VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JnanaSangama, Belagavi – 590018

A Project Report
On

"MODELING AND ANALYSIS OF SUV CHASSIS"

Submitted in partial fulfillment of the requirements as a part of the curriculum,

Bachelors of Engineering in Mechanical Engineering

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CERTIFICATE

Certified that the project work entitled "**Modeling and Analaysis of SUV chassis"** is a bonafide work carried out by **Mr.M S Vinay, Mr. Abhishek K, Mr.Ajay S, Mr. J Venkat Akhil,** bonafide students of **CMR Institute of Technology** in partial fulfillment for of the requirements as a part of the curriculum, **Bachelors of Engineering in Mechanical Engineering,** of **Visvesvaraya Technological University, Belagavi** during the year **2019-20**. It is certified that all correction/suggestion indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of the project work prescribed for the bachelor of engineering degree.

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Signature of the Guide	**Signature of the HOD**	**Signature of the Principal**

External Viva

Name of the examiners	**Signature with date**
1.	
2.	

DECLARATION

We, students of Eighth Semester, B.E, Mechanical Engineering, CMR Institute of Technology, declare that the project work titled **“Modeling and Analysis of SUV chassis”** has been carried out by us and submitted in partial fulfillment of the course requirements for the award of degree in **Bachelor of Engineering in Mechanical Engineering** of **Visvesvaraya Technological University, Belagavi,** during the academic year 2019-2020.

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Place: Bengaluru

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ABSTRACT

The automotive chassis forms the structural backbone of a commercial vehicle. The main function of the chassis is to support the components and payload placed upon it. When the vehicle travels along the road, the chassis is subjected to various stress distribution and displacement under various loading condition.

Truck chassis is a major component in a vehicle system. This work involves static and dynamics analysis to determine the key characteristics of a truck chassis. The static characteristics include identifying location of high stress area and determining the torsion stiffness of the chassis. The dynamic characteristics of truck chassis such as the natural frequency and mode shape were determined by using finite element (FE) method. Experimental modal analysis was carried out to validate the FE models. Modal updating of the truck chassis model was done by adjusting the selective properties such as mass density and Poisson's ratio. Predicted natural frequency and mode shape were validated against the experimental results. Finally, the modification of the updated FE truck chassis model was proposed to reduce the vibration, improve the strength and optimize the weight of the truck chassis.

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CHAPTER 1

INTRODUCTION

A chassis consists of an internal vehicle frame that supports an artificial object in its construction, can also provide protection for some internal parts. Chassis is the under part of a motor vehicle, consisting of the frame on which the body is mounted. The demand for cost and weight reduction and for payload increase is priority in vehicle industry. Thus, vehicle design typically represents a trade-off between performance and safety, since durability, especially of safety components, is of great importance. For the development engineer this means that the design of the components must be adapted as accurately as possible to the operating conditions. In order to achieve these goals, in the present scenario, the automotive industry has been one of the rapid growing industries and is facing heavy competition from the competitors. This necessitates the need to work on various functional aspects of the automobile, starting from chassis design to aesthetic design. As a part of this, the present work aims to study the static characteristics of automobile chassis. The chassis acts as a skeleton on which, the engine, wheels, axle assemblies, brakes, suspensions etc. are mounted. The chassis receives the reaction forces of the wheels during acceleration and braking and also absorbs aerodynamic wind forces and road shocks through the suspension. So the chassis should be engineered and built to maximize payload capability and to provide versatility, durability as well as adequate performance. All real physical structures, when subjected to loads or displacements, behave dynamically. The additional inertia forces, according to Newton’s second law, are equal to the mass times the acceleration. If the loads or displacements are applied very slowly, then the inertia forces can be neglected and a static load analysis can be justified, but in reality the loads are dynamic in nature.

1.1 ROLE OF CHASSIS IN AUTOMOTIVES

Every vehicle body consists of two parts; chassis and bodywork or superstructure. The chassis is the framework of any vehicle. Its principal function is to safely carry the maximum load for all designed operating conditions. It must also absorb engine and driveline torque, endure shock loading and accommodate twisting on uneven road surfaces. The chassis receives the reaction forces of the wheels during acceleration and braking and also absorbs aerodynamic wind forces and road shocks through the suspension. So the chassis should be engineered and built to maximize payload capability and to provide versatility, durability as well as adequate performance. To achieve a satisfactory performance, the construction of a heavy vehicle chassis is the result of careful design and rigorous testing. It should be noted that this ‘ladder’ type of frame construction is designed to offer good downward support for the body and payload 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. 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, suspensions etc. are mounted. The frame and cross members form an important part of the chassis. 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.

Fig 1.1: Image of a SUV chassis (ladder type chassis)

The chassis of an automobile consists of following components suitably mounted: • Engine and the radiator. • Transmission system, consisting of the clutch, gear box, propeller shaft and the rear axle. • Suspension system. • Road wheels. • Steering system. • Brakes. • Fuel tank. All the components listed above are mounted in either of the two ways, viz., the conventional construction, in which a separate frame is used and the frameless or unitary construction in which no separate frame is employed. Out of these, the conventional type of construction is being used presently only for heavy vehicles whereas for car the same has been replaced by the frameless type accept of course by small manufacturers, who still find it economical to use frame.

1.2 TYPES OF FRAMES

(i) Ladder frame

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

(ii) Perimeter frame

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

(iii) Sub-type frame

A sub-type frame is a partial frame often used on unit-body vehicles to support the power train and suspension components. Normally the various components are bolted directly to the main frame. But many a times, these components are mounted on a separate frame called sub-frame. This sub-frame is further supported by the main frame at three points. In this way the components are isolated from the effects of twisting and flexing of the main frame. The advantages of sub frames are: The mass of the sub-frame alone helps to damp vibrations. The provision of sub-frames simplifies production on the assembly line and facilitates subsequent overhaul or repair.

(iv) Unit body construction

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

(v) Space frame construction

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

1.3 CONVENTIONAL CHASSIS FRAME

Steel pressing of channel or box section form the side (frame) members. They are connected together by means of cross members (made of channel or box sections) so as to form a rigid but light frame work. The cross members are also used to mount the chassis components on them. These transverse members are usually riveted or welded to the side members, with the help of special enlarged flanges known as gusset plates.

At the front and rear ends, the longitudinal members are tapered in depth (beams of the uniform strength for minimum weight).The side rails at the front end are brought closer together when viewed in plan in order to provide space for the free turning of the steered wheels. It is usual to arch (upswept) the side rails towards the front and rear ends, in order to provide sufficient space for the vertical movement of the axles during its springing action while travelling on a rough road.

The chassis also receive the vibration and force produce from the car externally and internally. The road bumping, the load of passenger, the vibration of the vehicle engine and others can be the source of the external and internal force and it can be failure of the structure when the excitation of it coincides with the natural frequencies of the chassis which create resonant. Since the material is almost same for different chassis and differ for each chassis is come from its chassis design. Normally the chassis design is based on strength and stiffness. In the conventional design procedure the design is based on the strength and focus is then given to increase the stiffness of the chassis.

1.4 NEED OF STATIC, DYNAMIC AND MODAL ANALYSIS

Here in static analysis a typical ladder frame chassis is considered. The different load considerations are taken for analysis. The chassis is designed analytically by varying materials and cross section of beam. The different materials are chosen as • Aluminum Alloy

• Structural Steel Here analytical approach is considered for deciding the dimension of chassis cross section. During static condition the chassis frame is only subjected to bending loads due to the weight of the members over here. By considering the equation of bending the cross sections are decided. Then the same cross sections are analyzed by using FEM.

Automotive industry is one of the biggest users of the technology of modal analysis. The modal behavior of car chassis is a part of most necessary information for the inspection into car's dynamic behavior. In this essay the modal analysis of car chassis has been studied. As a car travels along the road, the car chassis is excited by dynamic forces induced by the road roughness, engine, transmission and more. Under such various dynamic excitations, the car chassis tends to vibrate. Whenever the natural frequency of vibration of a machine or structure coincides with the frequency of the external excitation, there occurs a phenomenon known as resonance, which leads to excessive deflections and failure. The literature is full of accounts of system failures brought about by resonance and excessive vibration of components and systems. The global vibrational characteristic of a vehicle is related to both its stiffness and mass distribution. The frequencies of the global bending and torsional vibration modes are commonly used as benchmarks for vehicle structural performance. Bending and torsion stiffness influence the vibrational behavior of the structure, particularly its first natural frequency. The mode shapes of the car chassis at certain natural frequencies are very important to determine the mounting point of the components like engine, suspension, transmission and more. Therefore it is important to include the dynamic effect in designing the chassis.

CHAPTER 2

LITERATURE SURVEY

Abd Rahman et, investigated stress analysis on a heavy-duty truck chassis using finite element method. Finite element result had shown that the critical point of stress occurs at opening of chassis which is in contact to the bolt. Thus it is important to reduce to stress at specific location.

Yuen Ren, Yongchang Yu[3] investigated force application to the frame during its operation mainly refers to bending moment, bending strength and deformation of the frame were analyzed. Due to symmetric force application, only a half of the frame was analyzed in static condition, with its load distributed in the whole surface.

Yuan Ren, also investigated on the frequencies that extracted from the different modes.

V. Veloso, H.S. Magalhaes [1] investigated a stress distribution caused by a load input of 35 KN applied in the chassis's centre of the stringer. The maximum Von Mises stress value was 442 Mpa. This value is greater than the UTS of the material.

Teo Han Fui, RoslanAbd. Rahman (2007) have studied a 4.5 ton truck chassis containing two C section side rails and five numbers of cross members against road roughness and excitations. Vibration of the components fixed to the chassis due to excitation and road roughness were studied. Chassis responses were examined by stress distribution and displacement. The suitable locations of engine and suspension systems were determined by the results of mode shape. Analysis results reveal that the major disturbance of the chassis is caused due to road excitation.

Yongjie Lu, Shaopu Yang, Shaohua Li and Liqun Chen (2010) have investigated tyre dynamic load by numerical simulation and experimental field test. MSC. ADAMS software was used to model the virtual prototype of heavy vehicle. Shock absorber, tire, suspension and road profiles were modeled to simulate the real time conditions. Experimental test was carried out in a four way lane road by using truck manufactured by Dongfeng Motor Company model conforms DFL1250A9. The GVW of the truck is 24.9

tons. Seven piezoelectric accelerometers were placed on the driver seat, front axle head, intermediate axle head and rear axle head. Effects of speed, mass, road roughness and tyre stiffness on dynamic load were studied in detail. The study revealed that increase in speed may have considerable effect on tire and road damage. The proposed virtual model has efficient and realistic simulation and the new methodology unveiled to study the interaction between road and vehicle.

CHAPTER 3

DESIGN PRINICIPLE

3.1 Selection of vehicle type and concept

In order to achieve a satisfactory structure, the following must be selected

a) The most appropriate structural type for the intended application.

b) The correct layout of structural elements to ensure satisfactory load paths, without discontinuities, through the vehicle structure.

c) Appropriate sizing of panels and sections, and good detail design of joints.

An assumption made in this project is that is satisfactory load path (i.e. if the equilibrium of edge forces between simple structural surfaces) are achieved, then the vehicle is likely to have the foundation for sufficient structural (and especially torsion) stiffness. Estimate of interface loads between major body components calculated by the simplified methods described are assumed to be sufficiently accurate for conceptual design although the structural members comprising load paths must still be sized appropriately for satisfactory results. Early estimates of stiffness can be obtained using the finite element method, but the results should be treated with caution because of simplifications in the idealization of the structure at this stage.

3.2 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 space frame 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.

3.3 MATERIALS

Different chassis materials can reduce the weight of the vehicle, improving the vehicle power to weight ratio. Material selection can also provide advantages by reducing member deflection, increasing chassis strength and can determine the amount of reinforcement required.

1. Q235A STEEL

Q235 steel is a Chinese steel grade of general carbon structural steel, this material divides into 4 quality grades**:** Q235A Steel, Q235B Steel, Q235C Steel and Q235D Steel, "Q" stands for Yield Strength, "235" is that the Yield Strength is 235 MPa (N/mm^2), and Tensile Strength is 370-500 Mpa, data is tested based on 16mm diameter steel bar or steel plate.

Q235 material is mainly rolled into steel wire rod, round steel, square steel, flat steel, I-beam, steel channel, steel section, steel plate and steel angle, etc.

Q235 steel is widely used in construction and engineering structures. It can be used to make steel bars or to build factory house frames, transmission towers, bridges, vehicles, boilers, containers, ships, etc., and is also used as a mechanical part that does not require high performance.

Below are Q235A, Q235B, Q235C & Q235D physical properties, chemical composition and equivalent.

