DESIGN, ANALYSIS AND FABRICATION OF AN OFF ROAD TRAILER

A Final Year Project Report

Presented to

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment
of the Requirements for the Degree of
Bachelors of Mechanical Engineering

by

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SEPTEMBER 2018

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Titled: "DESIGN, ANALYSIS AND FABRICATION OF AN OFF ROAD TRAILER" be accepted in partial fulfillment of the requirements for the award of MECHANICAL ENGINEERING degree.

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______________________ ____________

(Head of Department) (Date)

COUNTERSIGNED

Dated: ________________ __________________________

(Dean / Principal)

ABSTRACT

Modern Heavy duty vehicles are commonly used to transport heavy goods, materials from one place to another by carrying out best performance in transportation. Due to the running condition of vehicle as well as engine, there is a great impact of deformation which is produced in the chassis with the time. This deformation is due to the reason that the continuous shocks from the road as well the engine produces vibration and the vibration produces deformation. The stability of vehicle trailers is very importance during the transportation of goods through uneven surfaces likes Rocky Mountain Surfaces as the disturbances in the motion of vehicle can affect the cargo. Hence, the target is to achieve higher stability by reducing deformations and providing smooth journey to the cargo supported by Trailer by resisting shocks and loads. In this project, we will be studying different load conditions involved, the vertical deformation in the kingpin, Frame torsion and the respective deformations produced due to the loadings, by the involvement of Finite Element Analysis. The model of the trailer is a **Flat Bed Trailer**, and the proper analysis of a trailer is to be carried out. The analysis of trailer parts involves the Chassis analysis, Suspension parts analysis. The chassis that we are incorporating in our model is **Ladder Frame Chassis** with their respective side members and cross members. Chassis plays a vital role in supporting the frame of a trailer, as it provides trailer a capability to absorb shocks. The chassis is a lower body of an automobile that serves a framework for supporting the body and different parts and assembly of automobile including the Tires, Engine, Frame, Driveline and Suspension. The chassis should be capable of resisting Twisting, Vibrations, Shocks and other stresses. The frame consists of series of cross members, attached with the two side members. The analysis of the Chassis helps us to locate the critical points having the greater value of stresses and deformations at the respective points. Critical point is actually one of the reason of causing sort of Failure known as Fatigue Failure. The magnitude of the stress incorporated in it can be helpful in predicting the life span of Chassis. Finite Element Analysis (FEA) is done on ANSYS Workbench.

PREFACE

As a part of Mechanical Engineering curriculum, and in order to gain Knowledge in the field of Automobile Engineering with the involvement of basic Mechanical Principles, Concepts, Techniques, Methods etc., we are required to make a report on our Final Year Project that is "Design, Analysis and Fabrication of an Off Road Trailer". The basis objective behind this project is to get the knowledge of different aspects of Mechanical Engineering involved in constructing Vehicles and their parts.

In this project report we have compiled different concepts, techniques to design, analyze an Off Road Trailer. The analysis of an Off Road trailer has been carried out by imparting real life scenarios and conditions and relating them to the stresses and observing the response of Trailer to resist the shocks and varies Load factors. The critical points determining the maximum stress locations along with are indicated by the repetitive iterations. In these iterations, the relation of weightage of material is observed with the Stress Analysis.

Doing this Project helped us in enhancing the knowledge of various aspects of Mechanical Engineering, the role of Mechanical Software (Solid Works, ANSYS Workbench etc.) in developing the 3D Model and its Analysis. Furthermore, the Fabrication is to be carried out as soon as the Analysis terms and Conditions are approved. Through this report we get to know the role and importance of Teamwork, Task Division, Team Management and Time Management towards this work.

ACKNOWLEDGMENTS

A lot of Support has been provided and put into this Project from the University, Respected Faculty and relevant Students.

The Faculty Supervisor (Dr. SAMI UR REHMAN SHAH) deserves to be thanked and shown gratitude, first of all, for his continuous support and help in all the relevant discussions and support throughout the project. The junior fellow of ME-07(Mr. Junaid Ahmed, Registration Number ------) deserves to be thanked and shown gratitude for his support in the analysis of the Chassis. The University deserves to be thanked for providing the courses, software access and their availability till now. Our all faculty members deserve to be thanked for their continuous support by implicating knowledge of their respective courses. Thank you the fellow group mates for making this team capable of developing this Project to this extent.

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CHAPTER 1: INTRODUCTION

Trailers are used for transporting agriculture products, goods, building construction material, and industrial equipment on a large scale. The power required to pull the trailer is employed by human, animals and machines depending on the time frame. Talking about trailers, many varieties are available in the market and use of particular trailer depends upon their application. Each and kind of trailer serves its own purpose. The requirements or the transporting need of trailer manufacturing depend upon high performance, easy to maintains, longer working life and robust construction. The trailer that we are using is Flat Bed Trailer; such trailers are employed in heavy automobiles to carry tones of loads, goods safely from one place to another. Such trailers have a big role and involvement as far as the safety of the cargo loaded is concerned. The trailers carrying cargo are increasing day by day due to their greater number of applications on our daily life. Whenever the higher tons of cargo is being dispatched from the source place, people recommend Trailers for the provision of smooth journey as such trailers are capable of weighing the heavy amount of load. With the advancement in technology and industrialization, the increasing rate of fabrication of these trailers shows that how they are productive, why people recommend such Trailers?, due to their unique resistive behavior to the shocks and load factors. Nowadays, the ability of vehicle to absorb shocks and loads plays vital role in the selection of vehicles for transportation of goods.

Every vehicle has a body, which has to carry both the loads and its own weight. Vehicle body consists of two parts; chassis and bodywork or superstructure.

1.1 Chassis

Automobile Chassis refers to the lower body of the whole assembly connected to the varies parts of the assembly. It includes Tires, Engine, Suspension and frame. The support is provided by the frame to these assembled components and serves as a framework for supporting the body. It should be rigid and capable of withstanding the shock, twist, Load and Vibrations. Strength plays vital role in the resistive capability of frame along with the bending stiffness that is vital for deformation. The design and chassis comprises of the two criteria that is the Strength and the Stiffness. Based on these two criteria, we are able to do static structural analysis of the Trailer's chassis. Structural analysis can be analyzed easily with the help of Finite Element Analysis (FEA). FEA is done on Workbench for the chassis analysis.

The chassis we are employing for our Trailer is **Ladder Frame Chassis**

Figure 1: Ladder Frame Chassis

https://www.google.com.pk/search?q=ladder+frame+chassis&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj32KKt-YvZAhUB16QKHeHoCw0Q_AUICigB&biw=1366&bih=626#imgrc=LwiVralRna2PWM:

1.2 Ladder Frame Chassis

As the name suggests, the Ladder frame chassis consists of a ladder type layout with two longitudinal members with several cross members. In the frame, the chassis includes cross-members located at critical stress points along the side members. Through connection plates, the cross members are attached to side members. The joints are riveted or bolted in trucks and welded in the respective trailer parts. Nuts and bolts construction can also be used for easily removal components. The vehicle trailers are subjected to Static and Dynamic Loads. Dynamic Loads result from inertial forces occurring due to uneven mountain surfaces. The static load results from the Weight that is placed on the frame. It supports the weight of vehicle including the cargo and provides the frame for suspension and drivetrain. It is strong enough to support firmly the assembled components. Having a capability of resisting torsional stresses (involving bending and twisting of body),that are acting on to the vehicle, shows that the ladder frame chassis is most suitable frame chassis for supporting trailers cargo. That's the major reason that we're employing the Ladder Frame Chassis in our Trailer for the provision of firm support to all the assembly members. Heavier and heavier load may be subjected to the frame and the resisting capability to these loads play vital role in developing such chassis. The heavier nature of the ladder chassis makes it tougher and stable hence it is comparatively better than the Monocoque Frame for carrying heavier Cargo and towing heavier mass. Steel is mostly employed to make this frame. The steel that we are using is **AHSS S355** due to the reason that this steel is very hard, tough in its characteristics with the comparatively lower price than Aluminum.

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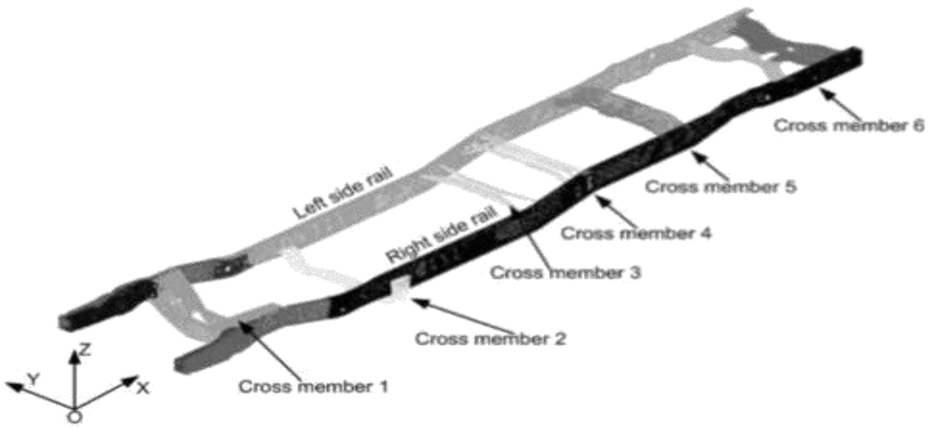

Figure 1: Detailed truck chassis model.

1.3 Finite element Analysis (FEA):-

Finding approximating solutions by the numerical technique in such a way boundary volume problem is incorporated for Partial Differential Equations. Dividing a large problem into similar relevant paths or elements that characterize the given problem are called Finite Elements. FEA incorporates variation methods from the Calculus of variations by approximating a given solution to minimize an associated error function. It is highly productive for problems with complex geometries, several loadings, and material properties where analytical solutions cannot be determined.

1.4 Suspension

CHAPTER 2: LITERATURE REVIEW

2.1 Background

New Zealand has a high incidence of rollover and loss-of-control crashes compared with other countries such as the United States and Canada. Rollovers occurred in 29 percent of the heavy vehicle crashes attended by the New Zealand Police Commercial Vehicle Investigation Unit between July 1996 and November 1999.

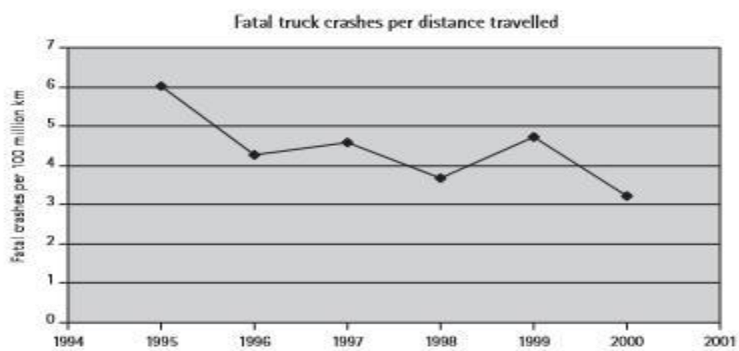

Figure 1: Fatal truck crashes per distance travelled

From the figure, This high number largely reflects New Zealand’s difficult driving conditions. The country has more bridges, corners and hills per 100 kilometers of road, and fewer divided highways, than most other developed countries. Drivers of large vehicles have a responsibility to do so considerately and professionally. Rollovers in single-vehicle crashes involving trucks often reflect their poor appreciation of general dynamics and stability issues. This means driving according to the conditions, and having a reasonable understanding of the forces at work on the vehicle and their effects.

A 1999 study showed a clear relationship between rollover crash risk and stability (characterized by the static roll threshold (SRT)). Figure 2 shows the relationship

Mueller, T.H., de Pont, J.J. and Baas, P.H.(1999) Heavy Vehicle Stability versus Crash Rates. TERNZ Research Report prepared for the LTSA, available online at www.ltsa.govt.nz/publications/docs/Stability.pdf.

between rollover crash risk and SRT. The poorest-performing vehicles (those with an SRT less than 0.3g) had four times the average rollover crash rate. The study also found that the 15 percent of vehicles with an SRT less than 0.35g were involved in 40 percent of the rollover crashes. It is clear that improving the performance of the poorest-performing vehicles in New Zealand's fleet should generate a substantial reduction in rollover crashes

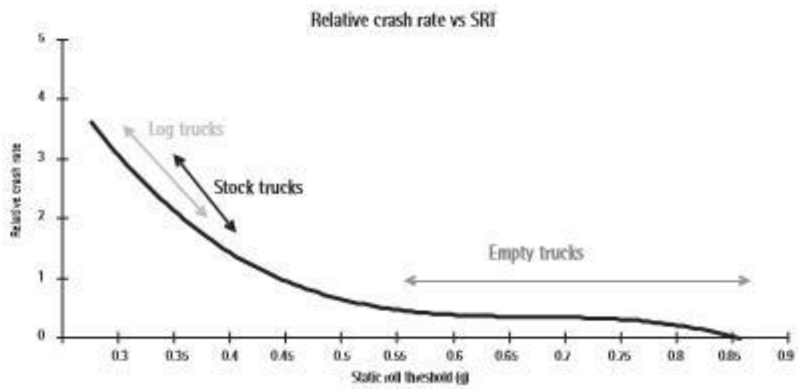

Figure 2: Relationship between rollover and crash risk and SRT

2.2 The Basics

These same principles apply to our vehicles, while they can't be ignored, they can be controlled.

- **Speed**

  The effect of speed on cornering stability, braking distance and impact forces increases at the square of the speed increase. This means, for example, that cornering forces don't just double when the vehicle speed doubles, they increase by four times.

