Design and Topology Optimisation of Truck Chasis for Maximum Stiffness to Reduce the Weight Using Altair

Mr. G. Williams Babu*, Mr. P. Sathish*, Mr. P. D M Satya Sai Vara Prasad*, Mr. S. Mani Kiran*, Mr. G. Sri Satya Sai Narasimha Raju*, Mr S Srikanth, Dr G Avinash****

***UG students, **Faculty, Department of Mechanical Engineering College, Pragati Engineering College (A)**

ABSTRACT - Automotive chassis is an important part of an automobile. The chassis serves as a frame work for supporting the body and different parts of the automobile. Also, it should be rigid enough to withstand the shock, twist, vibration and other stresses. Along with strength, an important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, maximum stress, maximum equilateral stress and deflection are important criteria for the design of the chassis. This report is the work performed towards the optimization of the automotive chassis with constraints of maximum shear stress, equivalent stress and deflection of chassis. Structural systems like the chassis can be easily analysed using the finite element techniques. The mass optimization of chassis is performed to reduce the weight of the chassis for maximum stiffness condition by using Altair inspire software.

Key words: Optimization, Topology, Chasis Stress, INSPIRE

I. INTRODUCTION

The chassis which is made of pressed steel members can be considered structurally as grillages. It acts as a skeleton on which, the engine, wheels, axle assemblies, brakes etc. are mounted. Every vehicle body consists of two parts; chassis and body work or superstructure. The chassis is the frame work of any vehicle. Its principle function is to safely carry the maximum load for all designed operating conditions. It must also absorb engine and drive line torque, endure shock loading and accommodate twisting on un even road surfaces. The chassis receives the reaction forces of the wheels during acceleration and breaking and also absorbs aero dynamic wind forces and road shocks through the suspension. So the chassis should be engineered and built to maximize pay load capability and to provide versatility, durability as well as adequate performance. To achieve a satisfactory performance, the construction of a heavy vehicle chassis is the result of careful design and rigorous testing. It should be noted that this 'ladder' type of frame construction is designed to offer good downward support for the body and pay load and at the same time provide torsion flexibility, mainly in the region between the gearbox cross member and the cross member ahead of the rear suspension. This chassis flexing is necessary because a rigid frame is more likely to fail than a flexible one that can 'weave' when the vehicle is exposed to arduous conditions. A torsionally flexible frame also has the advantage of decreasing the suspension loading when the vehicle is on uneven surfaces , assemblies, brakes, suspensions etc are mounted. The frame supports the cab, engine transmission, axles and various other components. Cross members are also used for vehicle component mounting and protecting the wires and tubing that are routed from one side of the vehicle to the other. The cross members control axial rotation and longitudinal motion of the main frame, and reduce torsion stress transmitted from one rail to the other.

Layout of chassis and its main components:

• Frame: it is made up of long two members called side members riveted together with the help of number of cross members.
• Engine or Power plant: It provides the source of power
• Clutch: It connects and disconnects the power from the engine fly wheel to the transmission system.
• Gear Box
• U Joint
• Propeller Shaft
• Differential

1.1.1 Functions of the Chassis Frame

• To carry load of the passengers or goods carried in the body.
• To support the load of the body, engine, gear box etc.
• To withstand the forces caused due to the sudden braking or acceleration.
• To withstand the stresses caused due to the bad road condition.
• To withstand centrifugal force while cornering

1.1.2 Types of chassis frames

• Conventional frame
• Integral frame
• Semi-integral frame

 DOI : 10.35291/2454-9150.2022.0239

A.Conventional frame: It has two long side members and 5 to 6 cross members joined together with the help of rivets and bolts. The frame sections are used generally.

a. Channel Section - Good resistance to bending.
b. Tabular Section - Good resistance to Torsion.
c. Box Section - Good resistance to both bending and Torsion.