Table-1 Q235A, Q235B, Q235C and Q235D Steel Chemical Composition

Steel Grade	Quality Grade	C%(≤)	Si%(≤)	Mn(≤)	P(≤)	S(≤)
	Q235A	0.22	0.35	1.4	0.045	0.05
Q235	Q235B	0.2	0.35	1.4	0.045	0.045
	Q235C	0.17	0.35	1.4	0.04	0.04
	Q235D	0.17	0.35	1.4	0.035	0.035
Quality Grade: A<B<C<D						

Table-2 Q235 Mechanical Properties

Grade	Yield Strength	Tensile Strength	Elongation %
Q235 Steel	235Mpa	370-500Mpa	26
Test Sample: ≤Ø 16mm steel bar, (Mpa=N/mm2)			

2. ALUMINUM

Aluminium is a nonferrous material with very high corrosion resistance and very light material compared to steels. Aluminium cannot match the strength of steel but its strength-to- weight ratio can make it competitive in certain stress application. Aluminium can also be alloyed and heat treated to improve it mechanical properties, which then makes it much more competitive with steels however the cost increases dramatically. Pure aluminium is also a possible material and is reasonably affordable and very light but it is the weakest and requires extra reinforcement to produce a rigid chassis. Aluminium is very hard to work with as it requires very skilled welding and is an overall softer metal. Basically there are several types of aluminium. For this project, decide to test with Aluminium Alloy 6063-T6. Aluminium alloy 6063 is one of the most extensively used of the 6000 series alloys. Aluminium Alloy 6063 is the least expensive and most versatile of the heat treatable aluminum alloys. It has most of the good qualities of aluminium. It offers a range of good mechanical properties and good corrosion resistance. It can be fabricated by most of the commonly used techniques. In the annealed condition it has good workability. The typical properties of aluminium alloy 6063 include medium to high strength, good toughness, good surface finishing, excellent corrosion resistance to atmospheric conditions, good workability and widely available. It is welded by all methods and can be furnace brazed. It is available in the clad form ("Alclad") with a thin surface layer of high purity aluminum to improve both appearance and corrosion resistance. This aluminum type is used for a wide variety of products and applications from truck bodies and frames to screw machine parts and structural components. 6063 is used where appearance and better corrosion resistance with good strength are required. Mechanical properties and typical composition of Aluminium Alloy 6063-T6 is shown in Table 3 and Table 4.

Table-3, Mechanical properties of Aluminum alloy 6063 T-6

Properties	Value and units
Ultimate tensile strenght	195MPa
Density	2.7g/cm3
Modulus of elasticity	69.5GPa
Shear strength	150MPa
Yield strength(0.2% of set)	160MPa
Melting point	600°C
Elongation	14%

Table-4, Typical composition of Aluminium Alloy 6063 T-6

Element	Value(%)
Cr	0.1
Fe	0.35 max
Mg	0.45-0.9
Mn	0.1 max
Si	0.2
Ti	0.1 max
Cu	0.1 max
Al	Balance
Zn	0.1 max

3. CAST IRON

Iron is a lustrous, ductile, malleable, silver-gray metal (group VIII of the periodic table). It is known to exist in four distinct crystalline forms. Iron rusts in dump air, but not in dry air. It dissolves readily in dilute acids. Iron is chemically active and forms two major series of chemical compounds, the bivalent iron (II), or ferrous, compounds and the trivalent iron (III), or ferric, compounds. Iron is the most used of all the metals, including 95 % of all the metal tonnage produced worldwide. Thanks to the combination of low cost and high strength it is indispensable. Its applications go from food containers to family cars, from screwdrivers to washing machines, from cargo ships to paper staples. Steel is the best known alloy of iron, and some of the forms that iron takes include: pig iron, cast iron, and carbon steel, and wrought iron, alloy steels, iron oxides. Iron is believed to be the tenth most abundant element in the universe. Iron is also the most abundant (by mass, 34.6%) element making up the Earth; the concentration of iron in the various layers of the Earth ranges from high at the inner core to about 5% in the outer crust. Most of this iron is found in various iron oxides, such as the minerals hematite, magnetite, and taconite. The earth's core is believed to consist largely of a metallic iron-nickel alloy. Iron is essential to almost living things, from micro-organisms to humans. World production of new iron is over 500 million tones a year, and recycled iron adds other 300 million tones. Economically workable reserves of iron ores exceed 100 billion tones. The main mining areas are China, Brazil, Australia, Russia and Ukraine, with sizeable amounts mined in the USA, Canada, Venezuela, Sweden and India. Mechanical properties and typical composition of Iron (Fe) is shown in Table 5 and Table 6.

Table-5, Mechanical properties of CAST IRON, Fe

Properties	**Value and unit**
Ultimate tesile strength	70MPa
Density	7.9g/cm3
Shear strength	45MPa
Yield strength(0.2% of set)	53MPa
Melting point	1538°C
Youngs modulus	211GPa

Table-6, Typical composition of CAST IRON, Fe

Element	**Value (%)**
C	3.4
Mg	0.06
Mn	0.4 max
Ni	1
P	0.1 max

3.4 MATERIAL MECHANICAL CONCEPT

Many materials display linear elastic behavior, defined by a linear stress- strain relationship, as shown in the figure up to point 2, in which deformations are completely recoverable upon removal of the load that is, a specimen loaded elastically in tension elongates, but it returns to its original shape and size when unloaded. Beyond this linear region, for ductile materials, such as steel, deformations are plastic. A plastically deformed specimen not returns to its original size and shape when unloaded. Note that there is elastic recovery of a portion of the deformation. For many applications, plastic deformation is unacceptable, and is used as the design limitation. Properties Value and unit Ultimate tensile strength Density Shear strength Yield strength (0.2% offset) Melting point Young's modulus 70 MPa 7.9 g/cm3 45 MPa 53 MPa 1538°C 211 GPa 18 After the yield point, ductile metals undergo a period of strain hardening, in which the stress increases again with increasing strain, and they begin to neck, as the cross-sectional area of the specimen decreases due to plastic flow. In a sufficiently ductile material, when necking becomes substantial, it causes a reversal of the engineering stress-strain curve (curve A); this is because the engineering stress is calculated assuming the original cross-sectional area before necking.

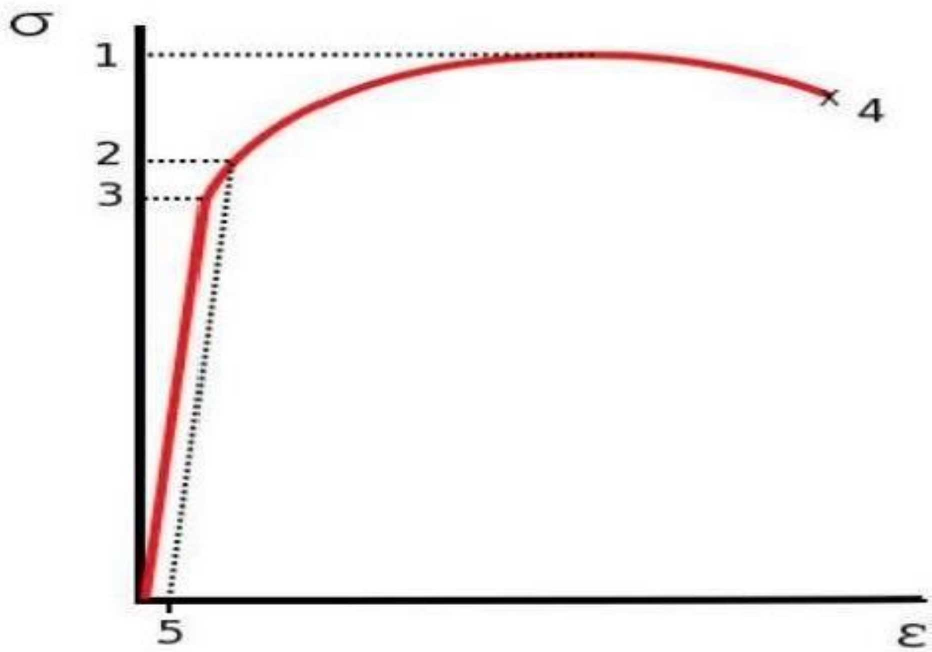
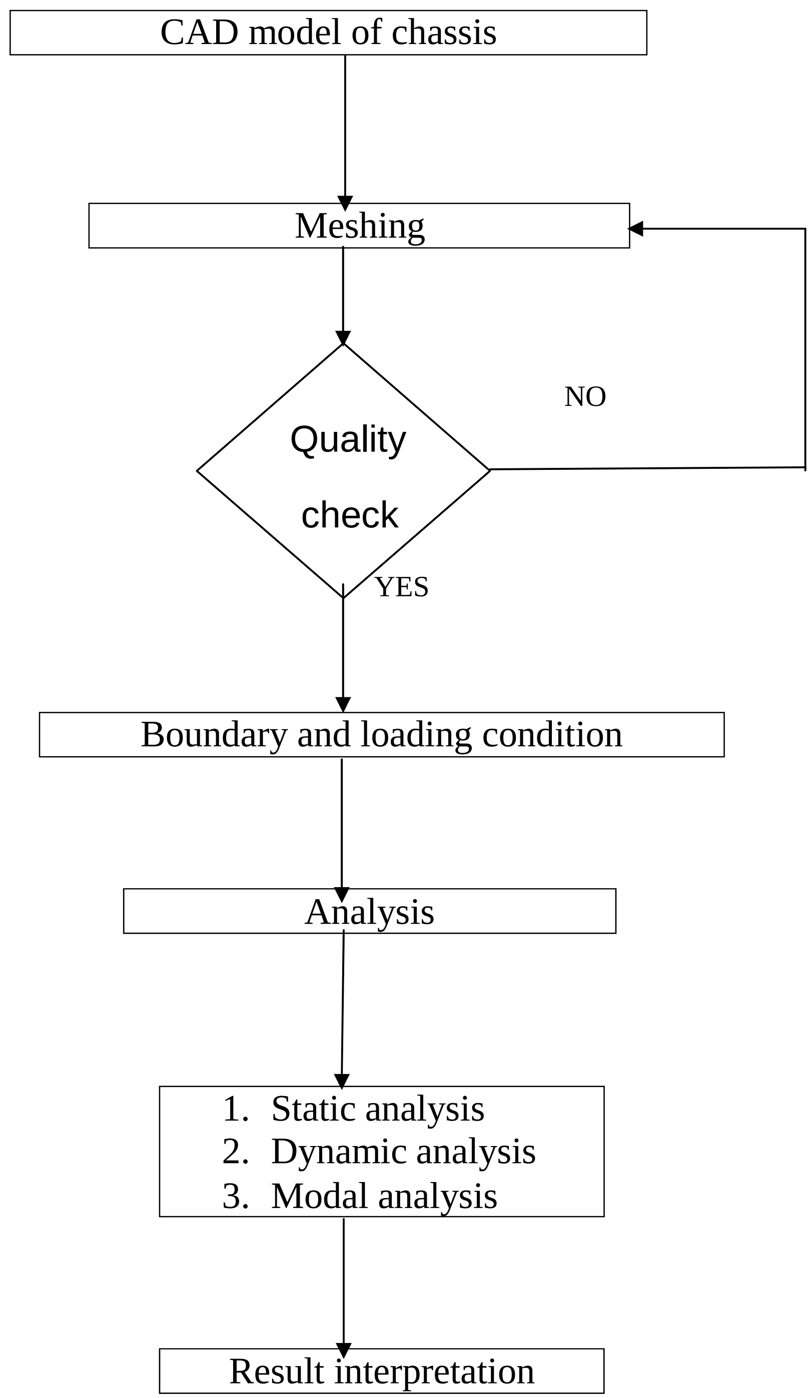


Fig 3.1 Stress vs strain curve for ductile material.

The reversal point is the maximum stress on the engineering stress-strain curve, and the engineering stress coordinate of this point is the tensile ultimate strength, given by point 1. The ultimate tensile strength is not used in the design of ductile static members because design practices dictate the use of the yield stress. It is, however, used for quality control, because of the ease of testing. It is also used to roughly determine material types for unknown samples. In Figure 2.7 shows the stress vs. strain curve of a ductile material, at point number one (1) is the ultimate tensile strength, refer to the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross section starts to significantly contract. At point number two (2) is yield strength, explained that the boundary between elastic region and plastic region. At the point number three (3) is point for the proportional limit stress, at this point explained that the amount of stress increasing proportional to the increasing of strain. Fracture occurred at the point number four (4). Fracture is the local separation of an object or material into two, or more, pieces under the action of stress. Lastly at point number five (5) is the offset strain (typically 0.2), this offset use in order to find the yield strength of material.