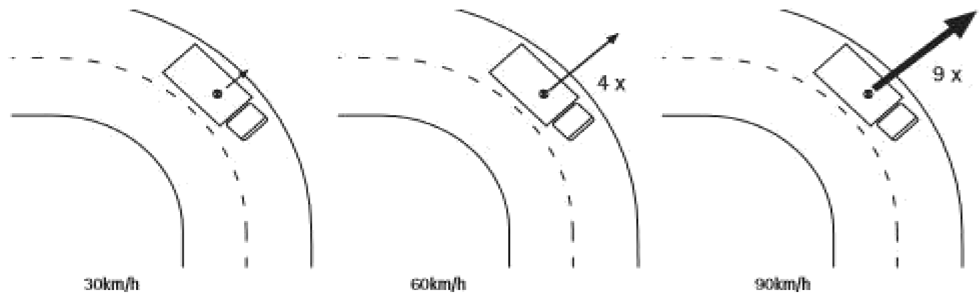

Figure 3: Speed squared effect on cornering force

- **Gravity**
- **Centre of gravity**
- **Kinetic energy**
- **Friction**
- **Centrifugal Force**

2.3 Stability

Of the factors that can influence a vehicle's tendency to roll over, the following are the most important:

- Speed
- CG height and Track width
- Suspension
- Tires.

If all these factors are maintained at acceptable levels, the vehicle will remain stable. The risk of loss of control and rollover will increase if they are not considered.

Static roll threshold (SRT)

SRT describes the maximum amount of lateral (sideways) acceleration a heavy vehicle

Mueller, T.H., de Pont, J.J. and Baas, P.H.(1999) Heavy Vehicle Stability versus Crash Rates. TERNZ Research Report prepared for the LTSA, available online at www.ltsa.govt.nz/publications/docs/Stability.pdf.

can handle without rolling over. This depends on the vehicle's speed and the tightness of the turn.

The centrifugal (side) force created by the lateral acceleration will push a part of the vehicle's weight to the outside of the curve when the driver turns the steering wheel. The SRT is the lateral acceleration required to transfer all the weight to one side of the vehicle, and is a fraction of 1g(Figure 4).

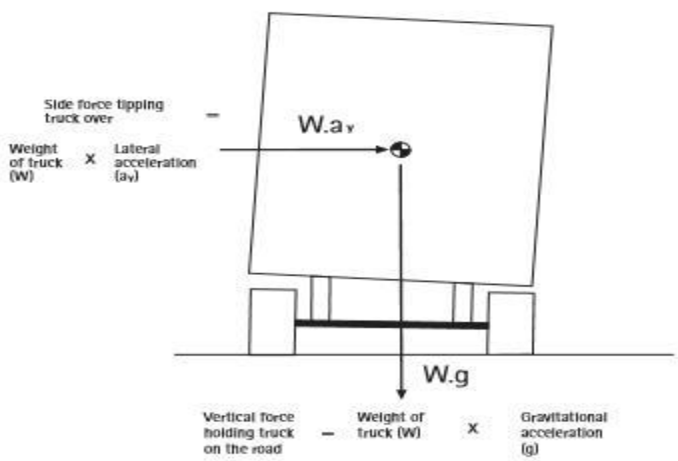

Figure 4: Side force and vertical forces acting on truck during cornering

Figure 5 illustrates the effect of SRT on the level of side force required to cause a vehicle to slide out or roll over. It clearly indicates the importance of CG height.

Mueller, T.H., de Pont, J.J. and Baas, P.H.(1999) Heavy Vehicle Stability versus Crash Rates. TERNZ Research Report prepared for the LTSA, available online at www.ltsa.govt.nz/publications/docs/Stability.pdf.

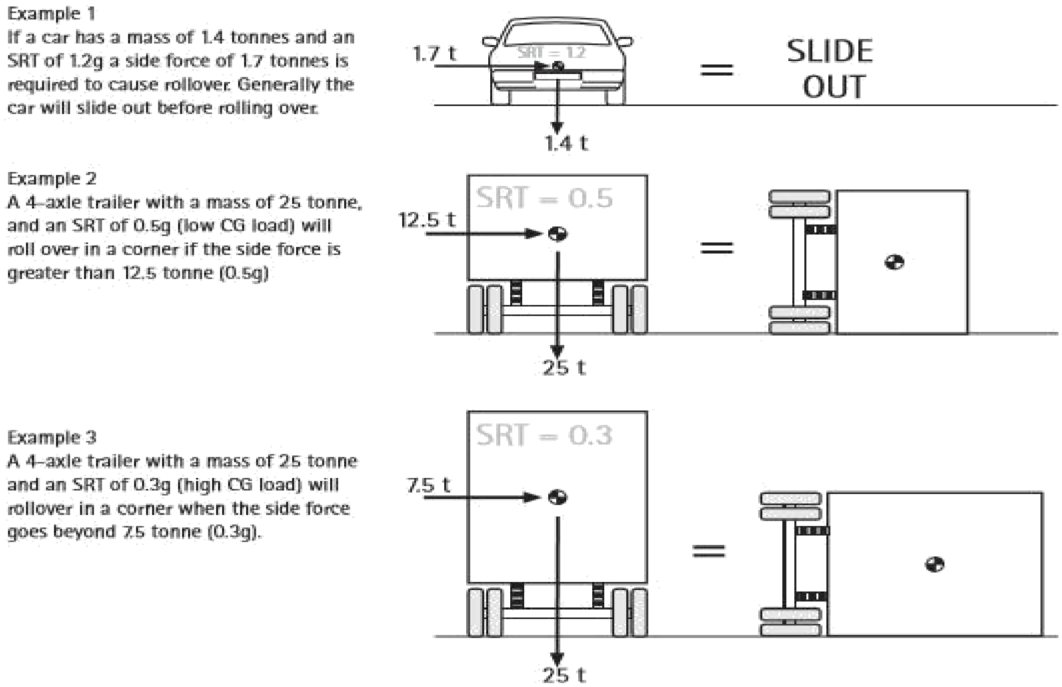

Figure 5: SRTs of different vehicles and loads

2.4 Chassis Design

The chassis frame plays a vital role in the construction of a truck or trailer connected to it. It is used to carry the weight or the whole load acting on the truck as well as on different parts of an automobile. It is supposed to be resistant to Shocks, Twist, Vibration and other stresses. In order to determine the design of chassis, Maximum Stress and Maximum deflection provide criteria to judge the strength of chassis by determining Critical Regions under static load conditions.

Chassis has a great significance in catering the weights of all the components. Almost all the weights of the components act onto the frame of chassis. Static, Dynamic and Cyclic loading conditions are implied while calculating the maximum stresses and deflections. Static stress analysis is then carried out, as it is very important to determine the Critical points of Maximum Stress in a region. These critical regions may cause failures. Such failures are known as Fatigue Failures. The automotive chassis is supposed to have two basic goals: Holding the weight of the components and to rigidly fix and suppress the suspension components together while in a motion.

Referring to the few research paper made by the following Authors and what they have concluded, their FEA Results etc. The data acquired belongs to their respective writers and all the rights are reserved.

1). P. S Madhu., T. R. Venugopal

RADIOSS is used as solver for the analysis, they found that location of maximum Von Misses stresses and maximum shear stresses are just near the support and at the joining portion of connecting plates and side rail. These stresses can be minimized by relocating the position of the cross members and deflection of the chassis side members can be reduced considerably.

FEA Results:-

After applying boundary condition, the file is imported to the solver. RADIOSS is used as solver here for the analysis. Finally the post-process is done by using HYPERVIEW software. The location of maximum Von-Mises stress and maximum shear stress are just near the supports and at the joining portion of connecting plates and side rail. The maximum Von-Mises stress is about 181.69MPa and the maximum deflection is about 5.65 mm

Design Modification:-

The Design modification (Re-design) is the process of achieving some desired set of specification which minimizes the critical factors of model. While modifying the model, the designer must have the knowledge about model, behavior of the model under given loading condition, and also some experience in similar projects and also previous results of existing model. In this study, the allowable stress is less than the yield strength, so stresses are not a critical issue, but deflection of chassis frame is about 5.64 mm. Deflection of chassis frame has different standard values for different vehicle frames and also has different values for different type of analysis. Still it is possible to minimize the deflection of chassis frame without increase the stresses. With the following different iterations, following changes in deflections are observed.

Table 1: Comparison of Results

DESIGN MODIFICATION RESULTS

Iteration	Von-mises stress in MPA	Displacement in mm
1	190.9	5.921
2	190.596	3.720
3	190.112	3.706

2). H. Patel, K. C. Panchal and C. S.Jadhav

They have work performed towards the optimization of the automotive chassis with constraints of maximum shear stress, equivalent stress and deflection of chassis. For optimization of chassis different cross sections are selected by changing the height and width of side members and cross members.

3). Mr.Birajdar M. D., Prof. Mule J.Y.

Results shown are only for span Section EG where change in cross section area is observed in each case. For span section AE no any changes in cross section because generated stresses are already much closer to the allowable stress limit. So generated stresses will be same in second, third and fourth cases as observed in first case (original cross section) for span AE.

Table 2: Comparison of Results

Sr No.	Bending Stress(N/mm^2)	Shear Stress(N/mm^2)	Deflection(mm) Span EF	Deflection(mm) Span FG
1	57.53	14.27	0.0003	0.032
2	71.02	17.12	0.769	0.082
3	80.67	18.98	1.3	0.13
4	96.28	20.74	2.19	0.23

4). K. I. Swami, Prof. S. B. Tuljapure

They considered Eicher 20.16 ladder chassis and they have studied the effect of varying thickness on chassis. They found that at the free end of beam highest deformation has occurred leading to lowest stresses. Deformation and stresses are directly proportional to load applied. As the thickness of cross members increases there is decrease in von misses stress and deformation.

Methodology

The following methodology is selected:-

1. A hybrid structure made by combining ladder and backbone chassis concept.
2. The area of research is concentrated on the behavior of the chassis on varying the manufacturing material.
3. Need to find maximum deformation, maximum stress and strain on the chassis when made by steel, aluminum alloy, and magnesium alloy under the applied load.

Conclusion:-

1. It is observed that for the taken materials, the minimum deformation observed is in order Steel<Magnesium alloy<Aluminum alloy.

2. The order obtained for the stresses developed in different materials is Steel< Magnesium alloy < Aluminum alloy.

3. Maximum strain obtained is in Aluminum alloy, moderate in magnesium alloy & minimum in Steel.

4. Thus the main load bearing element of chassis should be made of the steel.

5). J. S. Nagaraju, U. H. Babu

They have replaced the traditional material of chassis i.e. steel & Aluminum with Composite Material Carbon Epoxy and E glass Epoxy. By observing structural Analysis results the stress values for Carbon Epoxy and E glass Epoxy are less than their respective allowable stress values. So using composite for chassis the weight of the chassis reduced 4 times than by using steel because density of steel is more than the composites.

6).Aditya Patel,Akash Vishwakarma

The objective of research work is design the ladder chassis according to the application of load on it. It is observed that some area of the chassis comes under heavy load and remaining part of it under low load. The generation of stresses will be according to the applied load on the chassis i.e. in some area of chassis magnitude of stresses will be high and remaining portion of chassis will be under low stresses.

Considering these conditions:-

1. Design the chassis by considering its existence dimensions. It will give the magnitude of stresses and deflection which is generating in the chassis.

2. Reduce the area where intensity of stress is less.

3. Generated stresses and deflection after reducing area must be less than its allowable limit.

4. Calculate amount of weight reduction after reducing the area.

Methodology:-

In order to achieve objective the following methodology is selected.

1. Ashok Leyland truck Model No. IL super 3118 considering here for design.

2. Basically work of this research is concentrated on side member of ladder chassis.

3. Need to find maximum and minimum load intensity on the chassis.

4. By taking existing dimensions of chassis, need to find its bending stresses, shear stresses and deflection under the application of applied load.

5. Need to make necessary changes in cross section area of chassis according to applied load. And redesign changed cross section chassis for bending stress, shear stress and deflection. For safe design generated stresses and deflection should be less than allowable limit.

Table 3: Comparisons

S. No	Material Used	Deformation	Stress(Pa)
1	Steel	1.96*10^-2	Max= 33499 Min= 4.566
2	Aluminum	1.738*10-1	Max= 2.337*10^5 Min= 6.972*10^-1
3	Magnesium	9.849*10-2	Max= 2.383*10^5 Min= 6.984*10^-1

7). H. B. Patil, S.D. Kachave and E. R. Deore

They have selected ladder chassis of truck. They have selected different thicknesses for cross members and side members of truck. They have suggested that in order to achieve a reduction in the magnitude of stress at critical point of the chassis frame, side member thickness, cross member thickness and position of cross member from rear end were varied. Finally they have suggested that to change the thickness of cross member at critical stress point than changing the thickness of side member and position of chassis for reduction in stress values and deflection of chassis.

8). Dasaradh Palagiri, Chavali Joy Davidson, Ramesh Babu Vemuluri

In this paper the chassis made of two different composite materials such as carbon and E-glass epoxy are considered for static analysis.

Table 4: Comparison of Stresses and Deformations Induced in Various Materials

Materials	Stress Induced N/mm^2	Deformation mm
Structural Steel	130.29	6.852
Carbon Epoxy	127.52	8.402
E glass Epoxy	125.34	28.046

Conclusions:-

1. From the static analysis on chassis by varying the sidebar thickness it is found that 5mm thickness sidebar chassis deforms less compared to 6mm and 4mm and also reduced vehicle weight with reduced stresses induced.

