Engineering, 35100 Bornova, Izmir, Turkey ,Finite Elements in Analysis and Design 38 1115–1130
8. The effect of connection plat thickness on stress of truck chassis with riveted and welded joints under dynamic loads is carried out by M. zehsaz, Vakili Tahami and Esmaeili. Asian Journal of applied Science 2(1): 22-35, ISSN 1996-3343. [3]Dynamic Analysis of a Modified Truck Chassis by Mohammad Reza Forouzan., Majlesi Journal of Mechanical Engineering, Vol. 3/ No. 4/ Summer
9. Shi C Q, Ding H M, Yang S M. Finite element analysis of truck frame and effects of cargo body on frame performance. Automobile Technology
10. “Assessment of Fuel Economy Technologies for Light-Duty Vehicles.”[Online].[Accessed: 03-Aug-2018].
11. “Construction-Mechanic-Basic-Chapters-14. [Accessed: 27-Aug2018].
12. S. N. R. H. Kumar, “Automobile Chassis and Body Engineering.”[Online][Accessed: 13-Aug-2018].
13. A. Anand, “Torsional analysis of the chassis and its validation through Finite Element Analysis,” p. 7.
14. Ms. A. E. Chambers, Mr. S. A. Rodriguez, Mr. R. M. Walsh, and Dr. D.Wootton, “Development of a Test Stand for Determining the Torsional Rigidity of a Formula SAE Space Frame.
15. A. Tomar and D. Singh, “Modeling and Analysis of a Chassis Frame by Using Carbon Fiber and E-Glass Epoxy as Composite Material: A Comparative Study.”
16. A.H. Kumar, V. Deepanjali, Design & analysis of automobile chassis. Int. J. Eng. Sci. Innov.Technol. (IJESIT) 5, 187–196 (2016)

17. J. Rajpal, R.S. Bhirud, A.K. Singh, A.V. Hotkar, S.G. Thorat, Finite element analysis and optimization of an automobile chassis. Int. J. Eng. Res. Technol. (IJERT) 3, 2075–2082 (2015)

18. J. Rajpal, S.G. Thorat, B.S. Basavaraj, S. Kothavale, S.S. Hatwalne, Design considerations for automobile chassis for prevention of rolling over of a vehicle. Appl. Mech. Mater. 6, 41–49 (2014)

19. Vehicle Chassis Analysis: Load Cases & Boundary Conditions For Stress Analysis - Ashutosh Dubey and Vivek Dwivedi

20. Electric Vehicle Chassis Design and Structural Analysis by using CAD and CAE Techniques - D. Arun, D. V. Paleshwar , K. Sainath.

21. Mode Shape Analysis of EV-Bus Chassis with Reverse Engineering Method - N Nazaruddin, A Syehan , G Heryana, M Adhitya and D A Sumarsono

22. Structural and Modal Analysis on A FrameLess Chassis Construction of Heavy Vehicle for Variable Loads - K. P. Sirisha, R. Lalith Narayana, A. Gopichand, Ch. Srinivas, G. Ram Balaji

23. Structural Analysis of Ladder Chassis for Higher Strength - Abhishek Singh , Vishal Soni , Aditya Singh

24. Structural Analysis of Ladder Chassis Frame for Jeep Using Ansys - Vishal Francis , Rajnish Kumar Rai , Anup Kumar Singh , Pratyush Kumar Singh , Himanshu Yadav

25. Stress Analysis of Ladder Chassis with Various Cross Sections - Kamlesh Y. Patil , Eknath R. Deore

26. Shape Optimization of Automobile Chassis - Aayush Chugh, Rachit Ahuja, Sukriti Ranjan

27. Dynamic Analysis and Design Modification of a Ladder Chassis Frame Using Finite Element Method - Shrinidhi Rao , Ajay Bhattu

28. Design & Analysis Of Automobile Chassis - A.Hari Kumar, V.Deepanjali

29. A Review on Design and Analysis of Ladder Chassis - Scholar Shubham Agrawal, Prof. Arun Pate

30. Structural Analysis of Ladder Chassis Frame for car Using Ansys - S.Sivaraj , A.Hazemohzammed , M.Yuvaraj, N.Karthikeyan, V.Murugan