CHAPTER 4

METHODOLOGY



CHAPTER 5

MODELING OF CHASSIS

Specification of car chassis:-

Overall length: - 3937 mm

Overall width: - 1150 mm

Overall height: - 215mm

Basic calculation for car chassis

Capacity of car =weight per passenger x no. Of passengers

= 80kg x 8

= 640kg

Capacity of car with 1.25%=800kg

Total load acting on car chassis

= Gross vehicle weight + weight of passenger

=800+800

=1600kg

=15696N

Chassis as two longitudinal members so load will be acting on this two longitudinal members there for, load acting on each member will be off of the total load acting on chassis.

Load acting on one longitudinal member

$$= \frac{15696}{2} N$$

=7848N

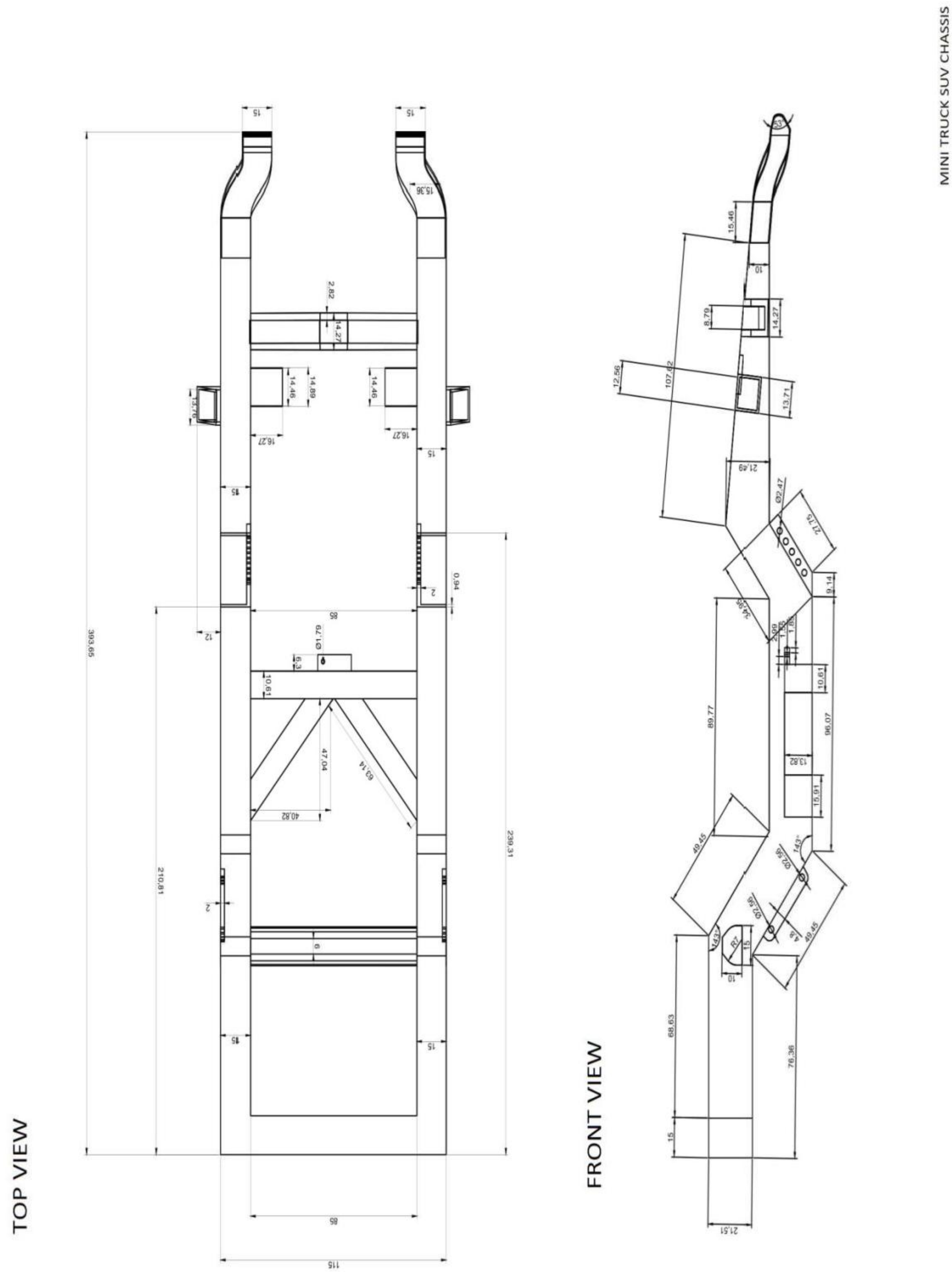


Fig 5.1 Top view and front view of SUV chassis

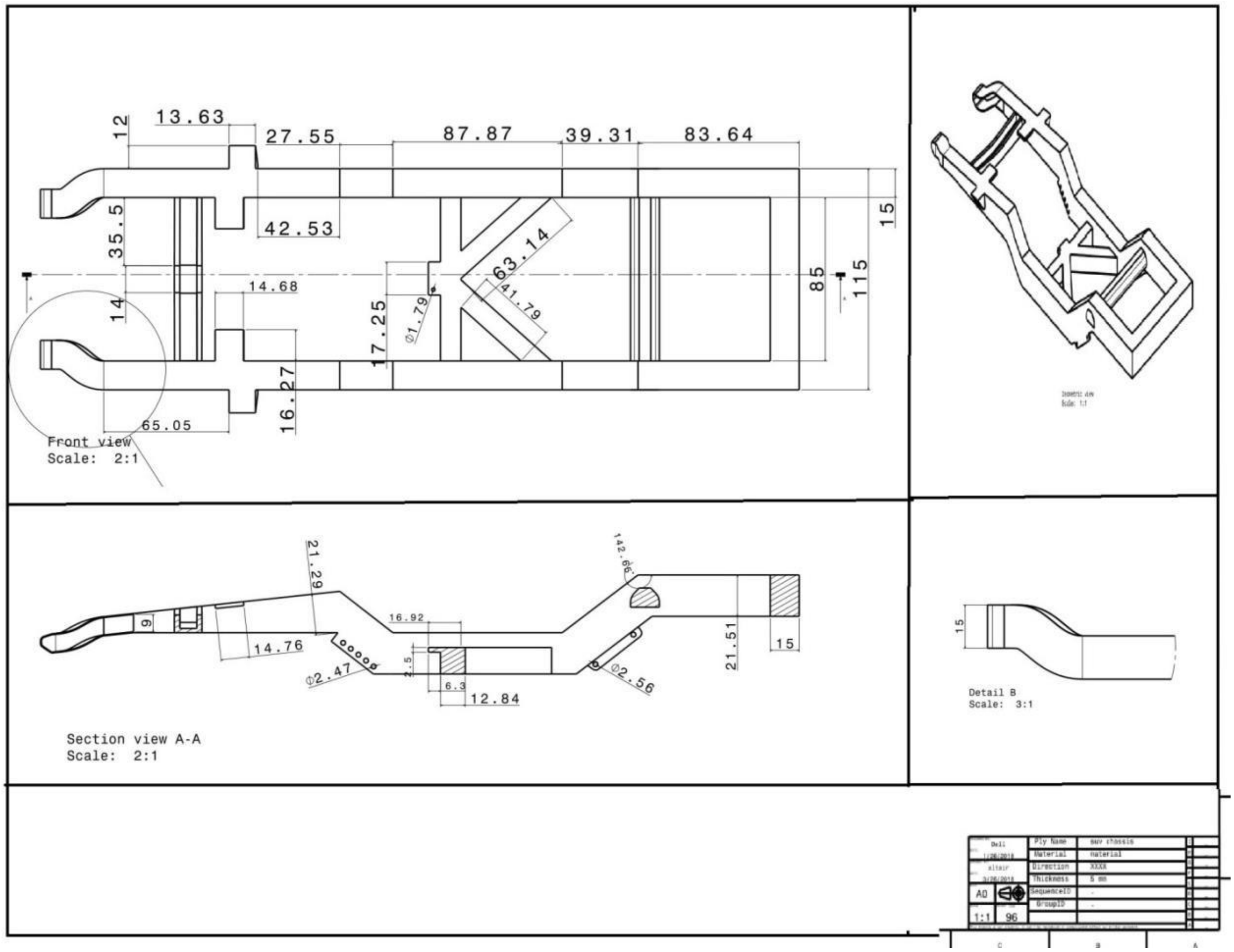


Fig 5.2 Dimensions of chassis

5.1 GEOMETRIC MODELING OF CHASSIS

The chassis model is created by using CATIA V5. Introduction to CATIA V5.

Part design This application makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface, from sketching in an assembly context to iterative detailed design. Part Design application will enable you to accommodate design requirements for parts of various complexities, from simple to advance.

2. Assembly design It allows the design of assemblies with an intuitive and flexible user interface. As a scalable workbench, Assembly Design can be cooperatively used with other current companion products such as Part Design and Generative Drafting.

3. Interactive drafting It is a new generation product that addresses 2D design and drawing production requirements. Interactive Drafting is a highly productive, intuitive drafting system that can be used in a standalone 2D CAD environment within a backbone system It also expands the Generative Drafting product with both integrated 2D interactive functionality and an advanced production environment for the dress-up and annotation of drawings. This provides an easy and smooth evolution from 2D to 3D-based design methodologies.

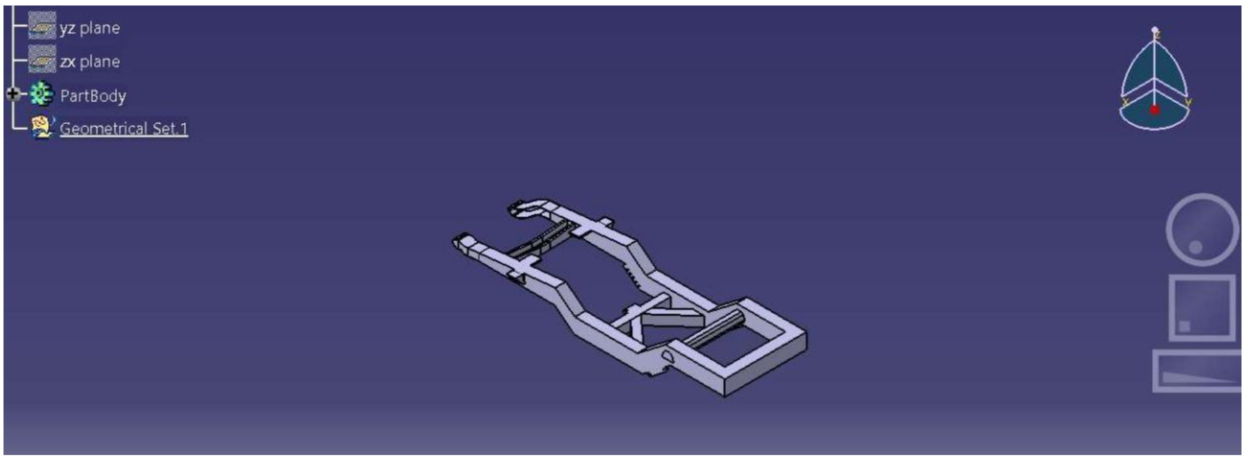


Fig 5.3 CAD model of chassis in CATIA V5

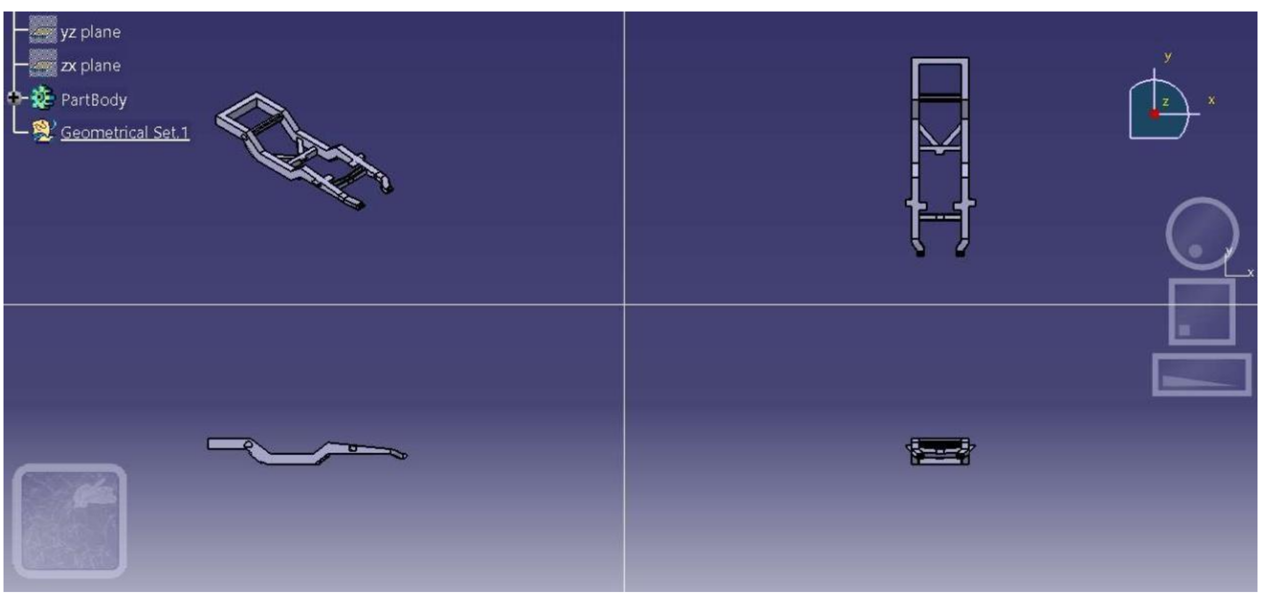


Fig 5.4 CAD model views

CHAPTER 6

MESHING

Basic theme of FEM is to make calculation at only limited number of point and then

interpolate the result for entire domain. Any continuous object has infinite degrees of freedom and it's just not possible to solve the problem in this format. Finite element method reduces degreed of freedom from infinite to finite with the help of discretization i.e. meshing (nodes and elements)