2. From the dynamic analysis of chassis system made of three different materials it is observed that the E-glass epoxy material develops less stress and higher deformations compared with rest of two.

3. The chassis made of carbon epoxy material induces stresses and deformations are in between the maximum and minimum values. This indicates reliability of material.

4. Dynamic analysis proves that carbon epoxy material chassis is the optimized system as its deformation is less than other two materials.

5. Harmonic analysis is done by considering cantilever end support for chassis and found first mode shape.

6. Hence it can be concluded that the more reliable and efficient chassis material would be the carbon epoxy as the stresses induced and deformation is comparatively less

8). Design K. Rajasekar, Dr. R. Saravanan

The study reviewed the literature on chassis design. After a careful analysis of various research studies they found that sufficient studies have not been conducted on variable section chassis concept.

9) A. Singh, V. Soni, A. Singh

They have carried out study on ladder chassis for higher strength. The research paper describes Structural analysis & optimization of vehicle chassis with constraints of maximum shear stress and deflection of chassis under maximum load. The dimensions of an existing vehicle chassis of a TATA LP 912 Diesel BS4 bus is taken for analysis. The four different vehicle chassis have been modeled by considering four different cross-sections. Namely C, I, Rectangular Box (Hollow) and Rectangular Box (Intermediate) type cross sections. From the results, they observed that the Rectangular Box (Intermediate) section is having more strength full than the conventional steel alloy chassis with C, I and Rectangular Box (Hollow) section.

10). Avinash V. Gaikwad, Pravin S. Ghawade

The truck chassis model is loaded by static forces from the truck body and load. For this model, the maximum loaded weight of truck plus body is 10.000 kg. The load is assumed as a uniform distributed obtained from the maximum loaded weight divided by the total length of chassis frame. Detail loading of model is shown in Figure. The magnitude of force on the upper side of chassis is 117720 N. Earth gravity is also considered for the chassis frame as a part of loading. There are 4 boundary conditions of model; the first two boundary conditions are applied in front of the chassis, the second and the third boundary conditions are applied in rear of chassis

Conclusion:-

The highest stress occurred is 106.08 MPa by FEA analysis. The calculated maximum shear stress is 9543 MPa. The result of FE analysis is bigger 10 % than the result of analytical calculation. The maximum displacement of numerical simulation result is 3.0294 mm. The result of numerical simulation is bigger 5.92 % than the result of analytical calculation which is 2.85 mm. The difference is caused by simplification of model and uncertainties of numerical calculation.

11). Suraj B Patil , Dinesh G Joshi

In this paper review of static structural analysis of chassis is presented. It is observed that most of the existing researchers utilized common FEA package ANSYS, while very less used packages are ABAQUS, NASTRAN, HYPERVIEW. After a careful analysis of various research studies conducted so far it has been found that sufficient studies have not been conducted on variable section concept and trailer chassis. Hence in order to fill the gap future research studies may be conducted on variable section chassis and trailer chassis concept in automobile.

12). Mohd Azizi Muhammad Nora, Helmi Rashida, Wan Mohd Faizul ,Wan Mahyuddin, Mohd Azuan Mohd Azuan, Jamaluddin Mahmud performs the stress analysis of an actual low loader structure consisting of I-beams design application of 35 ton trailer. Modeling is done in CATIA V5R18. The results of analysis revealed that the location maximum deflection and maximum stress agrees well with theoretical maximum location of simple beam under uniform loading distribution. It also shows that maximum stress is 571.4 Mpa on beam A. This study found out that there is discrepancy between the theoretical (2-D) and numerical (3-D FEA) results. It is observed that the maximum deflection is pointed in situated in between BC1 and BC2 with magnitude of 7.79mm

13). Ketan Gajanan Nalawade, Ashish Sabu and Baskar P did the static structural analysis and modal analysis of a TATA 407 truck chassis. Modelling is done in CATIA and finite element analysis is done using ANSYS workbench. After carrying out the analysis on the ladder frame with structural steel and E-Glass composite the results are obtained that maximum shear stress and equivalent stress generated in E-glass is under acceptable limit and total deformation is also within the limit. It also shows that for the same load carrying capacity E- glass is more suitable than steel and thereby able to reduce the weight by 60-68% and increase in stiffness.

14). Swami K.I.and Tuljapure S.B.(2014) investigated the static structural analysis of truck chassis with the help of ANSYS software. Here the chassis of Eicher 20.16 is of ladder frame type which has two side members or longitudinal members of C- cross section and seven transverse members called cross members of C- cross section. The results from graph shows that as the side member thickness increases, initially there is slight decrease in the maximum value of von misses stress but afterwards it starts increasing. The rate decreases in just before the end and again increases at the end. Side member thickness Vs maximum Von misses stress of ladder chassis. Structural analysis of vehicle chassis with constraints of maximum shear stress and deflection of chassis under maximum load through using Pro-e 4.0.

15). Madan Mohan Reddy and Lakshmi Kanta Reddy(2014) investigated the modeling and analysis of container chassis using FEM to improve load carrying capacity and reducing the failure of chassis with bending by adding stiffeners. The rectangular stiffeners to be placed in between the cross members and fastened to chassis by means of bolts. The analysis results of Ansys shows that there is reduction in von misses stress in chassis with stiffener up to the extent of 37.11% compared to without stiffener while stress intensity reduced up to 36.23% and deflection reduced by 36.16%.

Table 5: Result

	Von Mises Stress(N/m^2)	**Stress Intensity(N/mm^2)**	**Deflection(mm)**
Without Stiffener	1300000	1470000	9.76
With Stiffener	817527	937290	6.93

16). Bhat KA, Untawale SP, Katore HV(2014)[2] redesigned the chassis for tractor trolley. The existing trolley chassis uses „C‟ cross section and material used is mild steel. The total capacity of the trolley is 60KN but the weight of trolley and other accessories is 13 KN. Redesign is done by changing cross section from „C‟to „I‟by without change in material and dimension. The change in cross section resulted in more safer stresses than previous cross section and 31.79 kg reduction in weight, so cost of chassis ultimately reduced.

Table 6: Comparisons between C and I sections

Factors	Existing 'C'section	Suggested 'I'section
Von-misses stress	75.452Mpa	34.648Mpa
Total deformation	0.001877m	0.0002382m
Shear stress	20.875Mpa	7.5162Mpa
Normal stress	40.409Mpa	13.088Mpa
Mass	431.64Kg	399.85Kg

Table 6: Comparison between C and I Section

16). Roslan Abd Rahman, Mohd Nasir Tamin, Ojo Kurdi

The truck chassis model is loaded by static forces from the truck body and cargo. For this model, the maximum loaded weight of truck plus cargo is 36.000 kg. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between cargo and upper surface of chassis. The truck chassis model is loaded by static forces from the truck body and cargo. For this model, the maximum loaded weight of truck plus cargo is 36.000 kg. The load is assumed as a uniform pressure obtained from the maximum loaded weight divided by the total contact area between cargo and upper surface of chassis. There are 3 boundary conditions (BC) of model; the first BC is applied in front of the chassis, the second and the third BC are applied in rear of chassis. The type of BC 1 is pinned (the displacement is not allowed in all axes and the rotation is allowed in all axes) that represent the contact condition between chassis and cab of truck. The BC 2 represents the contact between chassis and upper side of spring that transfer loaded weight of cargo and chassis to axle. In the BC 2, the displacement only occurred in axis 2 and the rotation respect to all axes is zero. In the position where the BC 3 applied, there is a contact between inside surface of opening chassis and outside surface of bolt. In this case, the type of the interaction is frictionless surface to surface contact. In the BC3, the displacement and the rotation is zero in all axes on all of bolt's body. This condition is called fixed constrain. The bolt in BC 3 was assumed perfectly rigid. This assumption was realized by choosing a very high Young's Modulus value of the bolt properties.

RESULTS AND DISCUSSION

The location of maximum Von Misses stress is at opening of chassis which is contacted with bolt as shown in Figure 6. The stress magnitude of critical point is 386.9 MPa. This critical point is located at element 86104 and node 16045. The internal surface of opening of chassis was contacted with the very stiff bolt. The BC 3 is also a fixed constraint, thus it cause a high stress on it. Based on static safety factor theory, the magnitude of safety factor for this structure is 1.43. The formula of Safety Factor (SF) is defined by:

SF = significant strength of material / corresponding stress from normal load

CONCLUSION

Numerical analysis result shows that the critical point of stress occurred at opening of chassis which is in contacted with the bolt. The magnitude of highest stress is critical because the value of SF is below than the recommended value. Since fatigue failure started from the highest stress point, it can be concluded that this critical point is an initial to probable failure. Thus, it is important to take note to reduce stress magnitude at this point. The location of maximum deflection agrees well with the maximum location of simple beam loaded by uniform distribution force.

Chapter 3: METHODOLOGY

After the complete surveying of literatures related to our area of concern that comprises of complete study of Trailer, Chassis, the response of different chassis corresponding to the different scenarios, the variety of conditions on a chassis, Load case scenarios, Observing deflections produced due to different load cases, Ladder Frame Chassis, Static Load Analysis etc. We are now proceeding towards creating our own unique work that corresponds to the stability of the Trailer. We have started our work with the 3D Model of the **Flat-Bed Trailer**. The model was approved by the Faculty supervisor. The Trailer model design concept was obtained from (https://www.trailerplans.com.au/product/2500-flatbed-trailer/#theplan) and then with the changes been made according to our own requirement we have expanded it according to the design of trailer capable of supporting Toyota Land Cruiser.

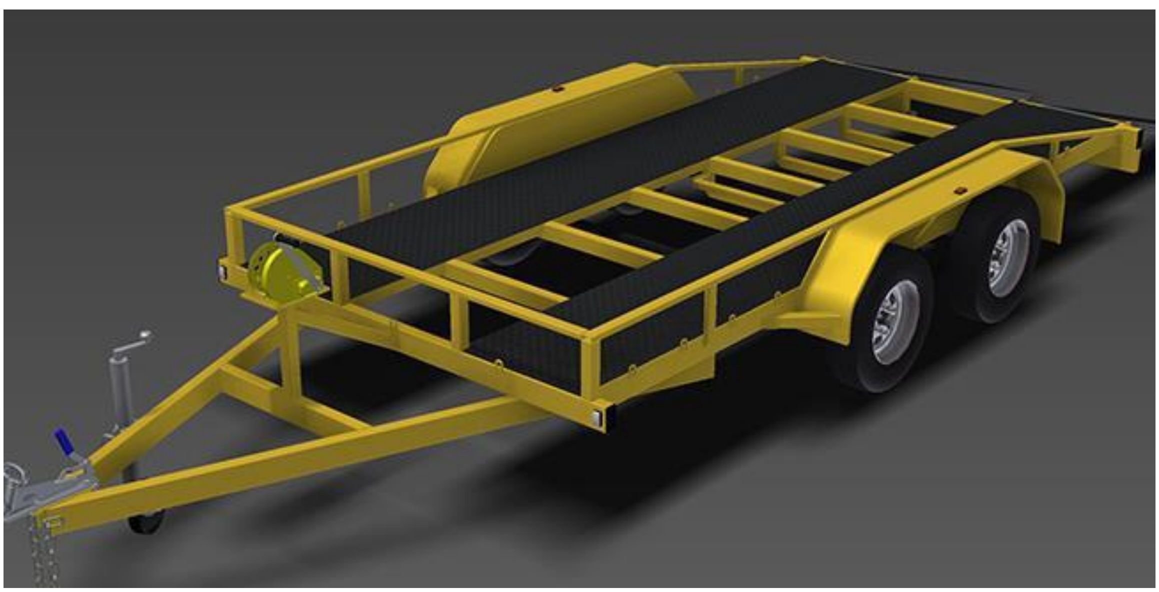

Figure 6: Flat Bed Trailer

3.1 3D CAD MODEL

The dimensions followed by the model correspond to the Trailer that is capable of supporting the weight of Land Cruiser. By figuring out the accurate dimensions of Land Cruiser, we have made the CAD Model in Solid Works with the following provided data.

PROVIDED DATA
Land Cruiser Data:-
Curb Weight = 2640 kg
Petrol Weight = 72.4 kg
Total Weight = 2712.4 kg
Length of Trailer = 4.95m
Width = 1.98m
Height = 1.88m(Adjustable)

Tires Dimension is assumed however it will be **285/50 R20**

With the following dimensions, we have created the 3D Model with four or six tires depending upon the requirement.