II. TYPES OF FRAMES

I. Ladder frame
II. Perimeter Frame
III. Sub-type frame
IV. Unit body construction:
V. Space frame construction:
VI. Conventional chassis frame:
VII. Frameless chassis (Integral chassis frame and body):
VIII. Tubular Chassis

The chassis of go-kart was designed on the parameters to guide complete safety of rider as well as to maintain the feasibility of go-kart for all loads applicable. The Chassis is the most integral part of the vehicle. It is the frame of the chassis on which the entire body of the vehicle is built. The entire external load of the vehicle including its self-weight is on the chassis. Thus, this chassis design and its analysis forms the most important part of the vehicle manufacturing. Chassis must be light in weight to reduce dead weight on the vehicles. Major challenge in today's automobile vehicle industry is to overcome the increasing demands for higher performance, lower weight in order to satisfy fuel economy requirements, and longer life of components, all this at a reasonable cost and in a short period of time. The go-kart is specially designed for racing and has very low ground clearance when compared to other vehicles. The common parts of go-kart are engine, wheels, steering, tires, axle and chassis. No suspension can be mounted to go-kart due to its low ground clearance. Surface Finishing process was designed to generate a particular geometrical surface and to correct specific irregularities and so must be applied carefully to a given production sequence. Also, each process is a final operation in the machining sequence for a precision part and is usually preceded by conventional grinding. This primer begins by explaining how industry controls and measures the precise degree of smoothness and roughness of a finished surface.

Fig. 2.1 truck chassis Chassis

A chassis consists of an internal framework that supports a man-made object in its construction and use. It is analogous to an animal's skeleton. An example of a chassis is the underpart of a motor vehicle, consisting of the frame (on which the body is mounted). If the running gear such as wheels and transmission, and sometimes even the driver's seat, are included then the assembly is described as a rolling chassis. The chassis takes a load of the operator, engine, brake system, fuel system and steering mechanism, so chassis should have adequate strength to protect the operator in the event of an impact. The driver cabin must have the capacity to resist all the forces exerted upon it. This can be achieved either by using high strength material or better cross sections against the applied load. But the most feasible way to balance the dry mass of chassis with the optimum number of longitudinal and lateral members. The chassis must be constructed of steel tubing with minimum dimensional and strength requirements dictated by ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS).

2.1 History

Racing Go Karts have evolved over the past 60 years to become one of the most competitive forms of motor racing in united states. Kart Racing has been a stepping stone for many drivers working their way up the professional ladder in NASCAR, FORMULA 1 and the INDY RACING LEAGUE. Drivers like TONY STEWART, DANICA PATRICK, MICHAEL SCHUMACHER and SARAH FISHER each got his or her start in this less expensive but adrenaline pumping form of motorsports racing. As a recreational activity, Karting can appeal to just about anyone. From age 5 to 75, racing Go Karts have become popular all over the world with people looking for an exciting of having fun. Most karting historians give credit to Californian Art Ingels as the first person to build a racing go-kart, originally called a go kart. It did not take long for this fad to catch on and go kart tracks started to pop up all across America. By the late 1950's an American company modified a two-stroke chain saw motor and the McCulloch MC-10 became the first motor manufactured specially for go kart racing.

Fig. 2.2 Art Ingles Go-Kart

Design objectives of chassis are:

 DOI : 10.35291/2454-9150.2022.0239

1. Provide full protection of the driver, by obtaining required strength and torsional rigidity, while reducing weight through diligent tubing selection.

2. Design for manufacturability, as well as cost reduction, to ensure both material and manufacturing costs are competitive with other Go Karts.

3. Improve driver comfort by providing more lateral space in the driver compartment.

4. Maintain ease of serviceability by ensuring that chassis members do not interfere with other subsystems.

5. Deciding the cost efficiency of such in terms of large scale manufacturing.

6. Calculation of stresses acting on the chassis of the vehicle under different loading conditions.

7. The product can prove to be very efficient in all the aspects such as cost, drivability, maintenance, easy usage, safety etc.