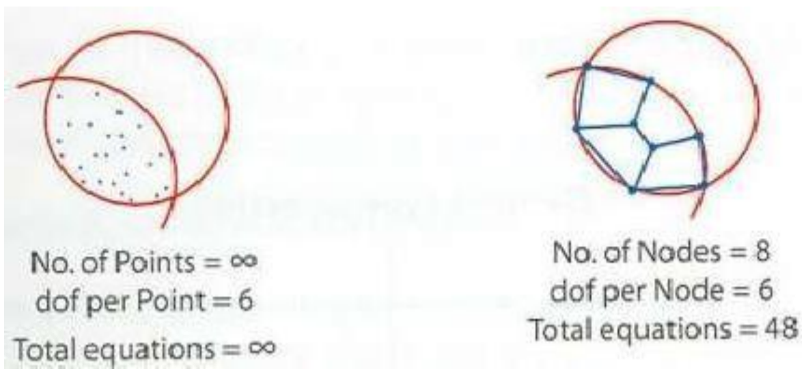


Fig 6.1 Discretization technique

6.1 PROCEDURE FOR MESHING

1) Spend sufficient time in studying the geometry

Common observation is CAE engineers start meshing immediately, without properly studying the geometry & paying minute attentions to all the requirements and instructions provided. Observing the geometry several times & thinking from all the directions is strongly suggested. Mental visualization of the steps or planning before starting the job is first step in right direction i.e. good meshing.

2) Time estimation

Now a day's trend is towards client or boss specifying time estimation for a given job to service provider or subordinate. Sometimes it is decided based on mutu l understanding.

Time estimation is very relative & one can find lot of difference in estimation by different engineers (as much as 2 to 3 times). Usually a less experienced person will estimate more time also if some one is handling the job for first time then also he will require more time. If similar kind of jobs are given to same engineer again and again, meshing time would reduce drastically.

3) Geometry check

Generally CAD data is provided in .igs format. Whatever software people might claim but the ground reality is "geometry cleanup is an integral part of meshing activity". CAE engineer should have at least basic knowledge of CAD. Before starting the job geometry should be carefully checked for:

- Free edges
- Scar lines
- Duplicate surfaces
- Small fillets
- Small holes
- Beads
- Intersection of parts (assembly of components)

If suppressing fillets, small holes, beads, generation of mid surfaces etc. is required for meshing then why not CAD data is provided like what is needed for CAE by the CAD engineers?

Yes theoretically it would be an ideal situation but practically every one works with very tight schedules & target dates. CAD data is generated keeping in mind final drawing to be released for manufacturing. The same drawing / CAD model is provided simultaneously to tools and jig /Fixture manufactures, vendors, purchase engineers and CAE engineers etc.

Simplification required for FEA are understood better bya CAE engineer rather than CAD engineer. All Meshing softwares provides special tools for geometry cleanup and simplification which are usually much faster than CAD software Many a times, for complicated geometry surfacing operations fails in CAD softwares & it could be easily handled by CAE engineer by avoiding the geometry and generation of mesh via manual or special meshing operations.

4) Symmetry check

Complete part symmetry

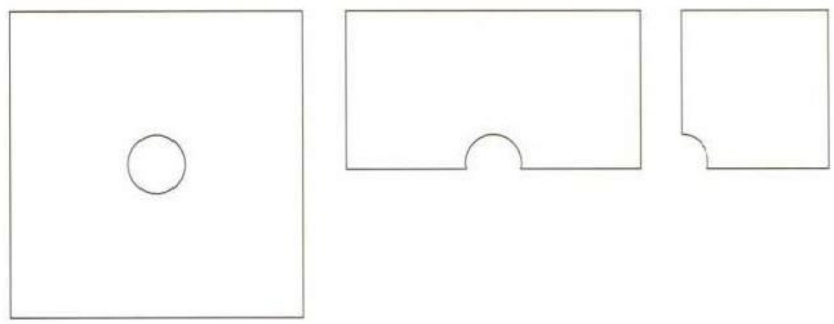


Fig 6.2 Symmetry of plate

Meshing only quarter of the plate & reflecting it twice is advisable.

>Sub part symmetry repetition of features & possibility of copy paste command

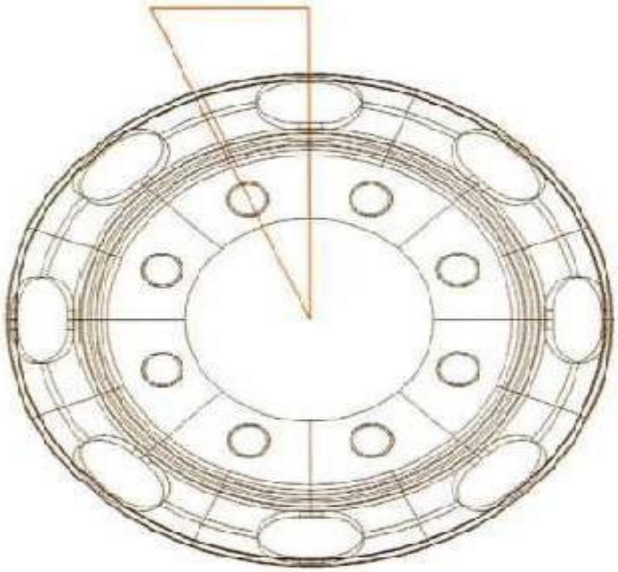


Fig 6.3 symmetry of disc

Meshing highlighted 22.5° portion and then reflection and rotation would lead to fast meshing as well same structure of elements and nodes around critical areas (holes).

5) Selection of type of elements

In real life rarely we use only one type of element, its usually combination of different types of elements, i.e. 1-d, 2-d, 3-d & others.

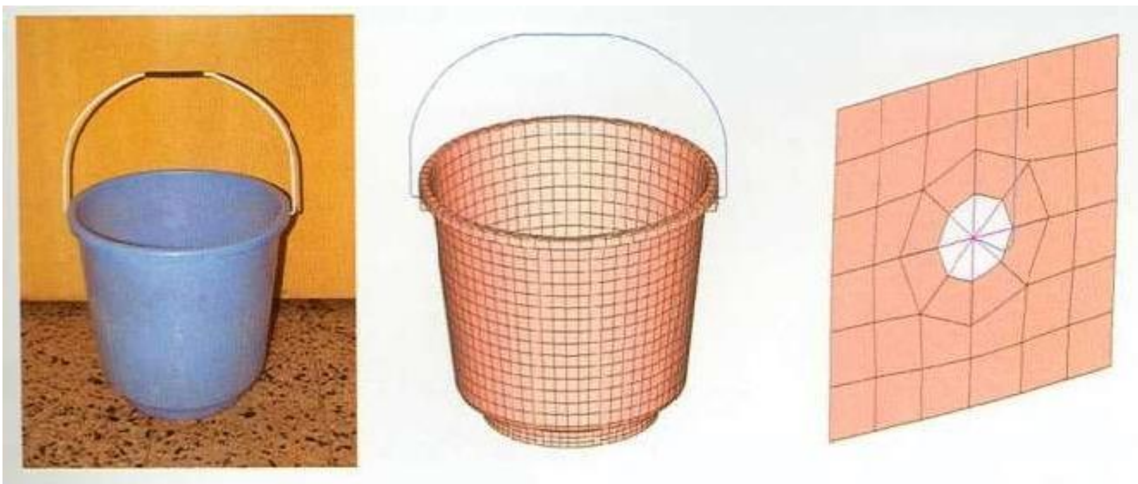


Fig 6.4 meshing of an object

In above figure the handle of bucket modeled by beam (1-d) elements, bucket body via shell (2d elements and connection between handle and bucket body through RBEZ (rigid) elements.

6) Type of meshing

i. Geometry based Mesh is associated to geometry. If geometry is modified mesh will also get updated accordingly (automatically). Boundary conditions could be applied on geometry like surface or edge etc.

ii. EE based Mesh is non associative. Boundary conditions to be applie on elements & nodes only.

7) Joint modeling

a. Special instructions for bolted joints (specific construction around holes)

b. Spot & arc weld

c. Contact or gap elements & requirement of same pattern on 2 surfaces in Contact

d. Adhesive joint

8) Splitting the job

Incase if time available is very less or if engineers in other group are sitting idle then the job could be split among several engineers by providing common mesh on Interfaces.

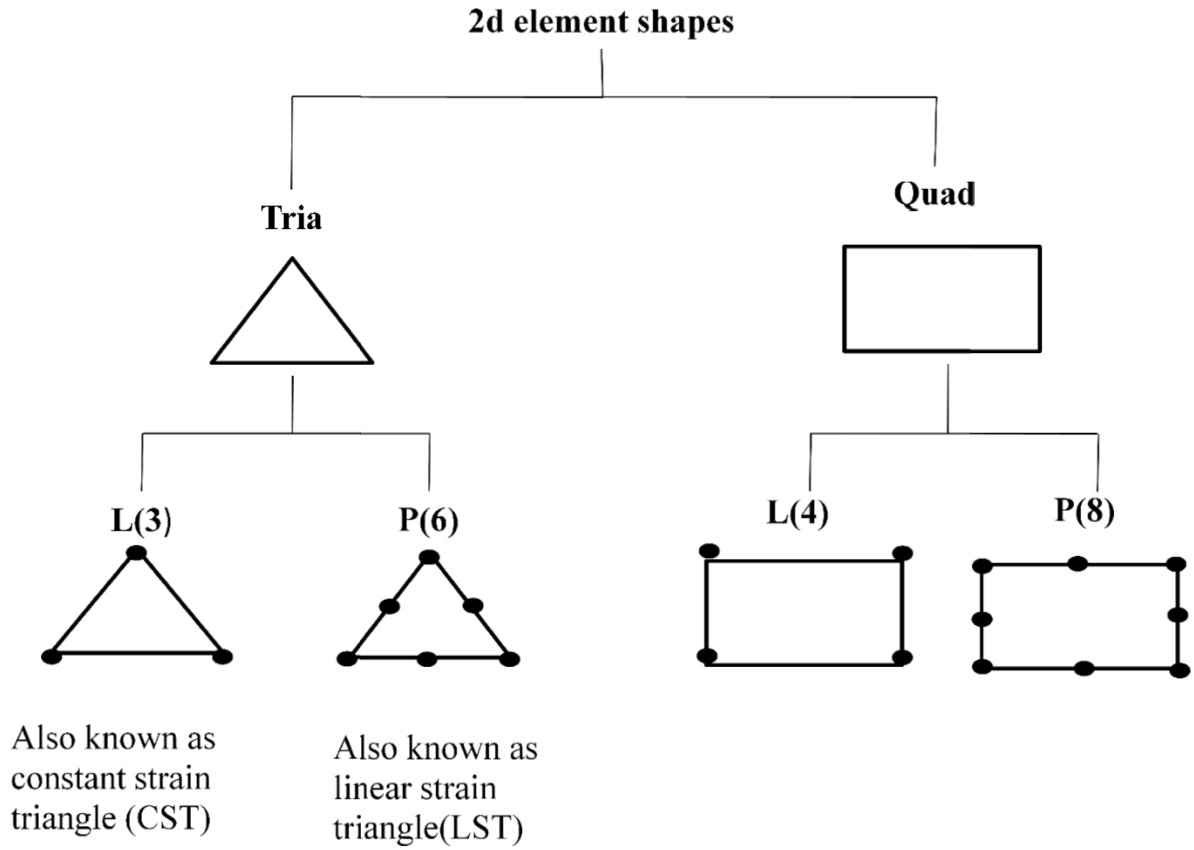
Batch meshing/ Mesh adviser

Now a day's all software's provide special programs for automatic geometry clean up and meshing with no or very little interaction from user. User has to specify all the parameters like min. hole dia., min. fillet radius, avg. and min. element length, quality parameters etc. & software will run a program to produce best possible mesh by fulfilling all or most of the specified instructions. Though these programs are still in initial stage & for many applications output is not acceptable but research is in progress & its performance will surely improve in coming years.