COMPLETE ASSEMBLY:-

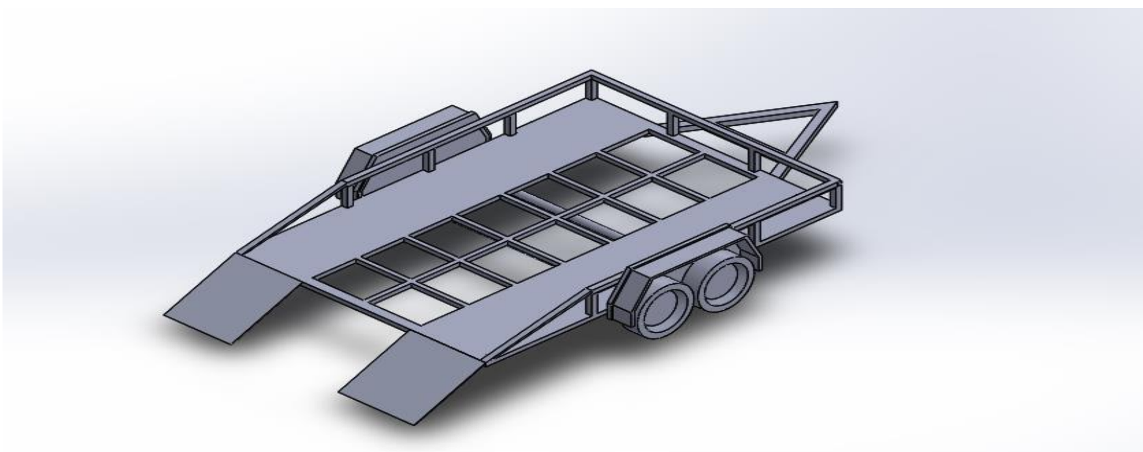
Figure 7: Solid Works CAD Model Complete Assembly

With the further modification in the cross-sectional area of Bed, the sheet of the Trailer on which the cargo is loaded is 1/16 in. The model designed can be varied depending upon the FEA Analysis, where we are supposed to determine the thickness and stability of the System. The Stability and Deformations can be controlled by the repeated number of iterations where the tonnage of material is changed to cater the Stresses that are implicated onto the system. Our major area of concern is to determine the maximum stresses or the critical points in our analysis. Adjusting the thickness of the material to meet the criteria by avoiding the impact of Critical point is vital. The front end of the trailer is kingpin where the trailer is towed to the truck for carrying the trailer or for the provision of Mechanical forces.

With the following models, we have proceeded with the following models to the ANSYS FLUENT.

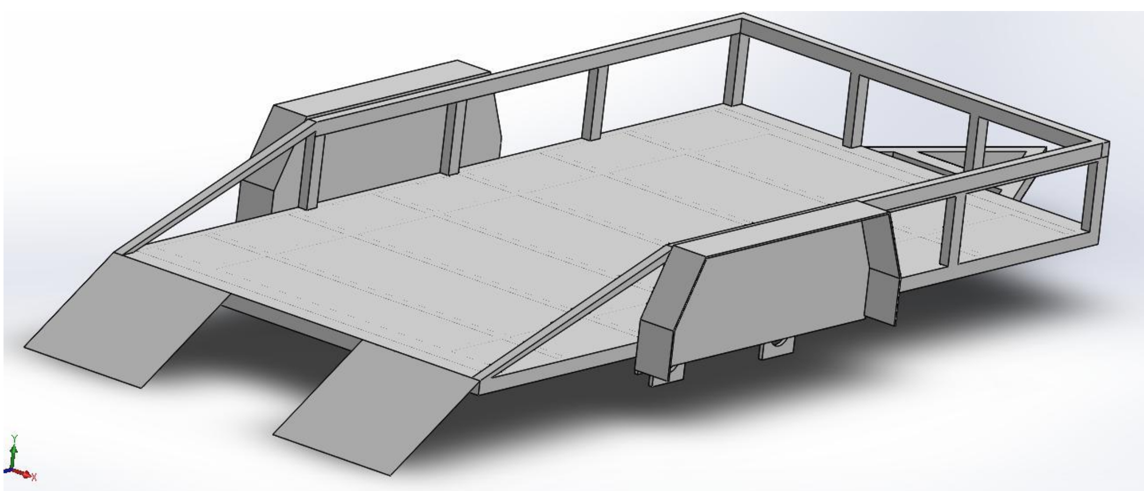

Figure 8: The Trailer with the inclusion of Bed with thickness 1/16in.

According to the Figure 8, the thickness of the sheet is capable of supporting the load or the cargo placed onto the bed of Trailer. Other than that, the two plates placed onto the ground are responsible for the entrance or exit in the movement of cargo. They can be adjusted in the backward direction.

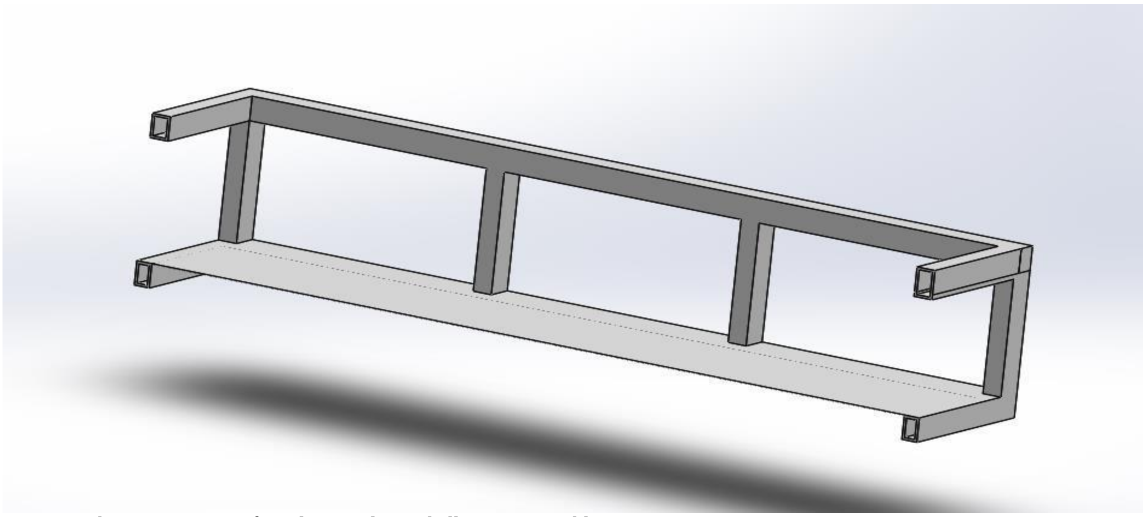

Figure 9: The cross-section of Trailer, involving shells in its assembly.

According to figure 9, the shell is assumed in the cross-section of trailer to minimize the material used in the assembly. As we are supposed to use minimum material for our trailer, hence shell is assumed here.

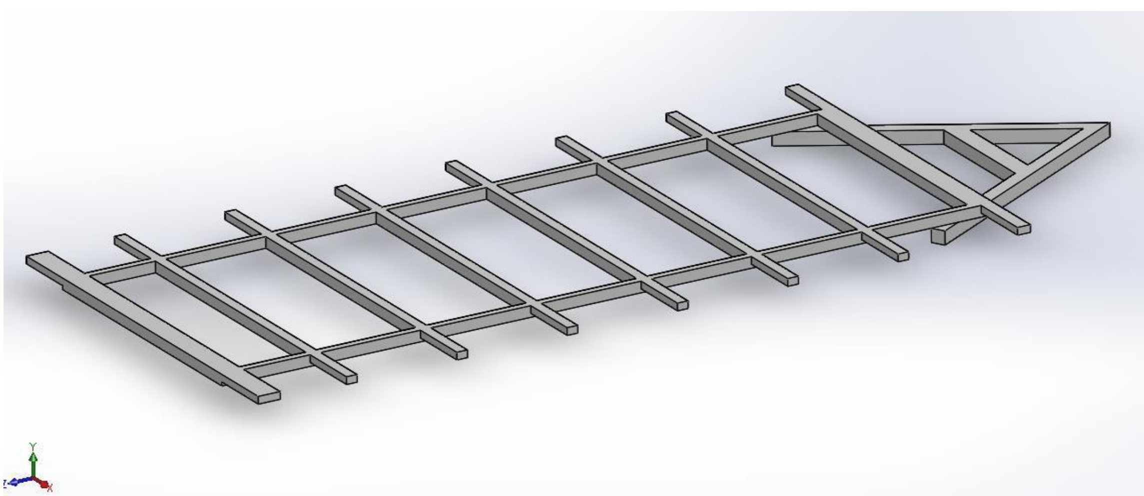

Figure 10: Chassis Assembled to the Bed of Trailer

According to the figure 10, this chassis supports the bed of the trailer in such a way that it is joined beneath the trailer. It consists of side members with different cross members attached together through Rectangle Cross-sections. The joints are made by welding. The KingPin Section is also attached to the chassis by welding means.

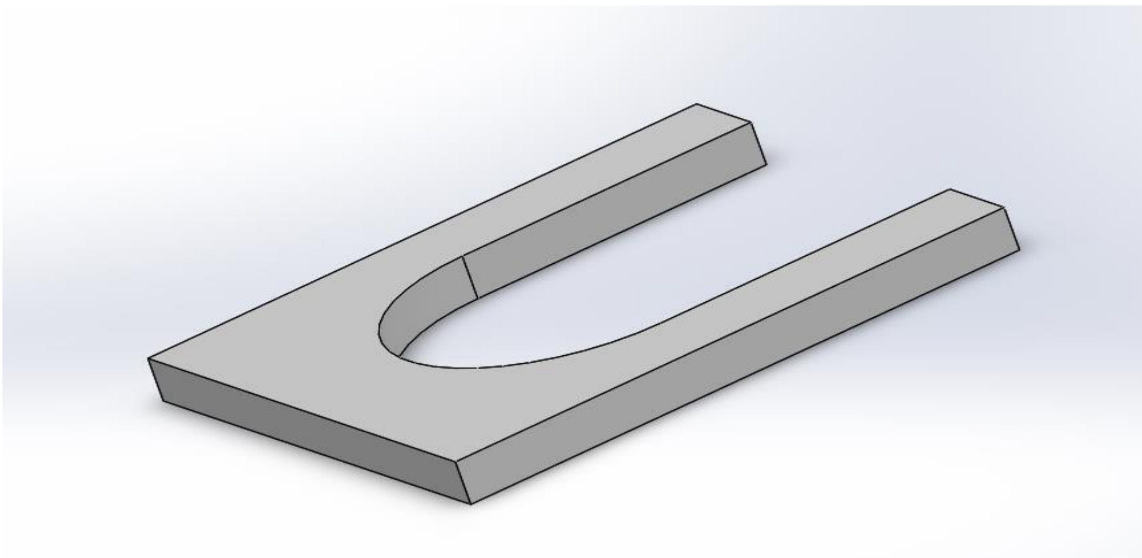

Figure 11: Attachment section for the Wheel Rod.

According to the Figure 11, the cross-section is attached to the wheel rod. It carries the suspension force(to be determined later).

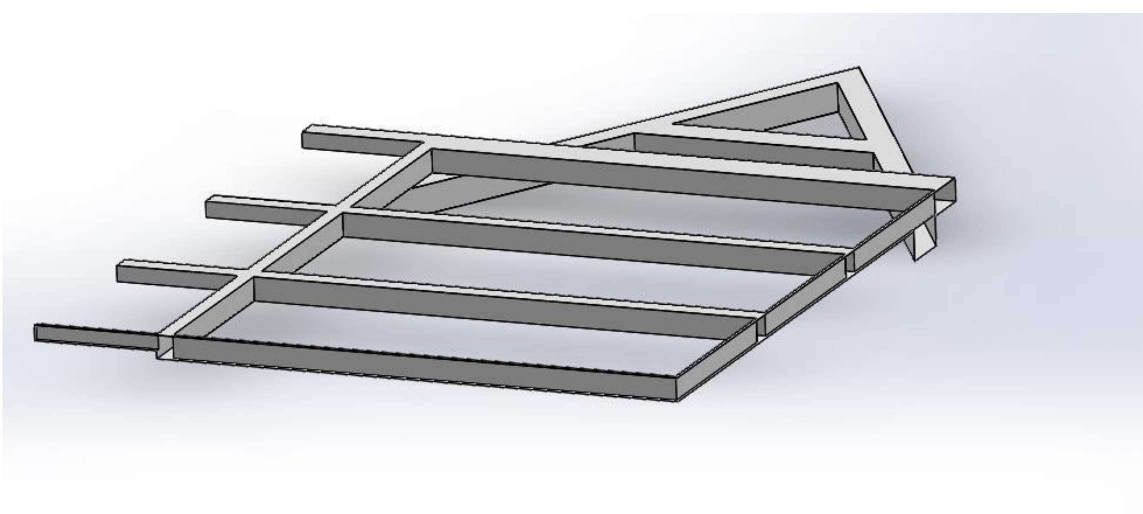

Figure 12: Frame cross-section occupying Shells in its section

Frame for chassis, involving shells in it, is incorporated in such a way that it is joined firmly to the chassis of the frame.

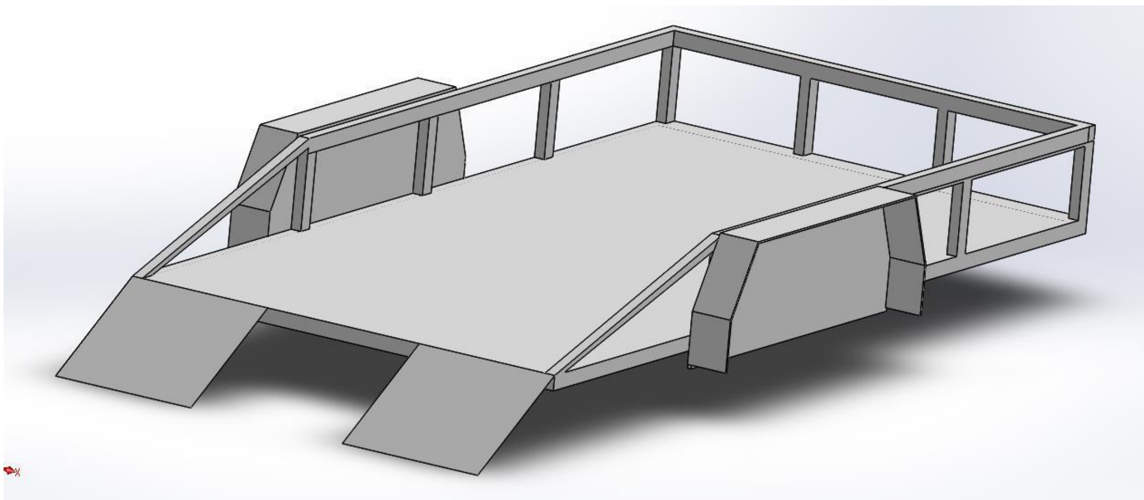

Figure 13: Trailer without the inclusion of tires.