William B. Riley1 and Albert R. George., 2002 have studied variety of issues related to frame and chassis design with an emphasis on Formula SAE cars. The different road loads and deformation modes were considered as well as some generic design targets based on experience and strain gauged suspension links. Sanlosh B. Belure Salish S. Kadam S. B. Wadkar., 2005 In this paper the criticality analysis of the passenger car, structure is presented under different operating conditions; such as normal Static load. Braking loads. Loads due to: speed breakers. Single wheel road bump, single wheel in. road pot hole and dynamic loads caused by: frontal impact. Finite Element modeling of a Bus is described for finding the Eigen pairs and analysis of vibration/stress levels at different locations of the vehicle. In this work an attempt is made to investigate the effect of stiffness, strength and vibration in car design. on the predicted stress distribution. In the given research work it is found that. The aluminum structure is .effective than M.S. structure by considering strength to weight ratio. Mohamed Reza Zalani Bin mohamed Suffian., 2010 , this paper explains about a solar car is a specialized type of car designed for race and powered by sun energy (solar). This is obtained from solar panels on the surface of the vehicle. Photovoltaic (PV) cells convert the sun's energy directly into electric energy. Solar vehicles are not sold as practical day-to-day transportation devices at present, but are primarily demonstration vehicles and engineering exercises. It have limited seating (usually one, sometimes two people), it have very little cargo capacity, and only be driven during the day. In this paper, 2011, automotive chassis design in view of car weight reduction is a challenging task due to the many performance targets that must be satisfied, in particular in terms of vehicle safety. In this paper a methodology for automotive chassis design in involving optimization techniques is presented. In particular, topology, topometry and size optimizations are coupled with FEM analyses and adopted in cascade for reaching an optimum chassis configuration. The methodology is applied to the design process of a rear-central engine high performance vehicle chassis. The objective of the optimization process is the chassis weight reduction, yet in fulfillment of structural performance constraints as required by Ferrari standards. The results demonstrate the general applicability of the methodology presented for obtaining the general trusses layout and thicknesses distribution of the structure. The numerical model at this stage shows a significant weight reduction when compared to the chassis of the Ferrari F458 Italia. Akash Lodhi, Kushal Gawande & Udbhav Singh., 2012 , this paper presents an analysis of chassis of TATA- 407 which includes the stress distribution and displacement under various loading conditions. The present paper aims at pinpointing the critically stressed points and thus improving the overall strength and improving other operational characteristics of the car chassis. Chassis is one of the important parts and every car passenger has it. This structure was the biggest component in the car and car shape dependent on it. It has a considerable affected to the performance of the car. The primary challenge in developing an effective solar car chassis is to maximize the strength but minimize the weight. There are various types of chassis, each with its own advantages and disadvantages. Every extra pound requires more energy to move down the road. This means that chassis must strive to minimize weight and a key area is the chassis. However, safety is a primary concern and the chassis must meet stringent strength and safety requirements. In this paper various stresses are calculated by using the applicable mathematical formulae. As conclusion this study has achieved its objectives. The calculation includes stress and displacement/deflection responses of the vehicle to the loads. CAD model provide solid modeling, surfacing, simulation, tolerance analysis. The particular part of the chassis, change occurred in cross-section is affected by static loads. The static force acting on the truck chassis were determined mathematically and by software also.

3.1 Chassis Design Principle

The fundamental principle of a chassis design states that the chassis is to be designed to achieve the torsional rigidity and light weight in order to achieve good handling performance of a race car. By the definition, torsional rigidity is refers to the ability of chassis to resist twisting force or torque. In the other words, torsional rigidity is the amount of torque required to twist the frame by one degree. These parameters also applied to spaceframe chassis. Generally, the effect of the torsional rigidity on spaceframe is different to the monocoque due to their construction format, but the structure is used to approximate the same results as the difficult to twist monocoque chassis. Figure 2.5 shows the torsional rigidity applies to race car chassis.

 DOI : 10.35291/2454-9150.2022.0239

(Matt, 1999). According to the statement above, chassis designed must have high torsional rigidity in order against the twisting force or torque. In order to increase torsional rigidity on the chassis, the format of tube pipes arrangement must be considered. By strategically positioning a frame member, torsional rigidity increases significantly.

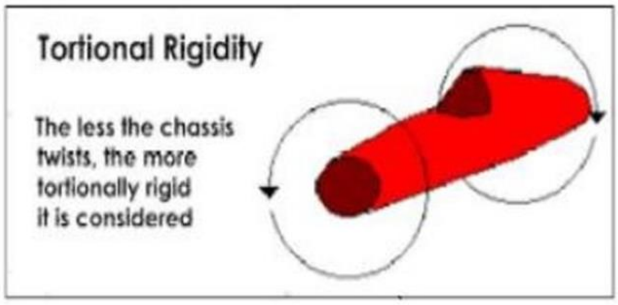


Fig 3.5: -Torsional Rigid of Car Chassis

The triangulated box imparts strength by stressing the diagonal in tension and compression. As shown, the box will not easily be deformed by bending force due to the triangulated format of frame. Hence, most race car chassis today designed in triangulated format as shown in Figure 2.6 below. (Matt, 1999).