Meshing in Critical Areas

Critical areas are high stress locations. Dense meshing & structured mesh (no trias /pentas) is recommended in these regions .Areas away from critical are general areas. Geometry simplification and coarse mesh in general areas are recommended (to reduce total DOFs and solution time).

6.2 DIFFERENT TYPES OF MESHES



a. QUAD MESHING

The shell shaped is a basic four sided one as shown in above figure. It is a most common in structure grids. The quadrilaterals element are usually excluded from being are becoming concave. The mesh contains only quad elements in its meshing.

Fig 6.5 Quad mesh

b. TRIA MESHING

This cell shape consists of three sides and one of the simple types of mesh. The triangular surface mesh is always quick and easy to create. It is most common in unstructured grids. This type of mesh is used in modal analysis.

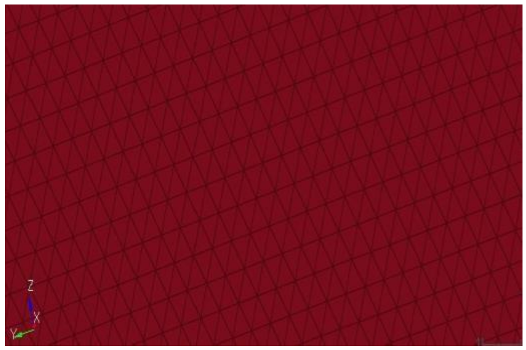


Fig 6.6 Tria mesh

c. MIXED MESH (QUAD + TRIA)

The mixed mode element type is the most common element type used due to the better mesh pattern that is produces (restriction: total tria %<5). Sometimes for structural analysis or for convergence and better results for a non linear analysis, the pure quadrilateral element meshing option is selected.

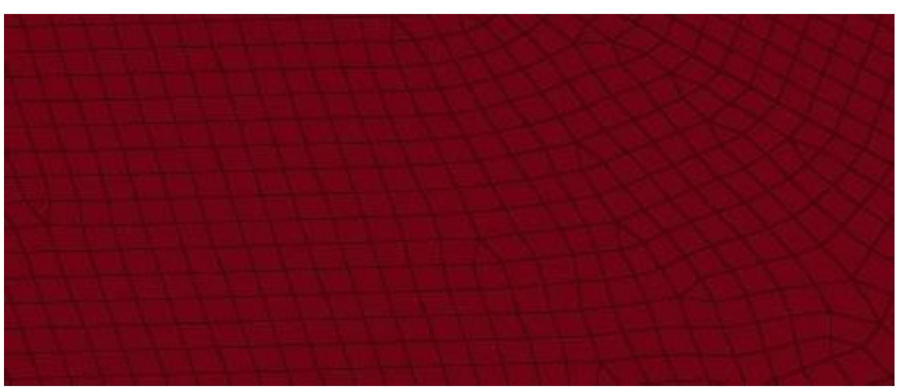


Fig 6.7 Mixed mesh

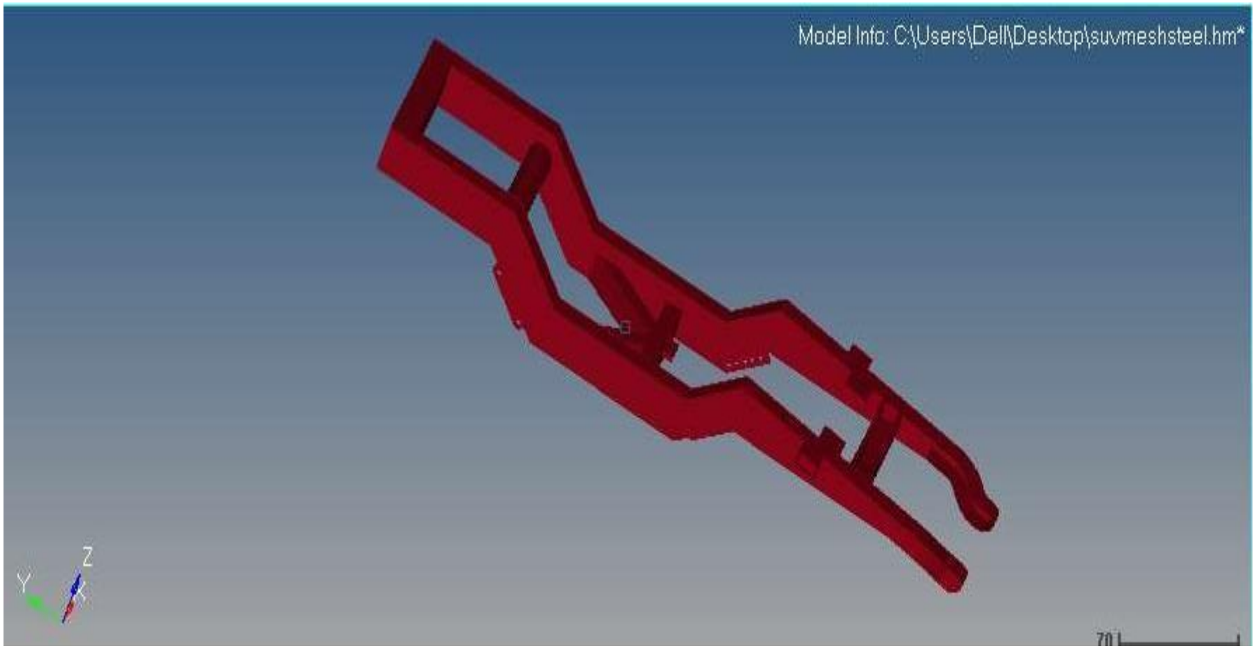


Fig 6.8 Meshed model of a SUV chassis

CHAPTER 7

QUALITY CHECK

Different quality parameters like skew, aspect ratio, included angle, jacobian, stretch etc. are the measures of how far a given element deviates from ideal shape. Square means all angles 90' and equal sides, while equilateral triangle is all angles 60° and equal sides. Some of the Quality checks are based on angles (like skew, included angles) while other on side ratios & area (like aspect, stretch).

To reduce solution time elements are mapped to local co-ordinate system (individual for every element at the centroid) instead of using a single one coordinate system (global). Effectiveness of this transformation is checked by Jacobian and distortion. Ideally all the nodes of quad element should lie in the same plane but at curvatures and complicated geometry profiles it is not possible. Measure of out of plane angle is warp angle.

Following are general definitions of various quality checks. Though the names sound same but exact definitions may differ from software to software.

a. Warp angle

warp angle is out of plane angle.

Ideal value = 0° (Acceptable < 10°).

Warp angle is not applicable for triangular elements. It is defined as angle between normals to two planes formed by splitting the quad element along diagonals. Max. Angle out of the two possibilities is reported as warp angle.

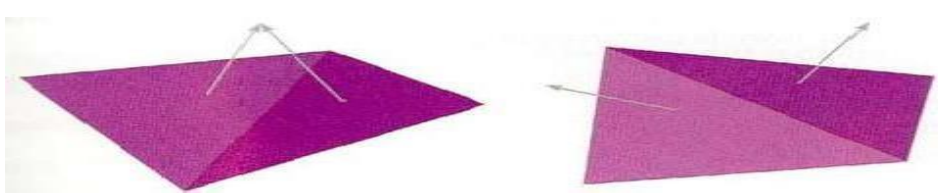


Fig 7.1 Warp angle

b. Aspect= Maximum element edge length / minimum element edge length.

Ideal value = 1(Acceptable < 5).

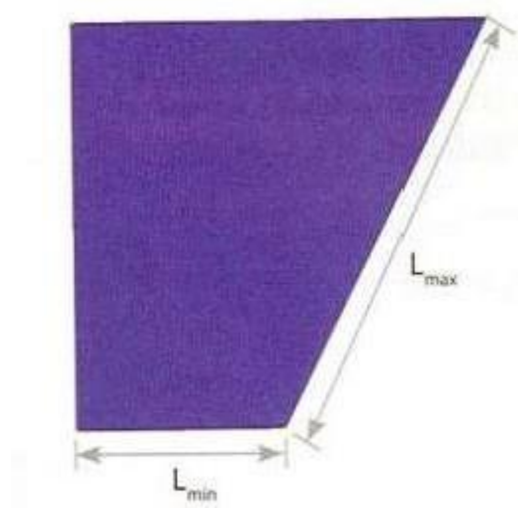


Fig 7.2 Aspect

d. Skew

Ideal value = 0(Acceptable < 45°).

Skew for quadrilateral element = 90° minus minimum angle between two lines joining opposite mid-sides of the element (α).

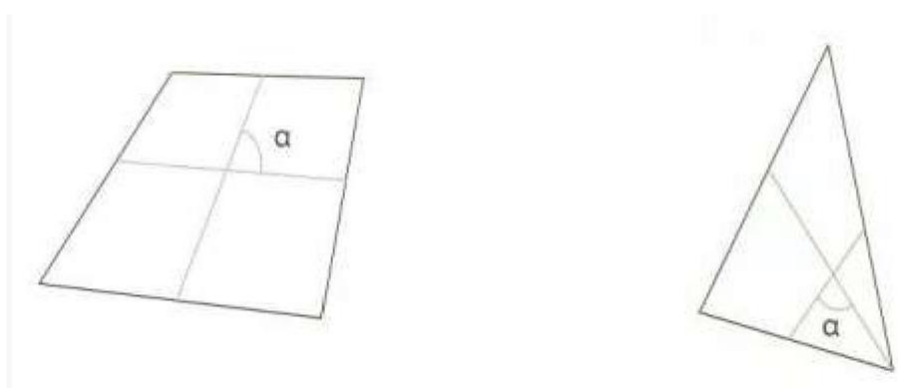


Fig 7.3 Skew

Skew for triangular element = 90° minus minimum angle between the lines from the each node to the opposing mid-side and between the two adjacent mid-sides at each node of the element.

e. Jacobia

Ideal value = 1.0 (Acceptable > 0.6)

In simple language, jacobian is a scale factor arising because of transformation of co-ordinate system. Elements are transformed from global coordinates to local coordinates (defined at centroid of every element), from faster analysis point of view.

f. Minimum element length

Very important Check for crash analysis (time step calculations).It is also applied in general to Check for minimum length feature captured and presence of any zero length elements.

g. Free edges

Conversion from tria to tetra is possible only when there is no free edge. NO free edge indicates mesh is forming enclosed volume.

CHAPTER 8

BOUNDARY AND LOADING CONDITIONS

8.1 MATERIAL PROPERTIES

'E' Modulus of elasticity is slope of normal stress-strain curve in linear elastic domain. It is defined as normal stress / normal strain. Units: N/mm2

'G' Modulus of rigidity is slope of shear stress and strain curve in linear elastic domain. It is defined as shear stress/shear strain. Units: N/mm2

' ν' Poisson's ratio is defined as ratio of lateral strain (**Δ** w / W) to longitudinal strain (**ΔL**/ L). It is unit less entity.

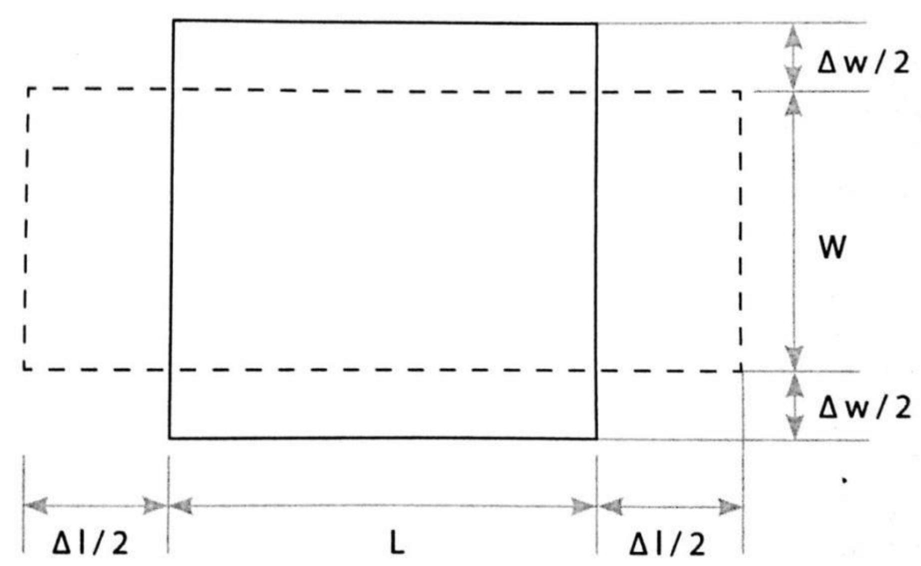


Fig 8.1 Cube of dimension 1x1x1

Physical interpretation of 1: Consider a cube of lx1x1 mm dimension. Poisson's ratio 0.30 means If the cube is elongated by 1 mm, lateral direction contraction would be 0.3 mm.