Figure 13 shows the overall assembly with all the components assembled together. Tires are not attached to the assembly due to the reason that they are not yet finalized.

3.2 FINITE ELEMENT MODEL

The analysis was done using FEA, by importing Solid Works parts that we had discussed in the previous chapter. We are going to import all the complete assembly into ABAQUS. ABAQUS has its unique behavior of automatically assembling the geometry by mean of welds. Hence all the assembly was preassembled in ABAQUS. The respective constraints were joined by welds in ABAQUS. For carrying out the Fluid Element analysis, all the assembly should have been merged parts to achieve the connectivity. Constraining should be applied to it as this leads to a comparatively faster analysis since the connected structure would be a sketch with mechanical properties.

Loading and Boundary Conditions:-

As we know that the Truck Chassis model is already loaded by weight of cargo. The weight of the cargo is the determination of Static Force. For this model, the maximum weight of the Truck is determined by:-

Curb Weight of Land Cruiser = 2640 kg

Petrol Weight = 72.4 kg

Total Weight = 2712.4 kg

The following boundary conditions are incorporated in our analysis:-

- Vertical Loading(Axle) or Cylinders of Suspension
- Kingpin Encastre

First boundary condition is applied along the vertical loading along the suspension systems or the axle. Our area of interest is to cater the effect produced in suspension. The other boundary condition is applied to the Kingpin. The kingpin is supposed to be fixed and firmly attached to the assembly. It won't allow the motion hence the condition is applied to restrict the kingpin's motion.

Basic Calculations:-

Material of Chassis= Steel AHSS S355 Steel

Curb Weight of Land Cruiser = 2640 kg

Petrol Weight = 72.4 kg

Total Weight = 2712.4 kg

Sheet Thickness= 1.5875mm

Length of Trailer = 4.95m

Width = 1.98m

Height = 1.88m (Adjustable)

Density = 7850 kg/m^3

Yield Strength = 200GPa

Poisson's ratio V= 0.30

Tires Dimension = is assumed however it will be 285/50 R20

MESHING

Tetragonal Meshing is being used for catering the complex assembly of this type (Mostly parts like Chassis, Axle etc.). We have also used Hexagonal Casing in minor parts of assembly that cannot be meshed easily by Tetragonal Meshing.

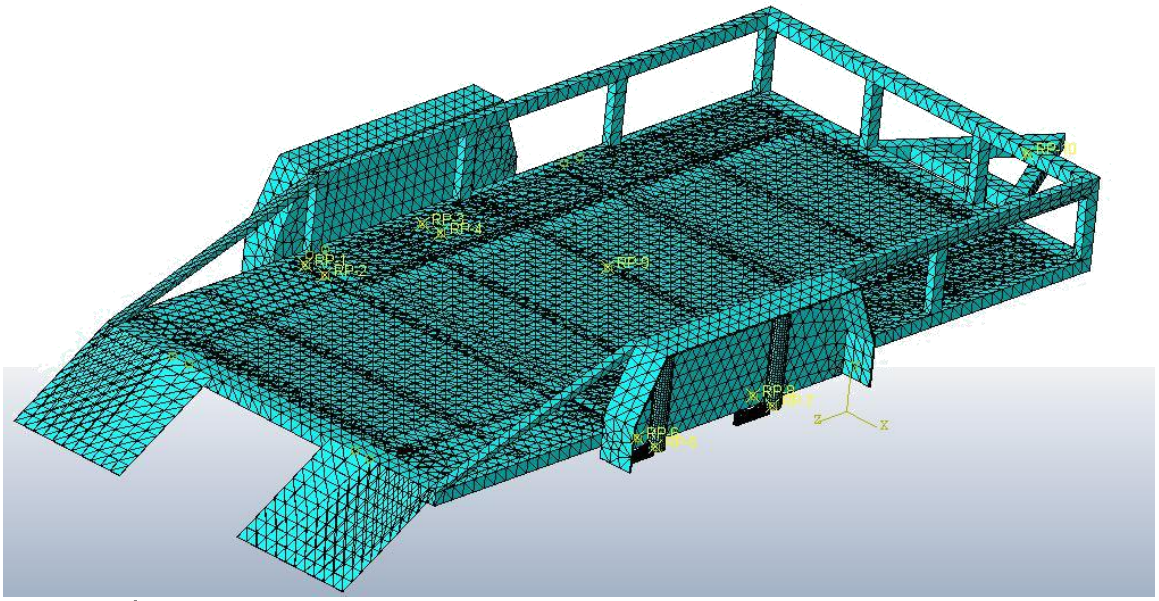

Figure 14: Meshing

LOAD CALCULATIONS AND BOUNDARY CONDITIONS

The point at the center of the Bed determines the Weight acting on the bed that is exactly the load applied on it. The points at the green cylinders are indicating the forces through the cylinders by suspension means. The weight of the cylinder is assumed to be one thrice so that it equals the weight of spring. As spring is involved in suspension, hence we have calculated the result most suitable for incorporating suspension cylinders.

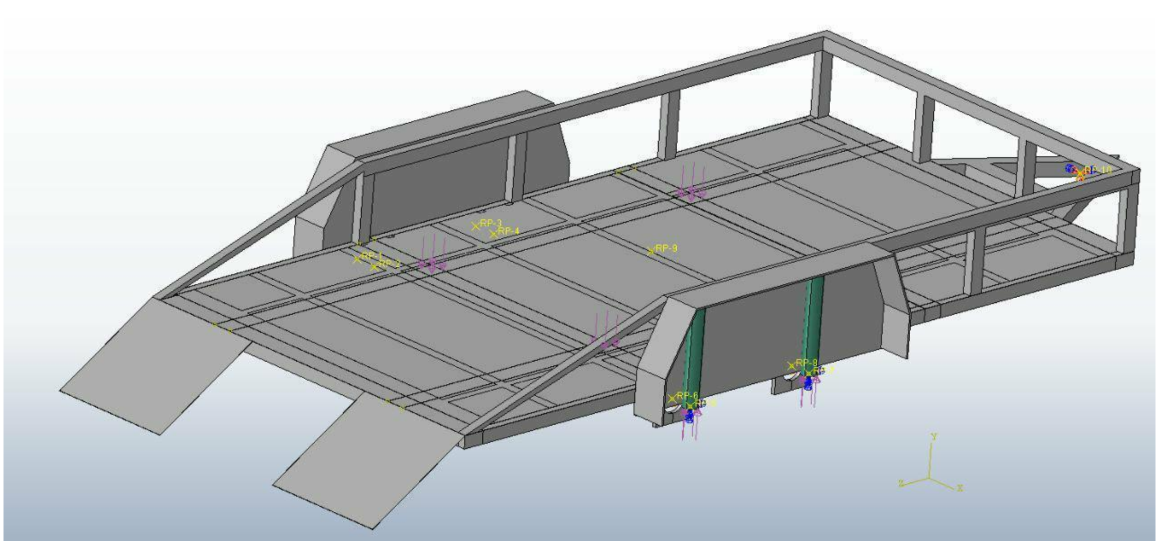

Figure 15: Model incorporating loading factors

Loading Condition to Generate Torsion:-

The loading condition is incorporated in such a way that pressure on one side is increased to two times the original and on the other side is reduced to zero to cater moment and Torque in the trailer. The side of the trailer where force is acting, was given the liberty to move 4cm and on the other side to 5cm to generate Torsion.

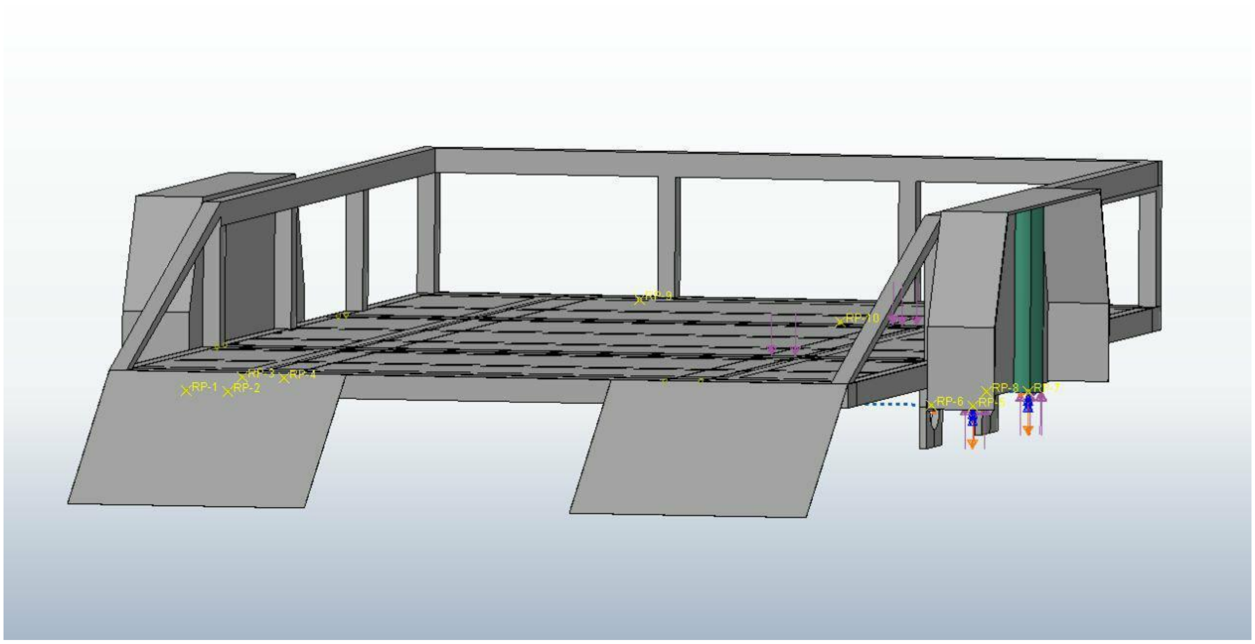

Figure 16: Loading Condition to create Torsion

Characteristics of Overall Assembly:-

- Sheet Thickness= 1.5875mm
- Overall weight of the material consumed= 2.93 ton
- Instead of Suspension Springs, we have assumed Green Cylinders here. As the mass of spring is relatively smaller than Cylinder, hence the 1/3rd of the mass of Green Cylinders is assumed so that the mass of spring is incorporated being equal to the Cylinder mass.
- **Meshes:-** Tetragonal(Mostly parts like Chassis, Axle etc.)

Assumptions:-

- The Force due to the weight of Land Cruiser is approximately equal to the four equal forces (forces along the Tires through Suspension means calculated through the density of cylinders that is assumed one thrice to make it equivalent to density of springs) along the axle due to suspension.
- For the generation of Torsion, the Loading condition is cooperated in such a way that the pressure is double onto one side of Rail and is assumed zero across the other Rail. In this way, due to this unstable force across the rail, the Moment generated produces Torsion. The upward pressure is exerted on to the spring incorporated by Cylinders. The load is 1/4th on each patch.

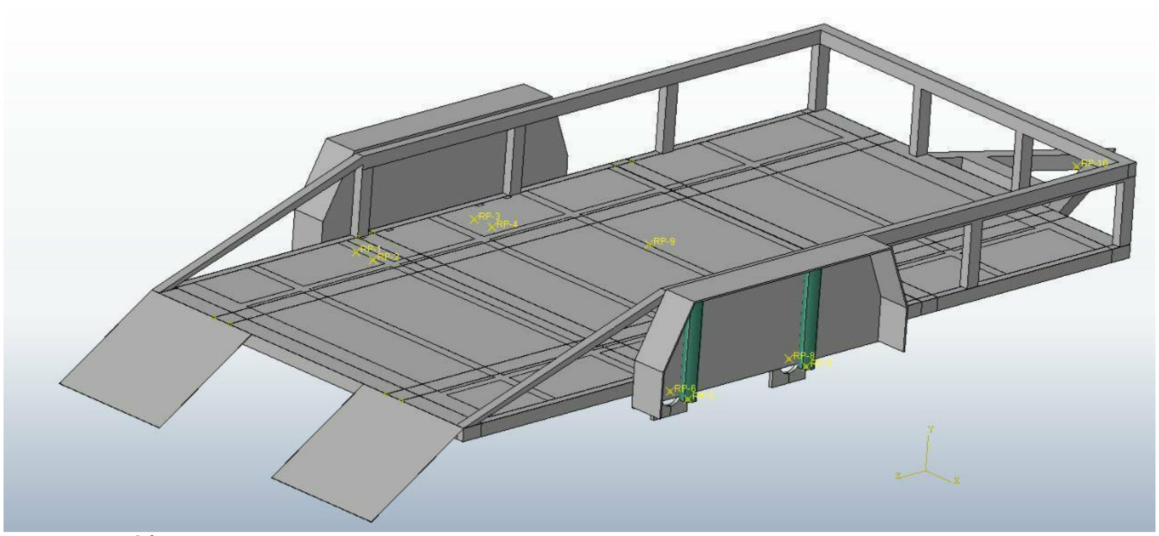

Figure 17: Load factors

Boundary’s Conditions:-

Torsion:-

- The Loading condition is cooperated in such a way that the pressure is double onto one side of Rail and is assumed zero across the other Rail. In this way, due to this unstable force across the rail, the Moment generated produces Torsion. The upward pressure is exerted on to the spring incorporated by Cylinders. The load is $1/4^{th}$ on each patch.