4.2 The Design Process

The design of the chassis must work around a number of parameters and constraints in order for it to perform well and for it to be eligible to compete in the competition. These requirements can be broken into several categories which will be discussed below. If any of these requirements are not met, the consequences range from sub-optimal performance to not being eligible to compete in the competition or even chassis failure. So it is clear that all requirements must be carefully considered and even re-visited when designing and building the chassis.

The engineering design process is the steps of chassis design construction process . In this chapter explain how chassis was designed and how stimulation of the chassis was performed. In this part, explained how chassis is performed. Before the last chassis design got, there are several steps must be considered to make the last result bring the best design. In this part, start

from the sketching process, then CATIA is used in order to create the model of the chassis. The analysis stage used ANSYS to analyze the, model of chassis.

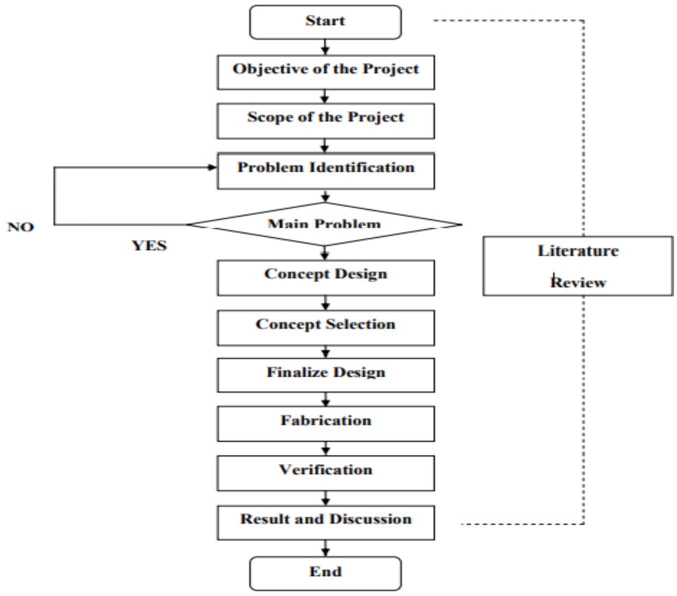


Fig 4.2: Flow Chart of Methods To Develop Frame

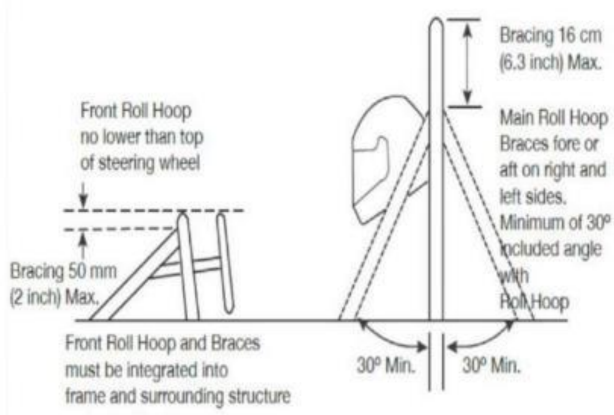


Fig 4.3: Main Hoop

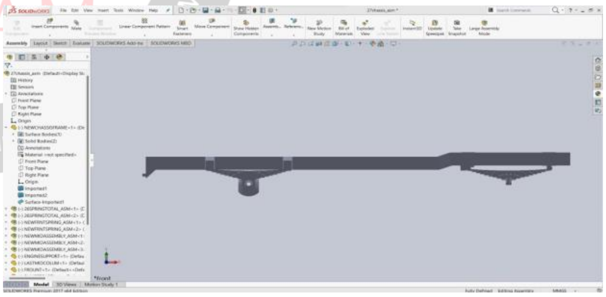


Fig front view of chassis

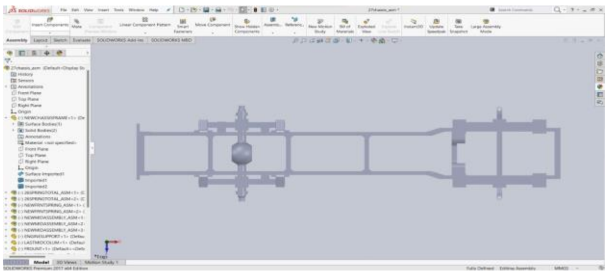


Fig back view of chassis

 DOI : 10.35291/2454-9150.2022.0239

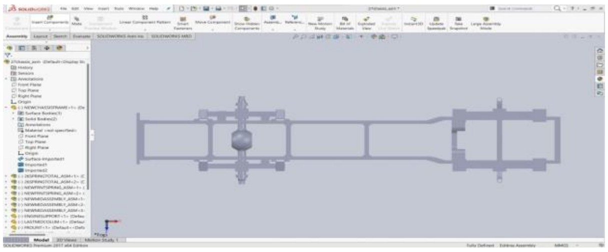


Fig top view of chassis

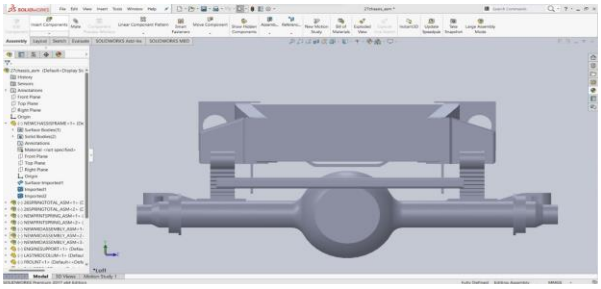


Fig left view of chassis

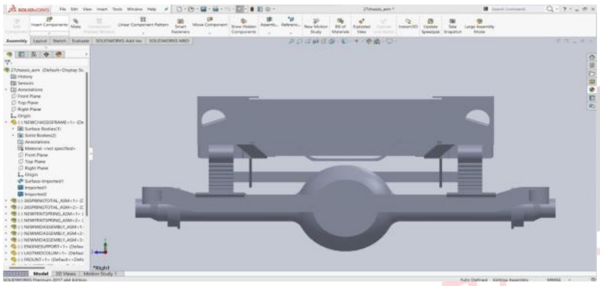