For metals poisson's ratio lies in the range of 0.25 to 0.35. Max. Possible value of poisson's ratio is 0.5 (for rubber).

E, G and 1) are inter-related by equation E = 2 G (1+ 1)) only two independent material constants are required for linear static analysis (i.e. any two out of E, u and G). Additional data required for gravity, centrifugal load and dynamic analysis is material density and for temperature induced stresses ‘α’ coefficient of linear thermal expansion.

8.2 BOUNDARY CONDITIONS

The boundary condition is the application of a force and/or constraint. In Hyper Mesh, boundary conditions are stored within what are called load collectors. Load collectors may be created using the right click context menu in the Model Browser (Create > Load Collector). Quite often (especially at the beginning) a load collector is needed for the constraints (also called SPC – Single Point Constraints) and a second one is needed for the forces and/or pressures. Keep in mind, you can place any constraints (e.g. nodes constraint) with respect to DOF 1, or nodes with constraints dof123, etc. in a single load collector. The same rule applies for forces/pressures. They are stored within a single load collector regardless of their orientation and magnitude.

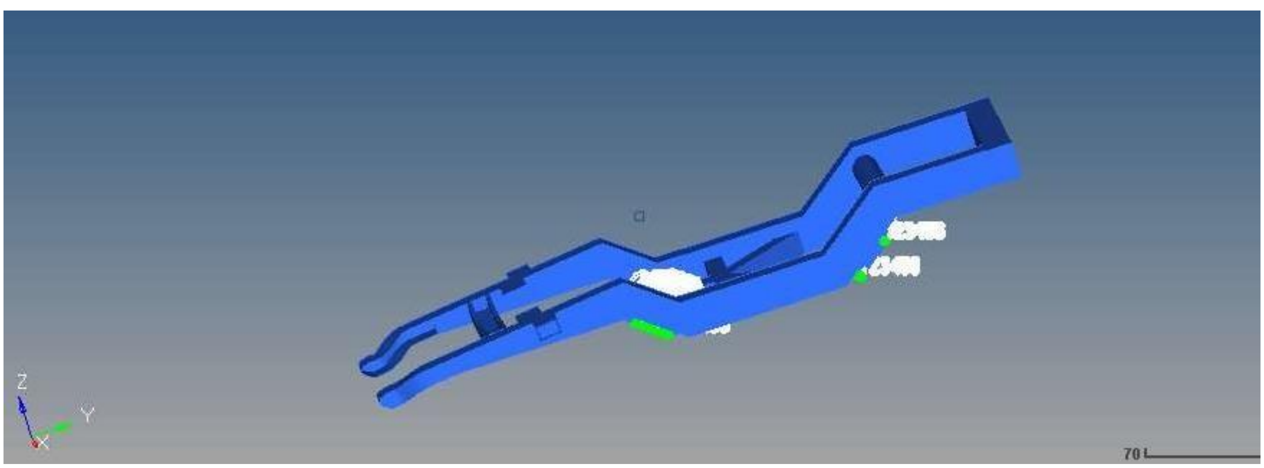


Fig 8.2 Meshed model with boundary conditions

8.2 LOADING CONDITIONS

In loading condition uniform load is applied on the chassis.

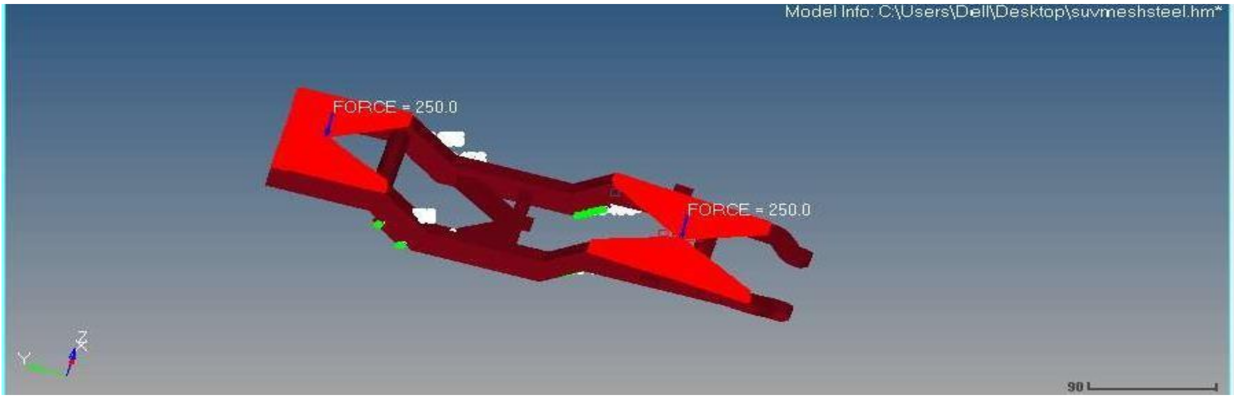


Fig 8.3 Meshed chassis with a boundary and loading condition

CHAPTER 9

STATIC ANALYSIS

The deflection and stress pattern in the model of the chassis is obtained by performing static analysis. The results of the model are shown in tables and the general pattern of the deflection Respectively. The design stress for the steel material of which the chassis is made is 250Mpa.

Here in static analysis a typical ladder frame chassis is considered. The different load considerations are taken for analysis. The chassis is designed analytically by varying materials and cross section of beam.

The different cross sections are considered as

Rectangular Section

Square Section

Tube Section

The different materials are chosen as

Aluminum Alloy

Structural Steel

Cast iron

Here analytical approach is considered for deciding the dimension of chassis cross section. During static condition the chassis frame is only subjected to bending loads due to the weight of the members over here. By considering the equation of bending the cross sections are decided. Then the same cross sections are analyzed by using FEM.

Below images shows the static analysis of SUV chassis, first image shows the max displacement when load is applied, second image shows the max stress that obtained when the load is applied.

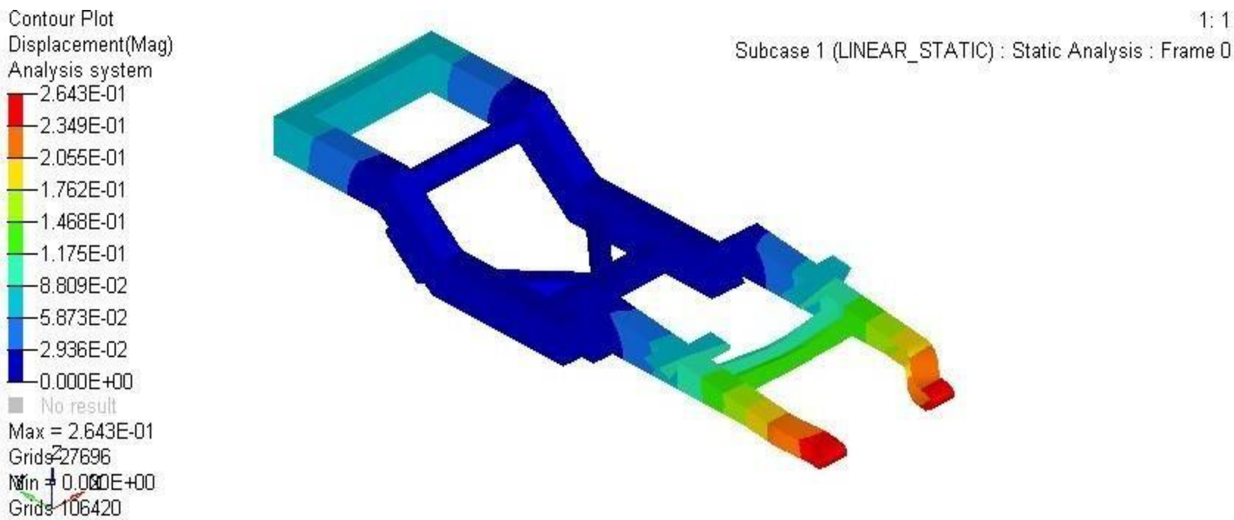


Fig 9.1 Maximum displacement of chassis under load 1150 KN

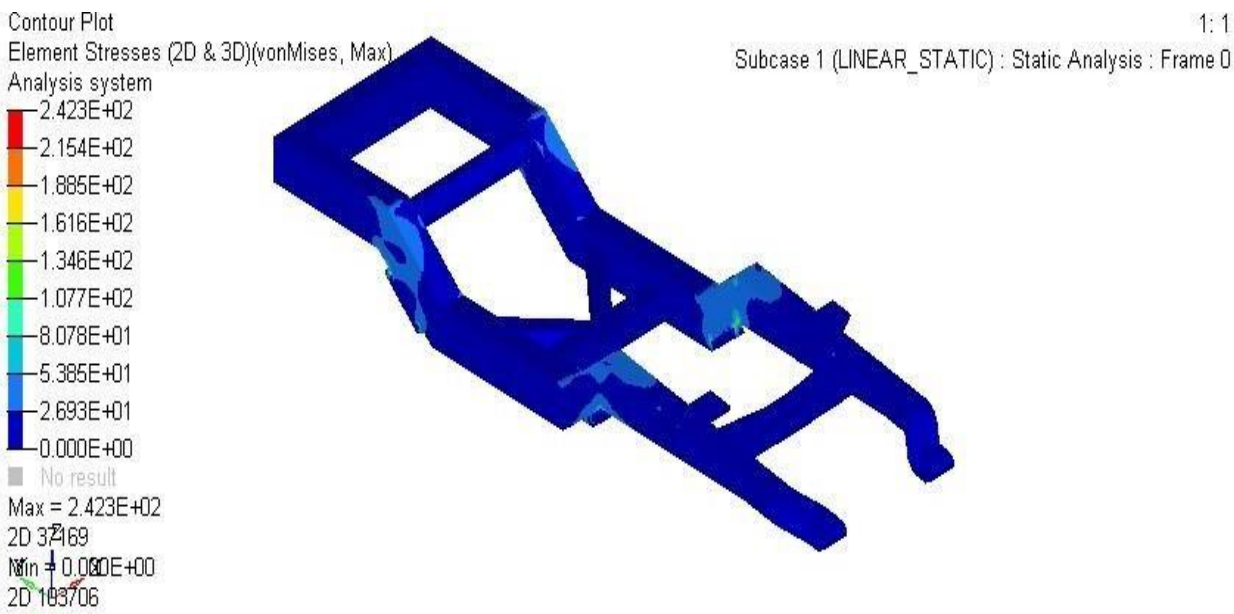


Fig 9.2 Maximum stress of chassis under load 1150 KN

9.1 LINEAR STATIC ANALYSIS RESULTS

Table-7 Static analysis on material Q235STEEL

	MATERIAL:-Q235STEEL	
Load(KN)	Maximum displacement(mm)	Maximum stress(N/mm2)
100	0.01149	10.54
150	0.01723	15.81
160	0.01838	16.86
200	0.02298	21.07
220	0.02528	23.18
240	0.02758	25.29
260	0.02987	27.39
300	0.03447	31.61
400	0.04596	42.14
500	0.05745	52.68
600	0.06894	63.22
700	0.08043	73.75
800	0.09192	84.29
900	0.1034	94.83
1000	0.1149	105.4
1200	0.1379	126.4
1400	0.1609	147.5
1600	0.1838	168.6
1800	0.2068	189.7
2000	0.2298	210.7
2040	0.2344	214.9
2100	0.2413	221.3
2160	0.2482	227.6
2200	0.2582	231.8
2220	0.2551	233.9
2240	0.2574	236
2260	0.2597	238.1
2280	0.262	240.2
2300	0.2643	242.3

Table-8 Static analysis on material ALUMINIUM ALLOY

	MATERIAL:ALUMINIUM ALLOY	
Load(KN)	Maximum Displacement(mm)	Maximum stress(N/mm2)
200	0.063	25.28
400	0.126	50.56
600	0.189	75.83
800	0.252	101.11
1000	0.315	126.4
1100	0.3465	139
1120	0.3528	141.6
1140	0.3591	144.1
1180	0.3717	149.1
1220	0.3843	154.2
1260	0.3969	159.3
1300	0.409	164.3
1340	0.4221	169.4

Table-9 Static analysis on material CAST IRON

	MATERIAL-CAST IRON	
Load(KN)	displacement(mm)	Stress(N/mm2)
100	0.01984	11.19
200	0.03986	23.85
400	0.07935	47.71
500	0.09919	59.64
600	0.119	71.56
640	0.127	76.33
680	0.1349	81.11

CHAPTER 10

MODAL ANALYSIS

Modal analysis is a powerful tool to identify the dynamic characteristics of structures. Every structure vibrates with high amplitude of vibration at its resonant frequency. It is imperative to know the modal parameters- resonant frequency, mode shape and damping characteristics of the structure at its varying operating conditions for improving its strength and reliability at the design stage.