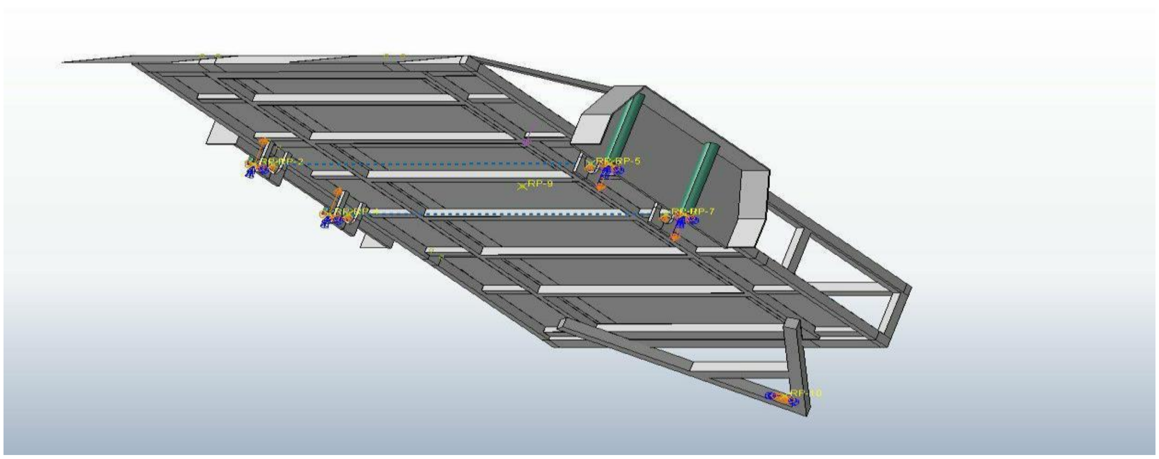

Figure 18: Torsion

Suspension:-

As the analysis on suspension isn’t yet completed, hence more research needs to be carried out on Suspension Analysis of Trailer. However the Axle forces are incorporated in our analysis through cylinders. Instead of Suspension Springs, we have assumed Green Cylinders here. As the mass of spring is relatively smaller than Cylinder, hence the $1/3^{rd}$ of the mass of Green Cylinders is assumed so that the mass of spring is incorporated being equal to the Cylinder mass. The Pressure being exerted onto the Green Cylinders (Springs) is $1/4^{th}$ times the load on each patch times the area. This pressure is exerted in upward direction onto the springs (Cylinders) and this will be approximately equal to 1/4th of the load on each patch and the reaction pressure on each patch.

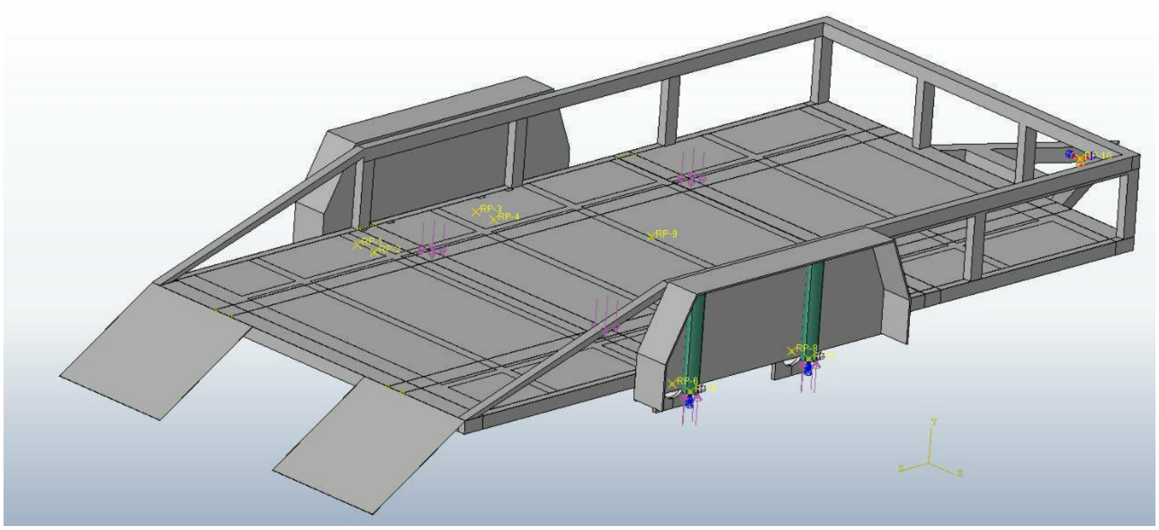

Figure 19: Suspension indication units

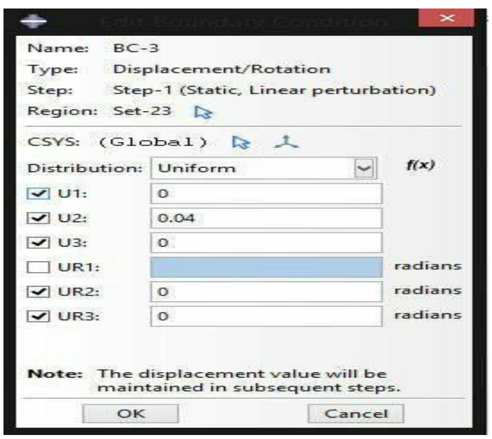

Figure 20: BCfor first Iteration for Suspension

We have assumed the deformation of 0.04 and -0.04 when solving for Suspension.

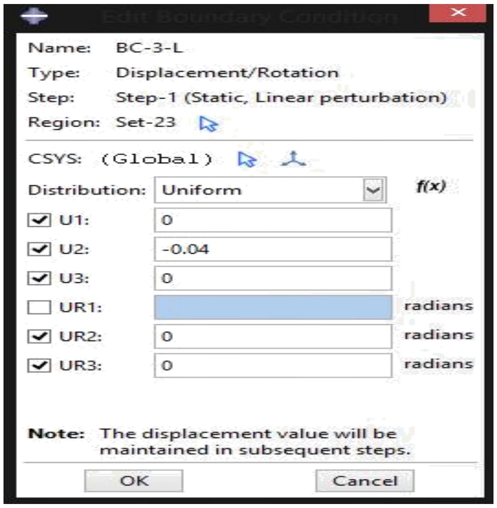

Figure 21: BC for second and third iteration for Suspension

Kingpin:-

The moment about vertical axis is only assumed just to cater the net effect of moment.

We had only allowed the deformation along only one axis that is UR2.

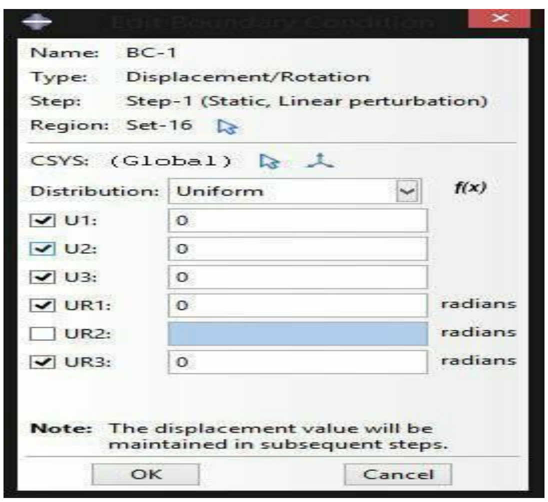

Figure 22: BC for Kingpin for all iterations

Constraints:-

Following are the overall points constrained. They are indicated by the joints.

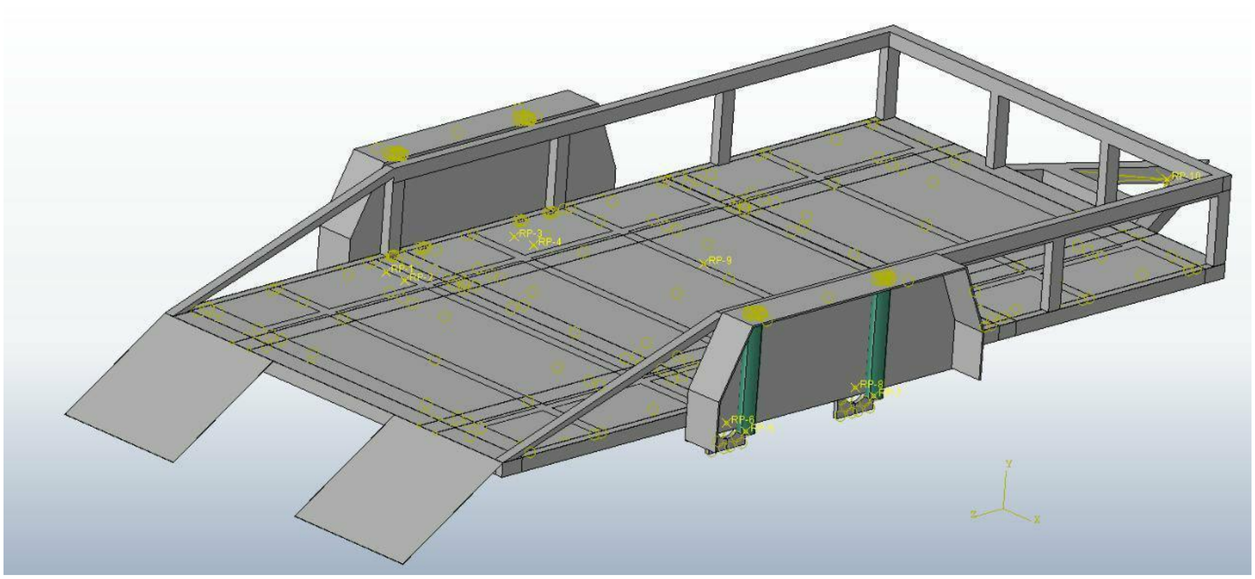

Figure 23: Constraints

Chapter 4: RESULTS AND DISCUSSIONS

After applying the concepts and methodology that involved different CAD Modeling techniques, Simulation of those CAD Models in ANSYS Fluent through Finite Element Analysis(FEA) etc. We are now proceeding towards the results that are obtained by the FEA that shows the location of maximum Stresses on to the different locations, pointing out those locations, calculating deflections etc. Such locations are pointed out by the critical points. The critical points are the points that indicate the greatest value over which the values that exceed over it may cause failure. However our goal is to identify those points and the failure cases are followed by increasing or decreasing the weightage of the material. We are following a technique where any Stress above any critical point can be figured out by increasing the thickness or more generally increasing the weightage of material. For changing the quantity of material, the model can be affected. Some portions of the model can be removed depending upon the provided scenario however the approach is the thing that plays vital role. Talking about provided scenario, we are supposed to design a system that is capable of resisting maximum loads by allowing minimum deflection to provide smooth journey to the Cargo being loaded into it.

As we have opted for the Flat Bed Trailer and with the applications of different boundary conditions applied across the parts that are need to be catered that could easily meet the criteria of Static Loading Conditions. Such loadings involve different scenarios as we had already discussed, depending upon the factors that may be affecting our trailer as a whole. Before that, we are moving towards the results that we had obtained after the three iterations where we have currently done two iterations. In the first iteration, the model was capable of resisting the maximum load by allowing very small deformations. The stresses value calculated from the first iteration is small compared to the second iteration that shows that the material used is comparatively very higher than the material used from first iteration. Hence the material weightage needs to be reduced to allow greater value of stresses. Our area of concern is use the minimum amount of material for our analysis. So for this purpose we have done another iteration that allows more stress value and allowing greater deformation. With this iteration, the quantity of the material is reduced to the extent from 9 ton to 2.9 ton. The maximum stresses at the respective locations after calculations are increased from the 106.5MPa to 355MPa. The respective maximum deflections or deformations that we have achieved after calculations were increased from 0.287cm to 4.14cm. These are the changes being observed after the first two iterations. The weightage of the material allocated is 2.9 ton. We have reduced the material required from 9 ton to 2.9 ton in this iteration. Depending upon the need, we can reduce it further by changing the thickness of sheet, changing the model (solid cross sections will be changed into shells etc.) and overall assembly. Following are the results obtained after applying the given sets of conditions.

RESULTS

I. Deformation:-

Maximum Deformation is 4.14cm. It is along the side cross sections of the bed plus towards the lower bottom of the trailer. This shows that these regions can cater the deflections up to 4.14 cm. They can be deformed to this extent hence such regions are pointed out depending upon the material. With the provided scenario, we can figure it out the further allowance of deformation by controlling the thickness or weight of material.