Fig right side view of chassis

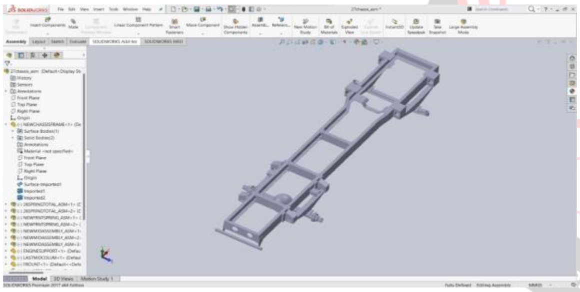


Fig isometric view of chassis

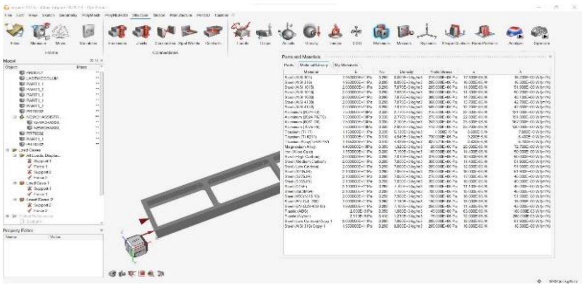


Fig material library of inspire tool

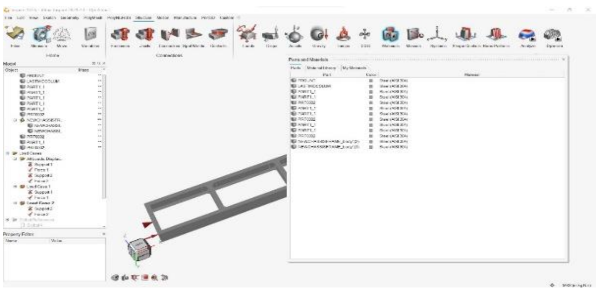


Fig assigning material to chassis

Fig defining design space

Fig assigning process parameters

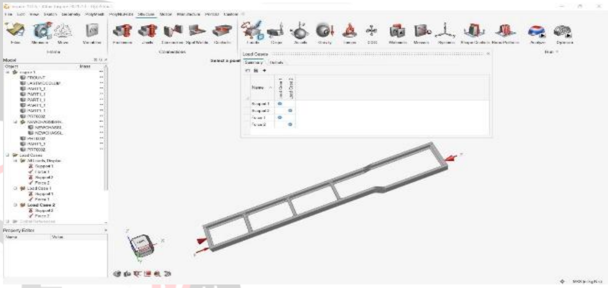


Fig defining loading condition

III. RESULTS AND DISCUSSIONS

6.1 Structural Analysis Of Truck Chassis For Rear Impact

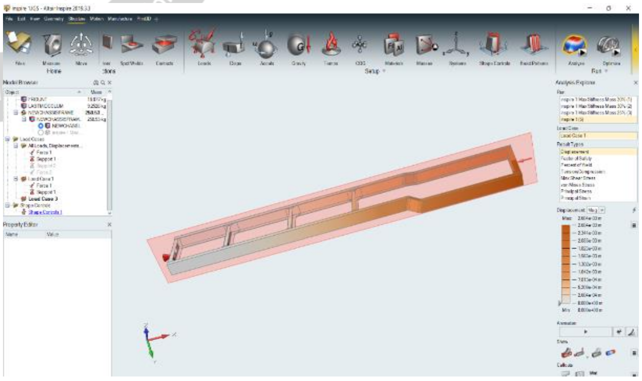
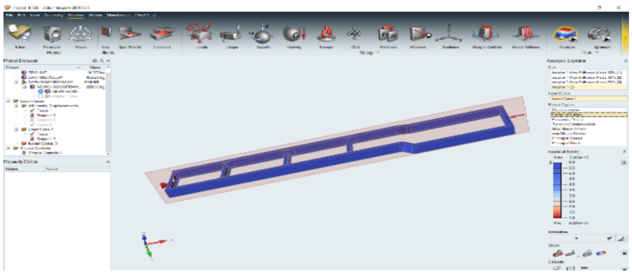


Fig displacement of truck chassis

Fig factor of safety of truck chassis



 DOI : 10.35291/2454-9150.2022.0239

International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 **Vol-08, Special Issue, MAY 2022**