The dynamic behavior of mechanical structures is typically done using a linear system modeling approach. 'The inputs to the system in general are forces ("loads"), that: outputs the displacement or acceleration responses. Using these variables, classical system analysis can be applied.

Specific to the mechanical problem is the straightforward physical interpretation that can be given to the system's Eigen values and Eigenvectors. System poles in structural dynamics usually occur in complex conjugate pairs, each pair corresponding to a structural "mode". The pole's imaginary part relates to the resonance frequency and the real part to the damping. Structural damping is typically very low (a few % of the critical damping), hence this damping is usually expressed as a ratio with respect to the critical damping. As a consequence, resonance effects are very outspoken, easily observed, and directly linked to many structural dynamics problems. The system's Eigenvectors, expressed in the basis of the physical coordinates on the structure, and then corresponds to characteristic structural vibration patterns, referred to as the system's "mode-shapes "Each mode can be considered as an independent single degree-of-freedom system. Use of this system model based on resonance frequencies, damping ratios and mode-shapes is the essence of the "**MODAL ANALYSIS**" approach.

10.1 IMPORTANCE OF MODAL ANALYSIS

In any kind of structural simulation, a modal analysis will help the engineer to understand the global behavior of the system. By performing a modal analysis first, it is possible to:

(i) Identify the natural frequencies and modal shapes of the system.

(ii) Verify if there are rigid modes in the system, and the link between components.

(iii)Understand if the BCs applied to the system are correct.

(iv) With the strain energy density for example, the Engineer can determine where the part should be reworked to improve the performance.

(v) It helps to predict the dynamic responses that this system will have. All the other dynamic simulations should be done only after a MODAL Analysis.

(vi) It is useful to know the modal frequencies of a structure as it allows you to ensure that the frequency of any applied periodic loading will not coincide with a modal frequency and hence cause resonance, which could lead to large responses and consequently fails.

To define the subsequent dynamic analyses (i.e., transient, frequency response, PSD, etc.), they should be based on Modal results. With a previous knowledge about the important modes, the analyst can chose the appropriate time or frequency step to solve the problem. If the analyst needs to work with a big model then the modal analysis results can be used to solve the FRF or Transient simulation. This is called a modal FRF or Modal Transient, where the equations are solved using a method called Modal superposition. This makes the dynamic solution much less expansive then the direct integration.

A modal analysis plays a key role when the analyst needs to compare the dynamic analyses with physical tests. It helps to define the right equipment that should to be used and the right location for accelerometers and strain gages. It helps during the test as well to understand the test results and correlate the virtual model with the prototype.

Mode shapes in modal analysis

Any physical system can **vibrate**. The **frequencies** at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using Modal Analysis. Analysis of vibration modes is a critical component of a design, but is often overlooked.