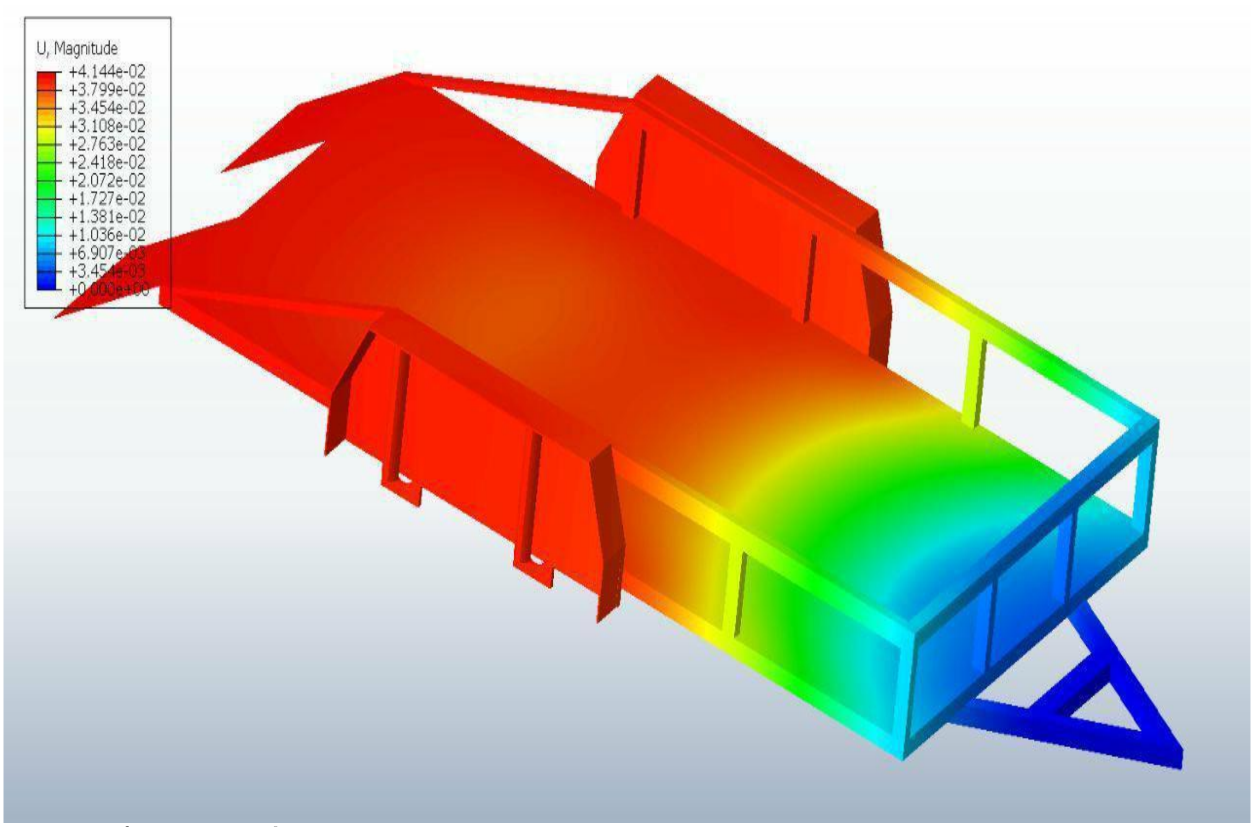

Figure 24: Deformations second iteration

II. Stress Generation:-

There are some regions where Stresses exceed the yield strength where the cross-sections can be increased to keep the stresses within the yield limit. The maximum stresses lie on the frame section area of the trailer nearer to the tires. The maximum stress occurred is 3056MPa from the graph. However red portion into the trailer shows that the maximum stress is around 355MPa. The pointed red areas show the points of greater stresses. Further allowance in stress can be figured out by controlling the quantity of material with the provided scenarios.

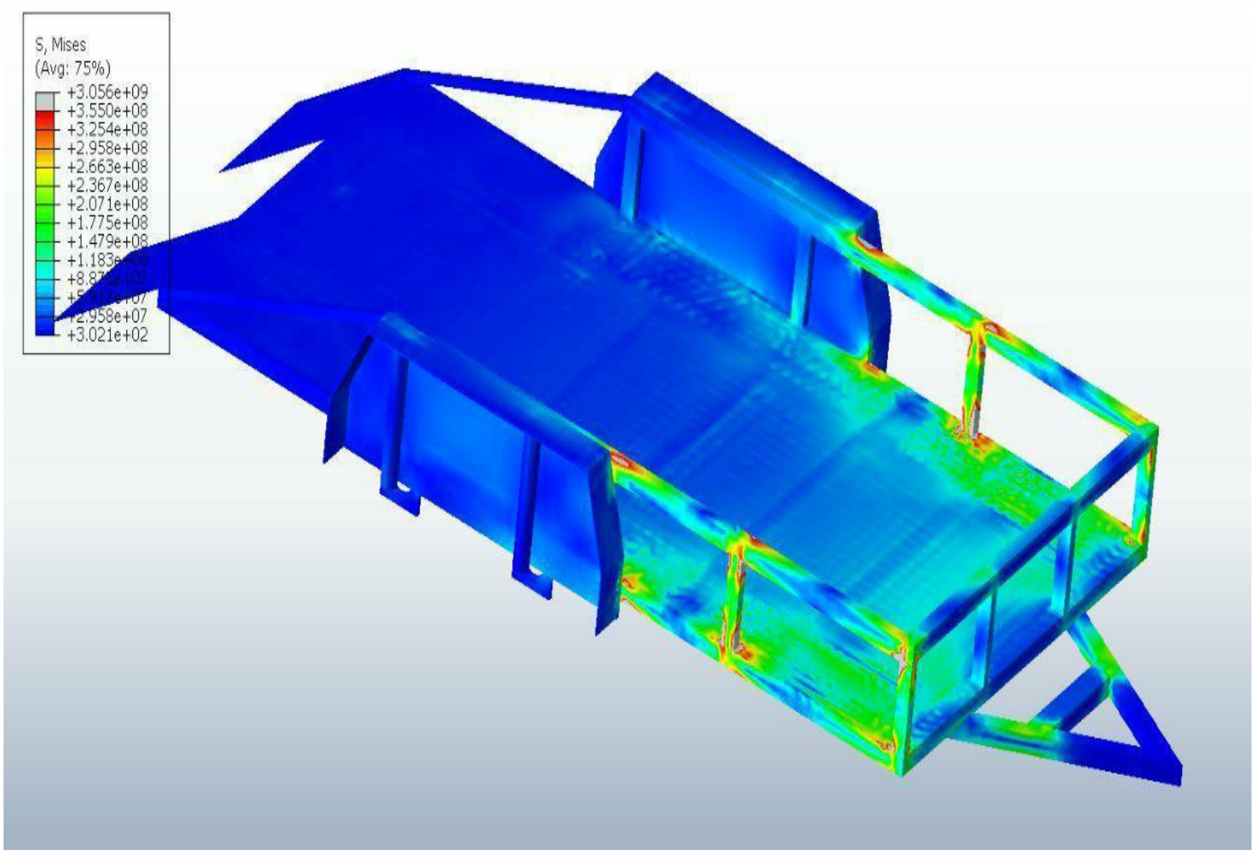

Figure 25: Stress Generation

III. Torsion Case Von Mises:-

Maximum Von Mises stress for Torsion lies nearer to Kingpin or on to the frame. It is 355 MPa. Along the frame, there are some critical points where stresses are actually maximum as indicated from the figure. They are determined by Red and Grey points. The red points indicate the locations with greater stresses that need to be addressed depending upon the given scenarios.

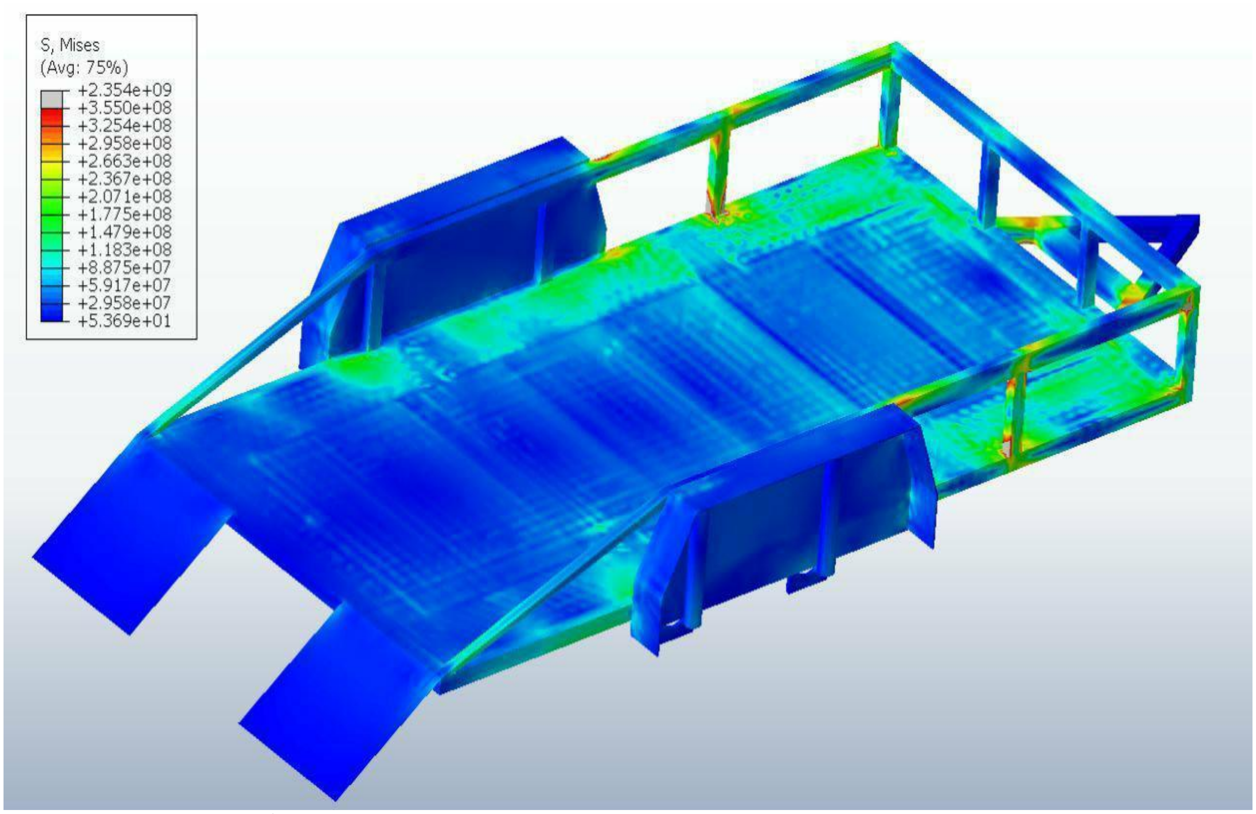

Figure 26: Torsion Von Mises for second Iteration

IV. Vertical Deformation:-

The maximum vertical deformation is 4.159cm that is along the tire sections. This is our area of concern. The red areas in the figure show the regions where maximum deformations are induced. Depending upon the required material, this deformation can be further adjusted.

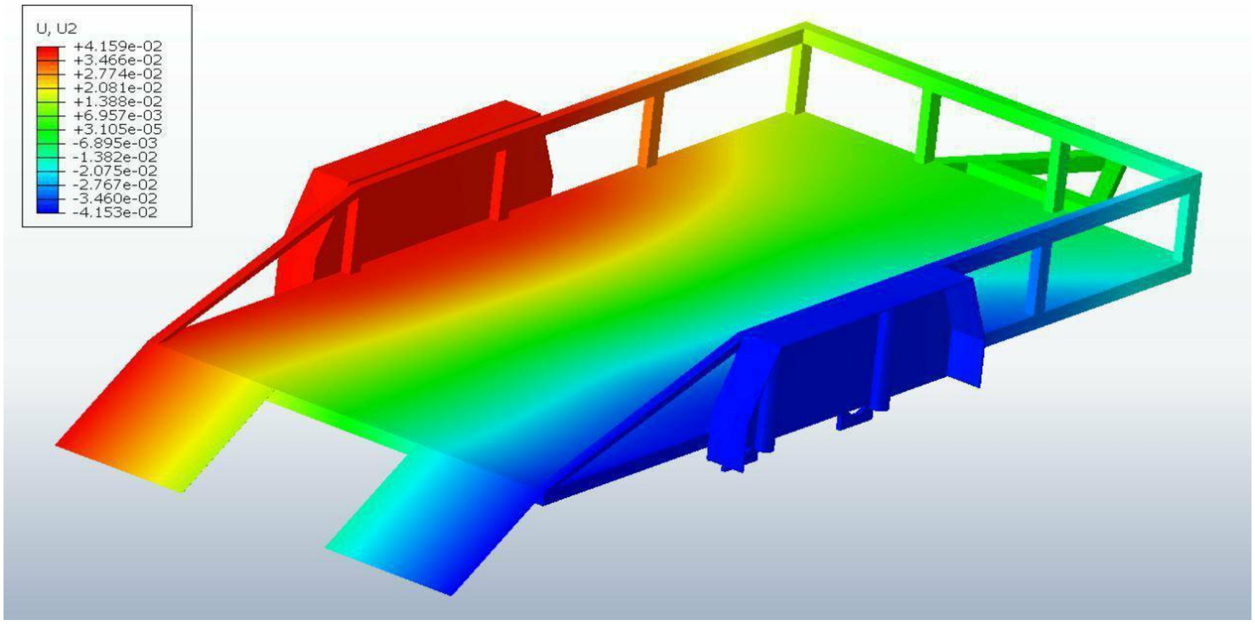

Figure 27: Vertical Deformation

First Iteration

In this iteration, the weightage of the material used is around 9 ton that is comparatively very high. Hence we modified the whole model and the changes were made accordingly.

Deformation:-

The maximum deformation is around 0.2087cm. They are indicated by their respective regions. As according to the figure, it is clear that maximum deformation reaches around 0.1913cm indicated by the orange color.