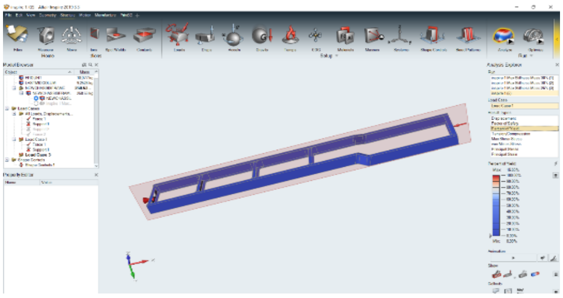


Fig percentage of yield of truck chassis

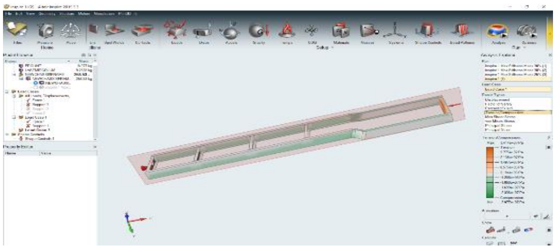


Fig tensile/compression of truck chassis

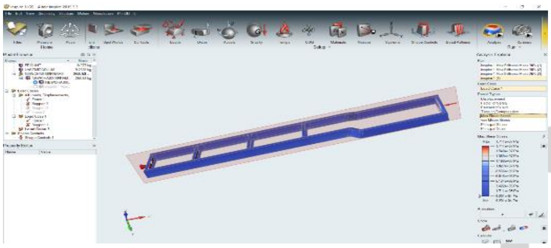


Fig maximum shear stresses of truck chassis

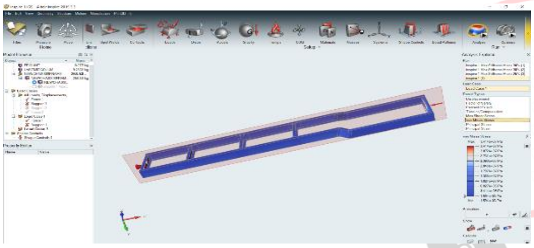


Fig von mises stresses of truck chassis

6.2 Structural Analysis Of Truck Chassis For Front Impact

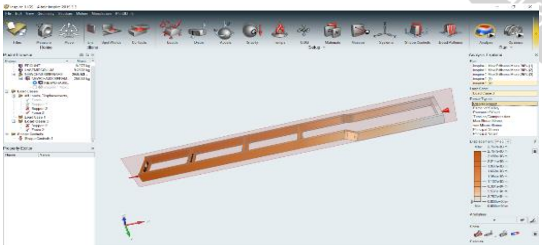


Fig displacement of truck chassis

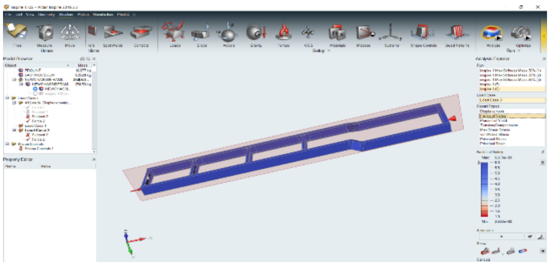


Fig factor of safety of truck chassis

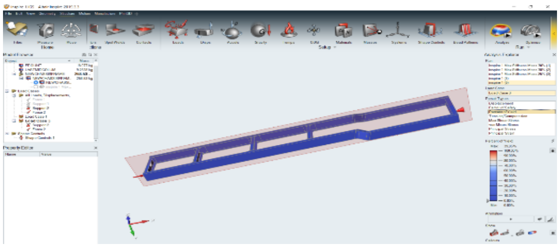


Fig percentage of yield of truck chassis

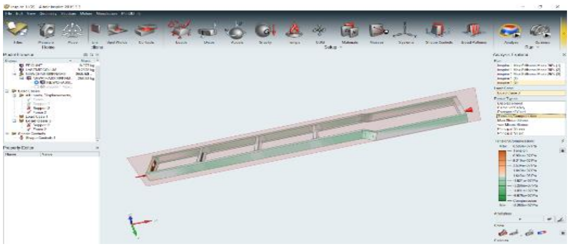


Fig tensile/compression of truck chassis

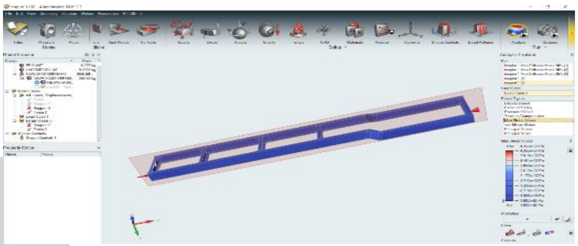


Fig maximum shear stresses of truck chassis

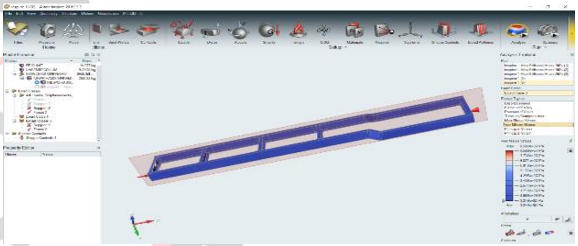


Fig von mises stresses of truck chassis

6.3 Mass Optimization Of Truck Chassis For Rear Impact

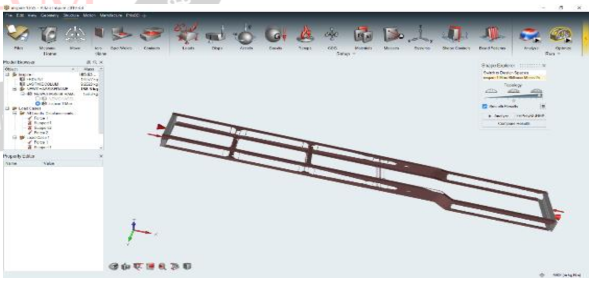


Fig mass optimization of truck chassis for rear impact

6.4 Mass Optimization Of Truck Chassis For Front Impact

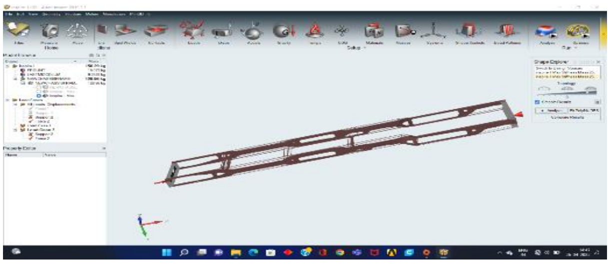


Fig mass optimization of truck chassis for front impac

 DOI : 10.35291/2454-9150.2022.0239

IV. CONCLUSION AND FUTURE SCOPE

Chassis is the heart of the vehicle. When the load act over the vehicle during the impact force chassis will distribute the impact load. Due to acting more load over the chassis it needs to be rigid and strong. From the above results we have performed

By conducting the front rear impact, the truck chassis exposed to different loading conditions

We have performed mass optimization after conducting the front and rear impact. By conducting mass optimization process the weight reduced to 156 kg for maximum stiffness condition, considering the front and rear impact the chassis deformation is very close. The factor of safety of front impact and rear impact is still very close further optimization can be done.

The maximum tension compression in the front impact is more when compare to rear impact. Other factors like von mises stresses and maximum shear stress, tension/compression values are high for front impact and low for rear impact. But from the force optimization we can observe that in both the condition the factor of safety is very close and the chassis can sustain longer period. When mass optimization performed for both the condition for front impact it gives 156 and for rear 185 kg. due to very less change in the factor of safety we can go for front impact ass optimized model.

REFERENCES

[1] Sujatha C & V Ramamurti, Bus Vibration Study-Experimental Response to Road Undulation, Int. J. Vehicle Design, Vol. 11, no. 4/5, pp. 390-400, 1990.

[2] H J Beermann, English translation by Guy Tidbury, The Analysis of Commercial Vehicle Structures, Verlag TUV Rheinland GmbH Koln1989.

[3] Thomas D Gillespie, Fundamentals of Vehicle Dynamics, SAE 1999.

[4] J Reimpell& H Stoll, The Automotive Chassis: Engineering Principles, SAE -2000.

[5] J Reimpell& H Stoll, The Automotive Chassis: Engineering Principles, ARNOLD-1996.

[6] John Fenton, Handbook of Automotive Body Construction & Design Analysis, Professional Engineering Publishing-1998.

[7] John Fenton, Handbook of Automotive Body Systems Design, Pro fessional Engineering Publishing-1998.

[8] T. R. Chandupatla, A D Belegundu, Introduction to Finite Element in Engineering, PHI-2000.

[9] Doe’s effort to reduce aerodynamic drag through joint experiments and computations. SAE, 2005- 01-3511, 2005.

[10] Volvo 3P/CVL. Optifuel lab - demotruck: Fuel economy results. Technical report, Volvo 3P, 2009.

[11] CD-Adapco. STARCCM+ Manual, version 4.06.011 edition.

[12] Meshing Research Corner. http://www.andrew.cmu.edu/user/sowen/survey/tetsurv.html, accessed 11 May 2010.

[13] L. Davidson. An introduction to turbulence models. 2003.

[14] Volvo Trucks global homepage. www.volvo/trucks/global/en-gb/home.htm, accessed 23 February 2010.

[15] Don Bur’s homepage. www.donbur.co.uk/index.shtml, accessed 16 Mars 2010.

[16] W Seay J.Bledsoe, D. Landman and R Wood. Understanding practical limits to heavy truck drag reduction. SAE, 2009-01-2890, 2009.

[17] J. Leuschen and K.R. Cooper. Full-scale wind tunnel tests of production and prototype, second generation aerodynamic drag-reducing devices for tractor-trailers. SAE, 2006-01-3456, 2006.

 DOI : 10.35291/2454-9150.2022.0239