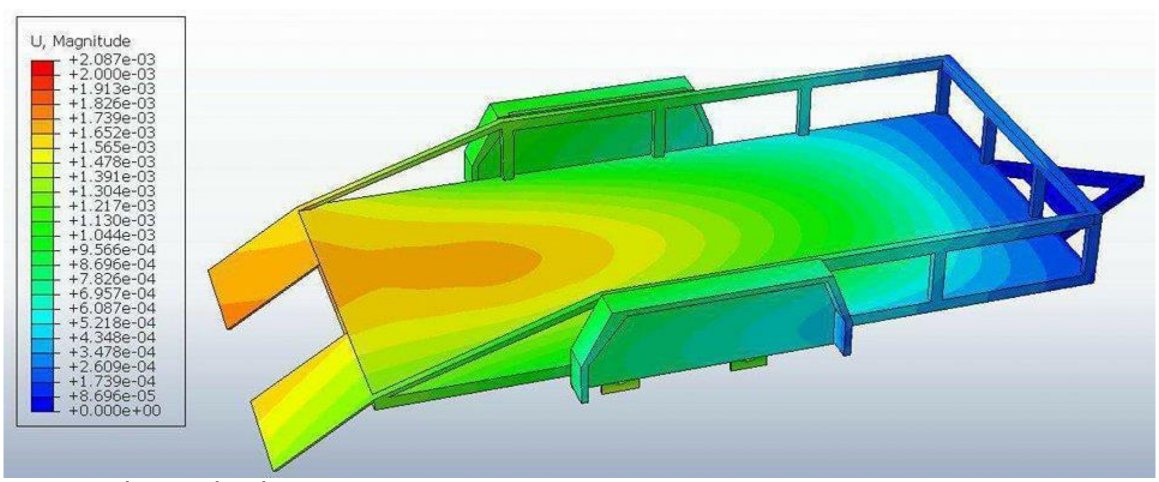

Figure 28: Deformation from first Iteration

Von Mises Stresses:-

The maximum stress is 106.5MPa occurring onto the critical points determined by the diagram. The grey portion of the trailer in the figure indicates that the stresses act along the frame section majorly.

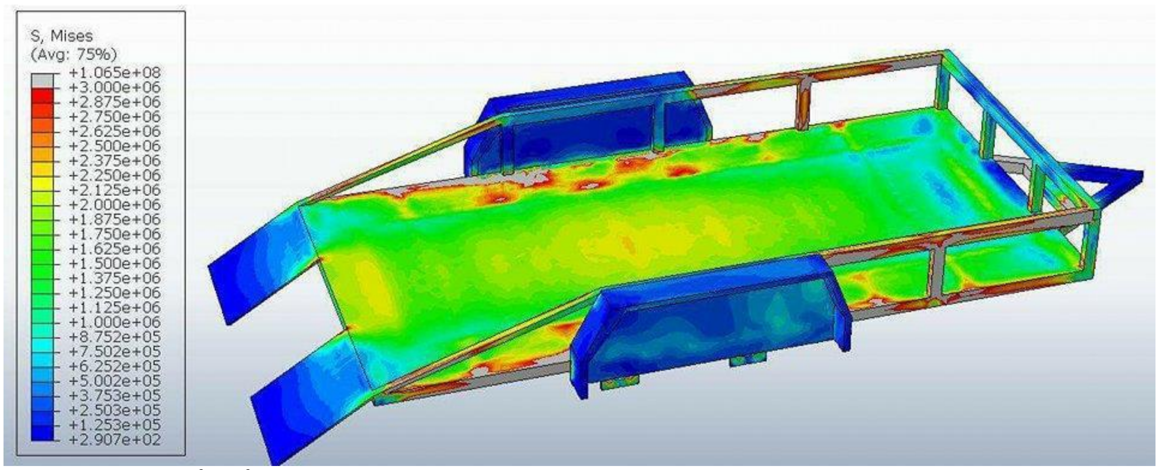

Figure 29: Von Mises from first iteration

Third Iteration

In this iteration, the weightage of the material is almost same, hence the results are almost nearly the same.

Deformations:-

The maximum deformation calculated, for this iteration was 4.238cm. It is indicated by the red portion area of the Trailer.

For the cross section below the trailer:-

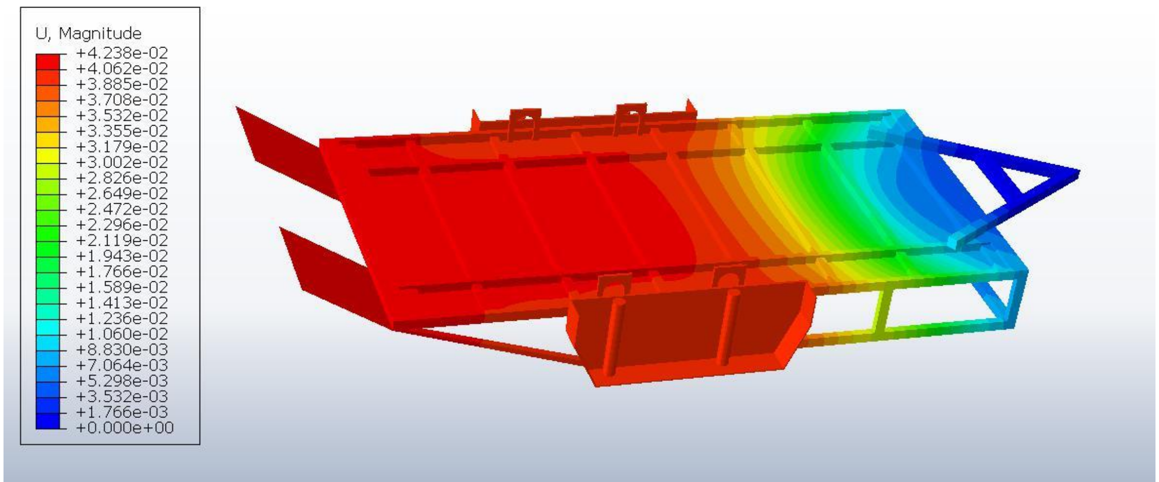

Figure 30: Deformations for 3rd Iteration (Below the trailer)

For the cross section above the trailer:-

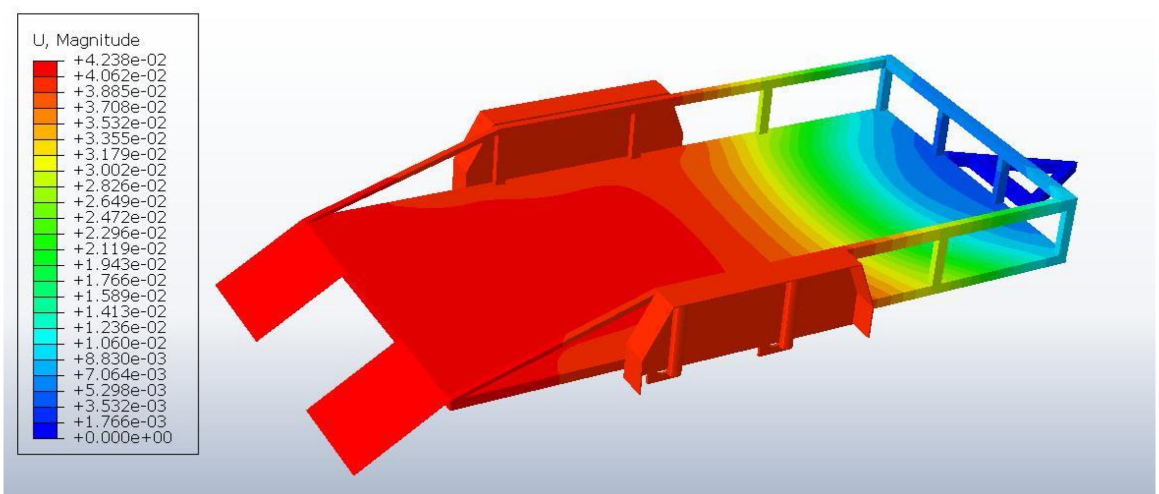

Figure 31: Deformations for 3rd Iteration (Above the trailer)

Von Mises stresses:-

The maximum stress doesn't exceed from the calculated value that is 355MPa that is nearly equal to the value calculated from the previous iteration.

For the cross section below the trailer:-

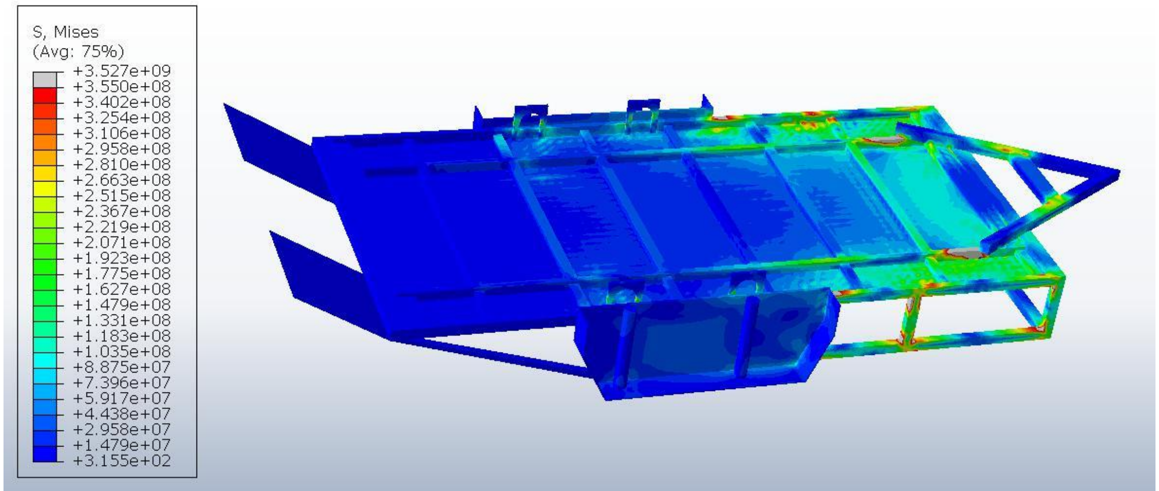

Figure 32: Von Mises for 3rd iteration (below the trailer)

For the cross section above the trailer:-

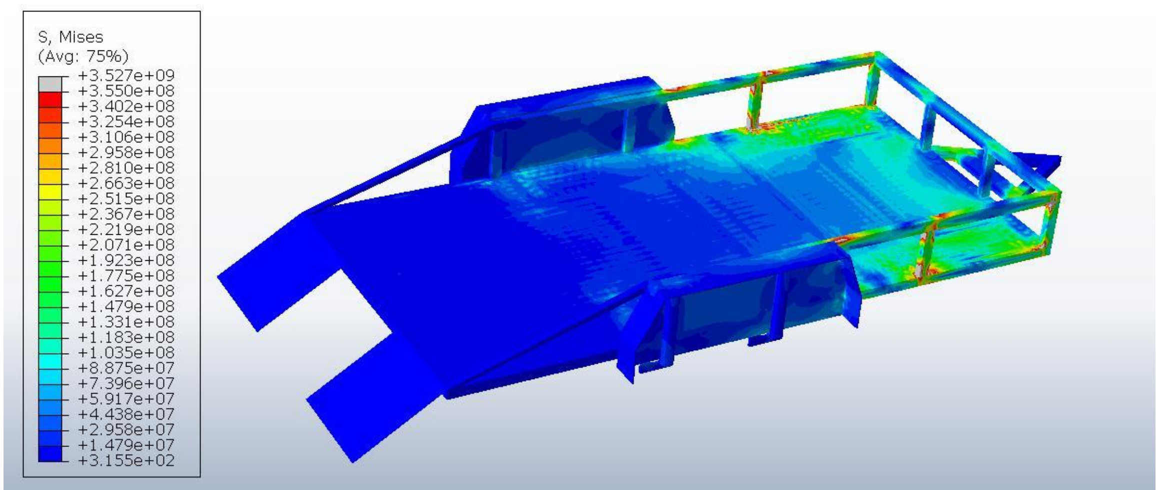

Figure 33: Von Mises for 3rd Iteration (above the trailer)

DISCUSSION

After the complete introduction, we moved towards the literature review. From the literatures, we came to know the basics of analysis. We got to know about the major techniques involved in the analysis of chassis. From the basic principles to the complete methodology involved in trailer chassis. After importing the CAD model into the analysis, we were supposed to complete the analysis with the relatively smaller amount of material used. The material is capable of supporting the heavier weight of Cargo. The steel that we used has a great tensile stress to endure. We started off with the few iterations depending upon the scenario. From these iterations, we calculated different results and analyzed the result whether it is exact according to our requirement or not. By summarizing the first iteration, it was clear that the material usage was literally much higher than what we had asked to use. However, the strength of the trailer was very higher and the deflections were also small. Hence it could further accommodate any changes if they were necessary. Accommodating changes mean that the model can be changed depending upon the removal of material. However we simulated the model with another approach, the second iteration. We removed the material by changing the solid cross sections into shell cross sections. Different sections were converted into shells. As we all know that shells consume lesser amount of material than the Solids. Other than that, the thickness of the sheet of the material was reduced to 1/16in. Therefore the material with the reduced weightage has improvised the stresses. The maximum stresses were increased comparatively to the first approach.

REFERENCES

Example of a web link referencing:

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[2] https://www.trailerplans.com.au/product/2500-flatbed-trailer/#theplan

Example of a research paper referencing:

[1] Vijaykumar V. Patel and R.I. Patel, "structural analysis of ladder chassis frame" , ISSN 2231 2581, Mechanical department, Government engineering college, Gujrat.

[2] Sairam Kotari and V. Gopinath , "Static and dynamic analysis on tatra chassis", vol 2, ISSN: 2249-6645 department of mechanical engineering, QIS college of engineering, Andhra Pradesh.

[3] Chetan J. Choudhury and akash lodhi, " Static load analysis of TATA-407 chassis" - an approach , ISSN 2231-5063, Mechanical department, K.D.K. college of engineering, Maharashtra.

[4] Introduction to chassis design, by Keith J. Wakeham, Memorial University of Newfoundland And Labrador.

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