10.2 MODAL ANALYSIS ON SUV CHASSIS

Different Mode shapes of chassis

a. MATERIAL:- **Q235 STEEL**

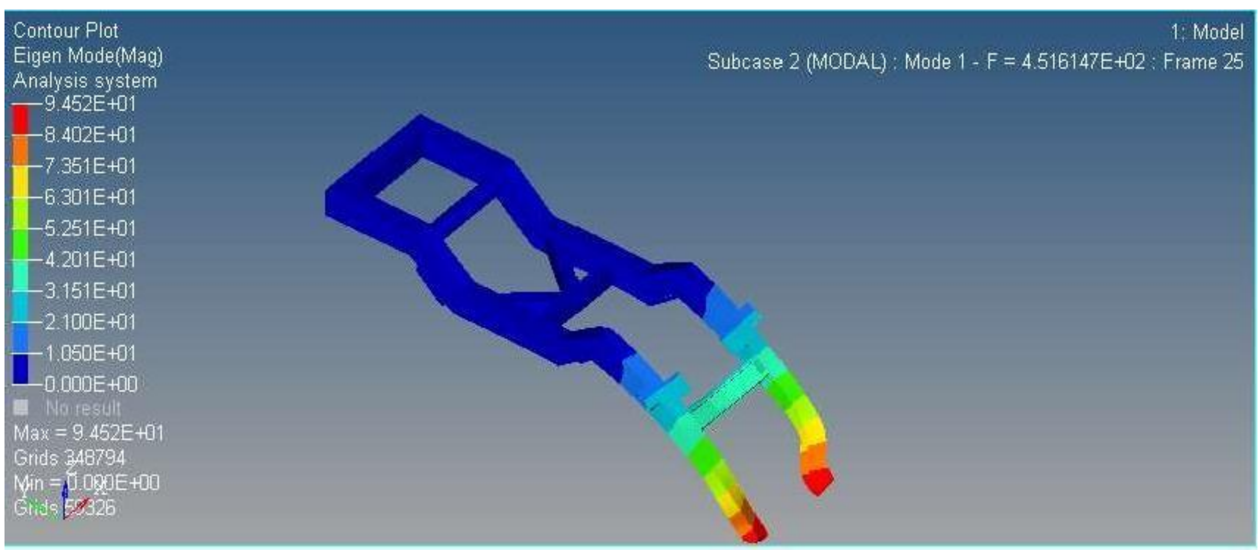


Fig 10.1 Mode shape 1 of chassis for modal frequency of 4.516E+2Hz

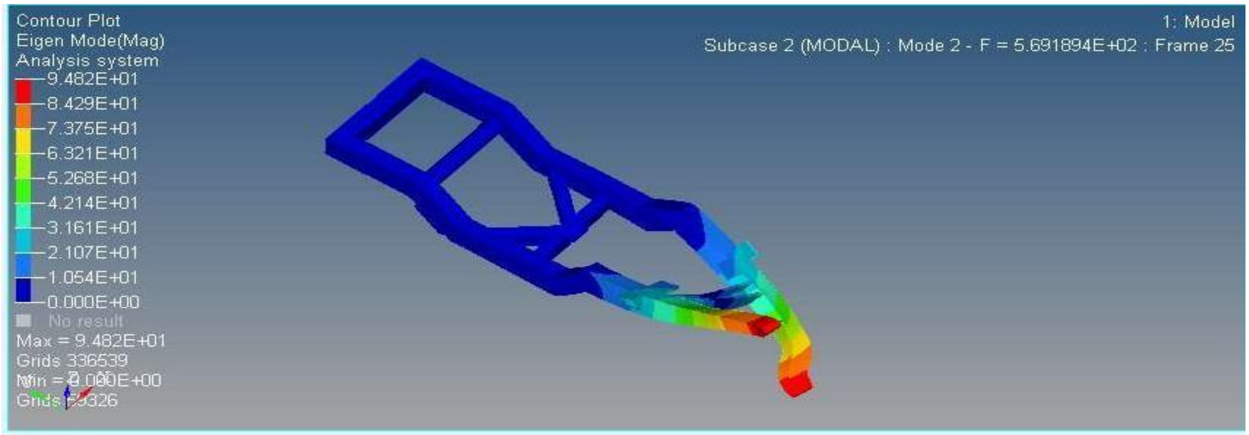


Fig 10.1.1 Mode shape 2 of chassis for modal frequency of 5.6918E+2Hz

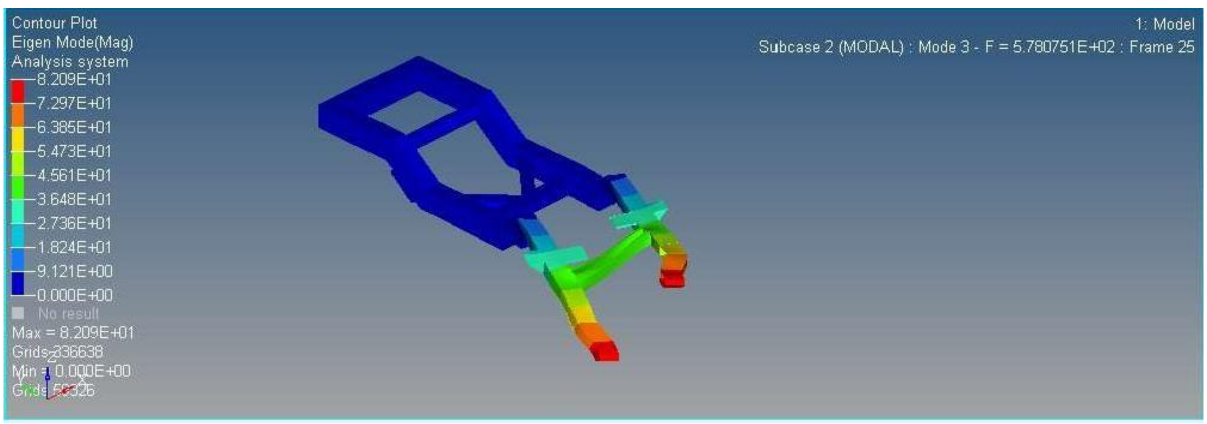


Fig 10.1.2 Mode shape 2 of chassis for modal frequency of 5.78E+2Hz

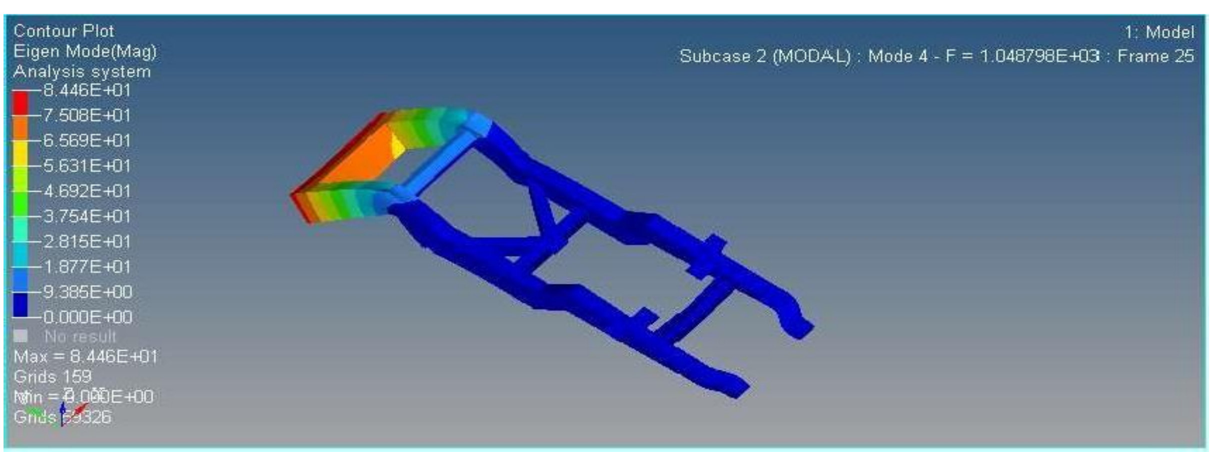


Fig 10.1.3 Mode shape 4 of chassis for modal frequency of 1.048E+3Hz

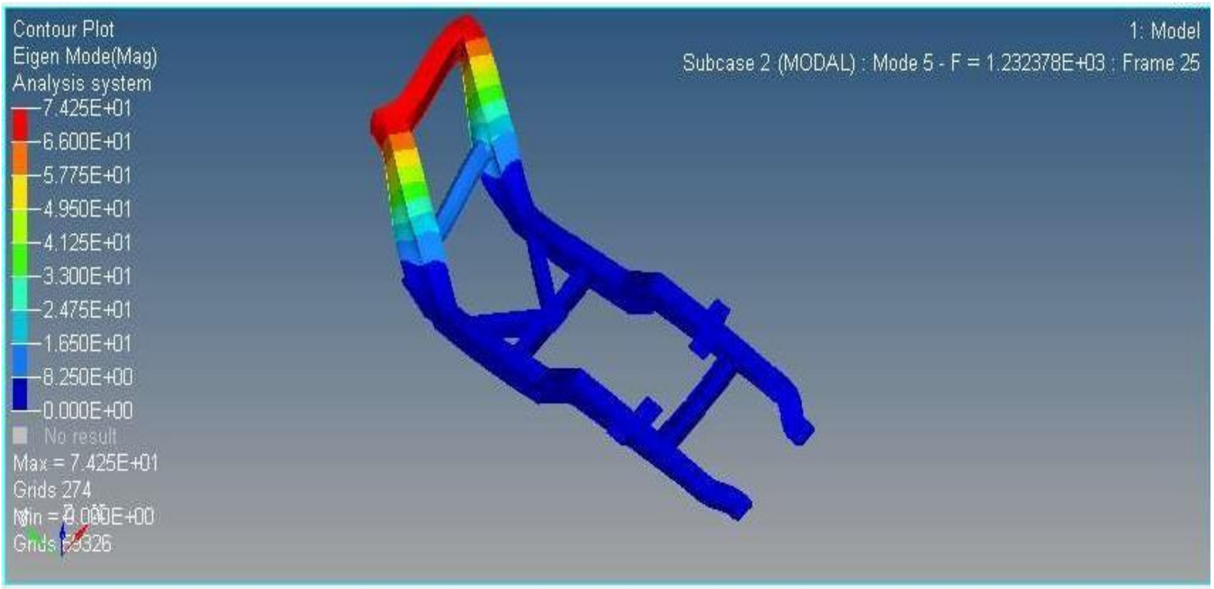


Fig 10.1.4 Mode shape 5 of chassis for modal frequency of 1.23237E+3Hz

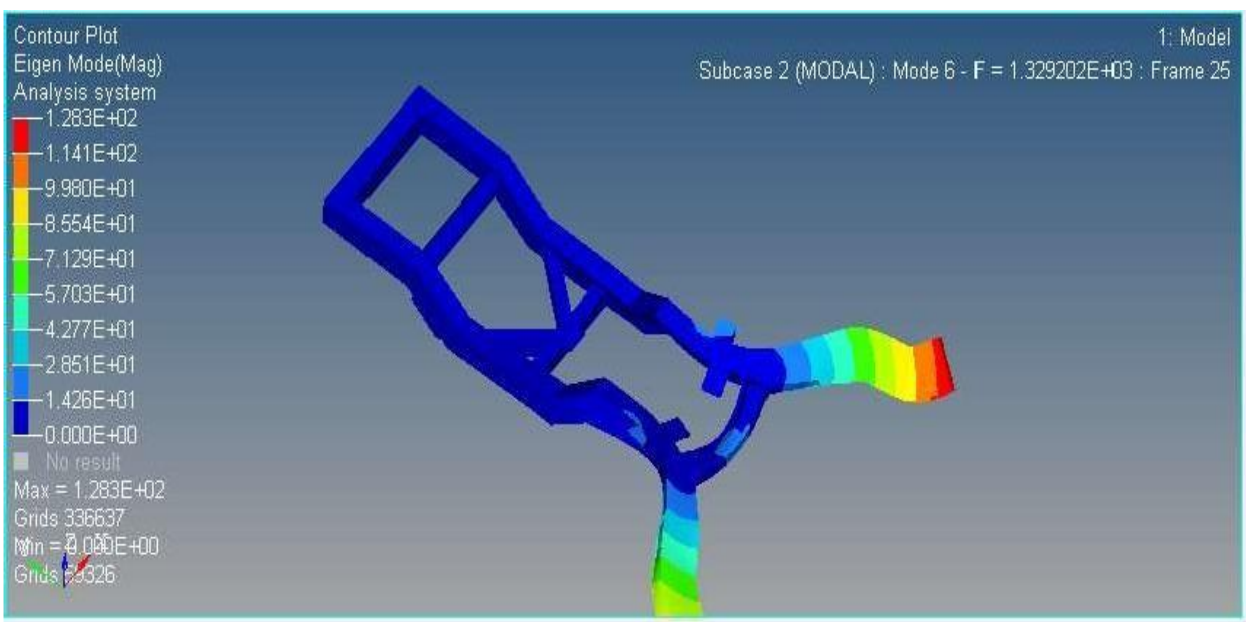


Fig 10.1.5 Mode shape 6 of chassis for modal frequency of 1.329202E+3Hz

Modal analysis has been performed after creating the chassis finite element model and meshing in free-free state and with constraints. The results have been calculated for the first 25 frequency modes and show that road simulations are the most important problematic for truck chassis. In this analysis we have made use of RADIOSS Solver. 3 modes are related to the chassis displacement in x, y and z directions and 3 modes are related to chassis rotation about x, y and z axes. Above results shows related natural frequencies and mode shapes for chassis with maximum displacement in y direction in each mode, first mode having a frequency of about 451 Hz and 6^{th} mode having frequency of 1329 Hz. Found natural frequencies from modal analysis of truck chassis, are used for determining the suitable situations for truck parts in working conditions.

It is necessary to notice that in usual, the first 6 modes of frequency (mode numbers 1 to 6) play the main role in dynamic behavior of chassis and effects of higher frequencies, because of the increasing noises effects and limited energy of motor to generate these frequencies can be ignored. In general the natural frequency can be calculated using the equation (1)

$$\omega_n = \sqrt{\frac{k}{N}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where K and m stand for stiffness and mass respectively

b. MATERIAL: - **CAST IRON**

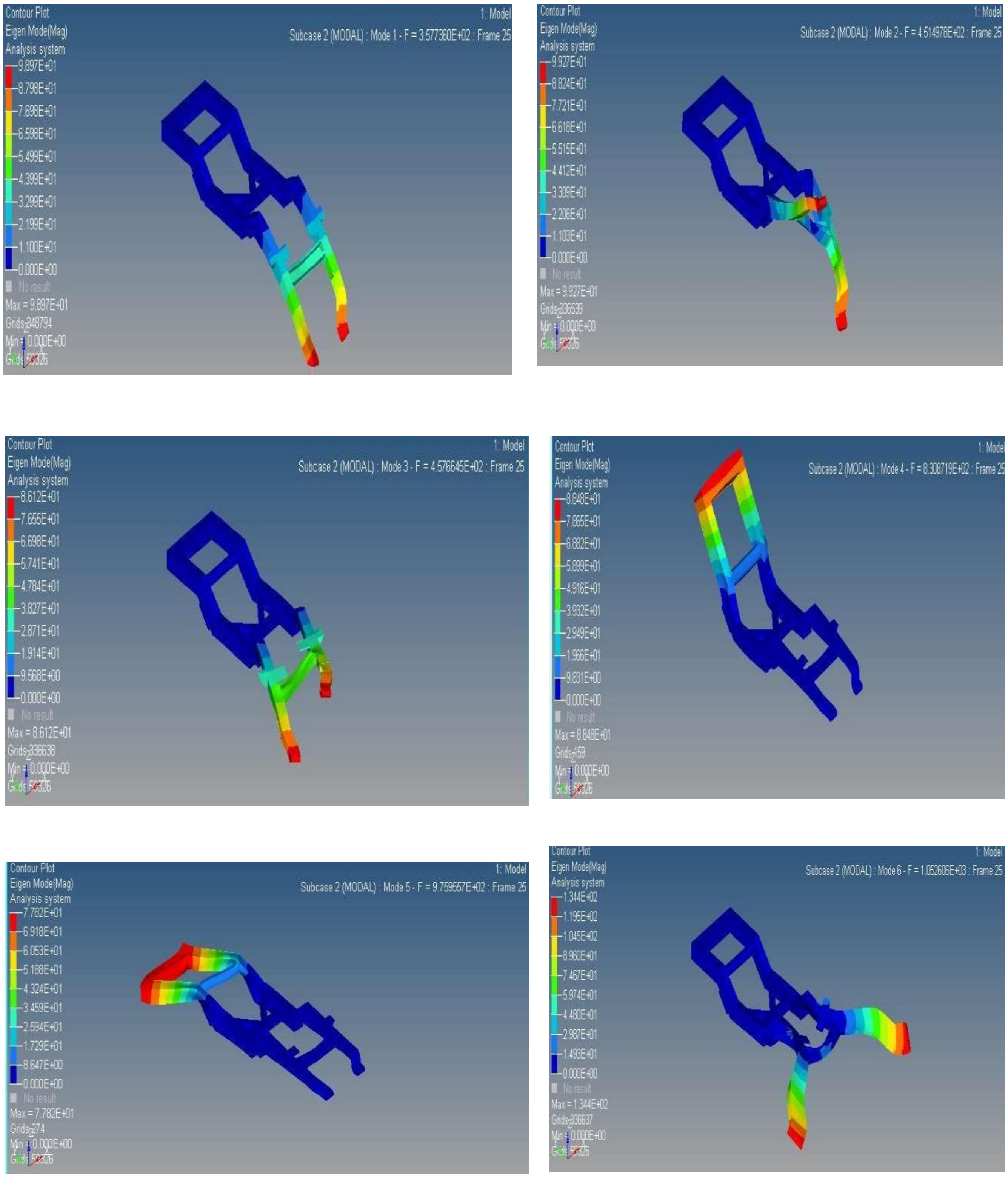


Fig 10.2 Modal frequency of different mode shapes of cast iron chassis

c. MATERIAL: - **ALUMINIUM ALLOY**

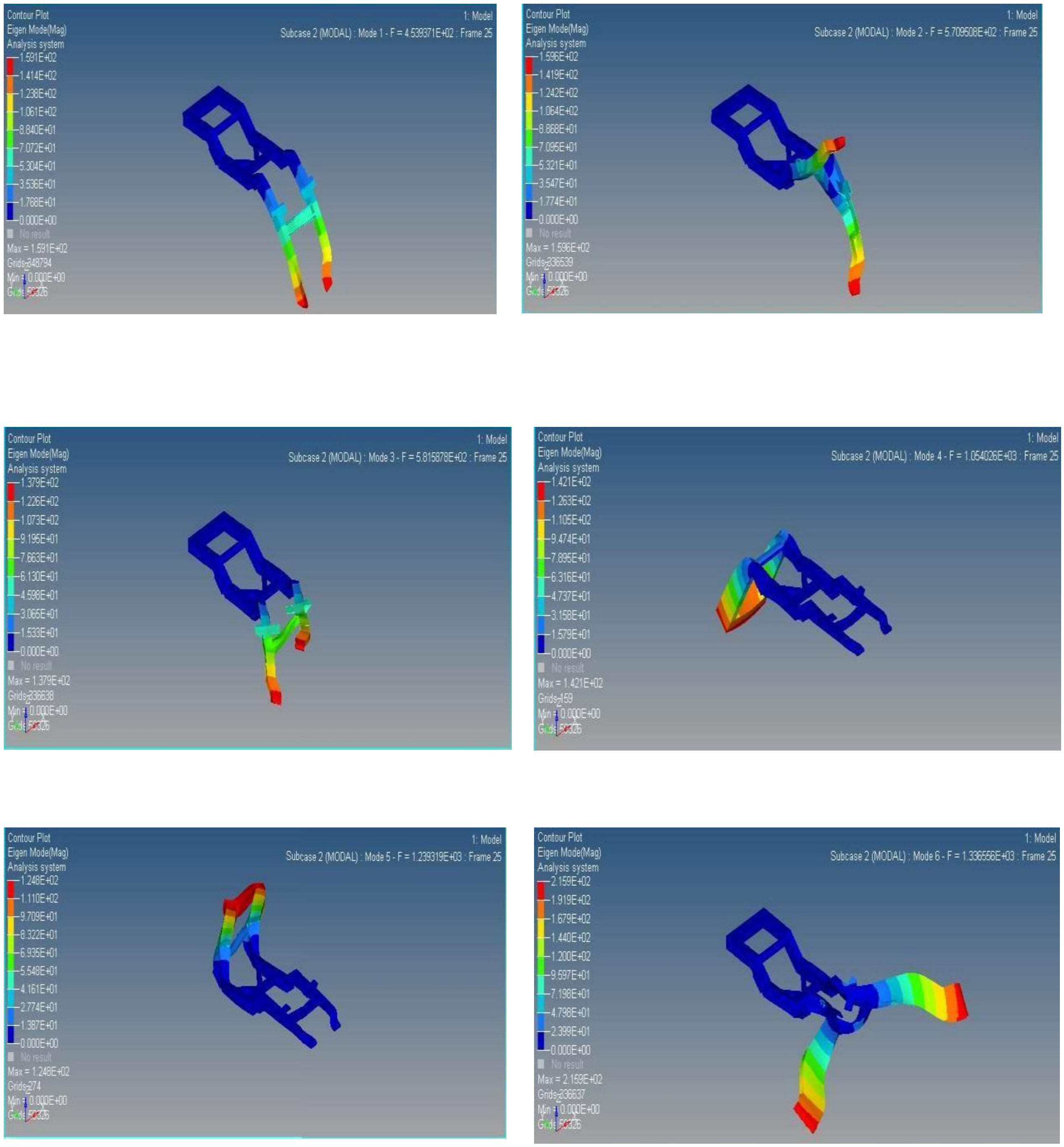


Fig 10.3 Modal frequency of different mode shapes of Aluminium alloy chassis

MODAL ANALYSIS RESULTS WITHOUT CONSTRAINING THE CHASSIS

For unconstrained chassis first 6 modes frequency will be zero

Material: Q235 STEEL

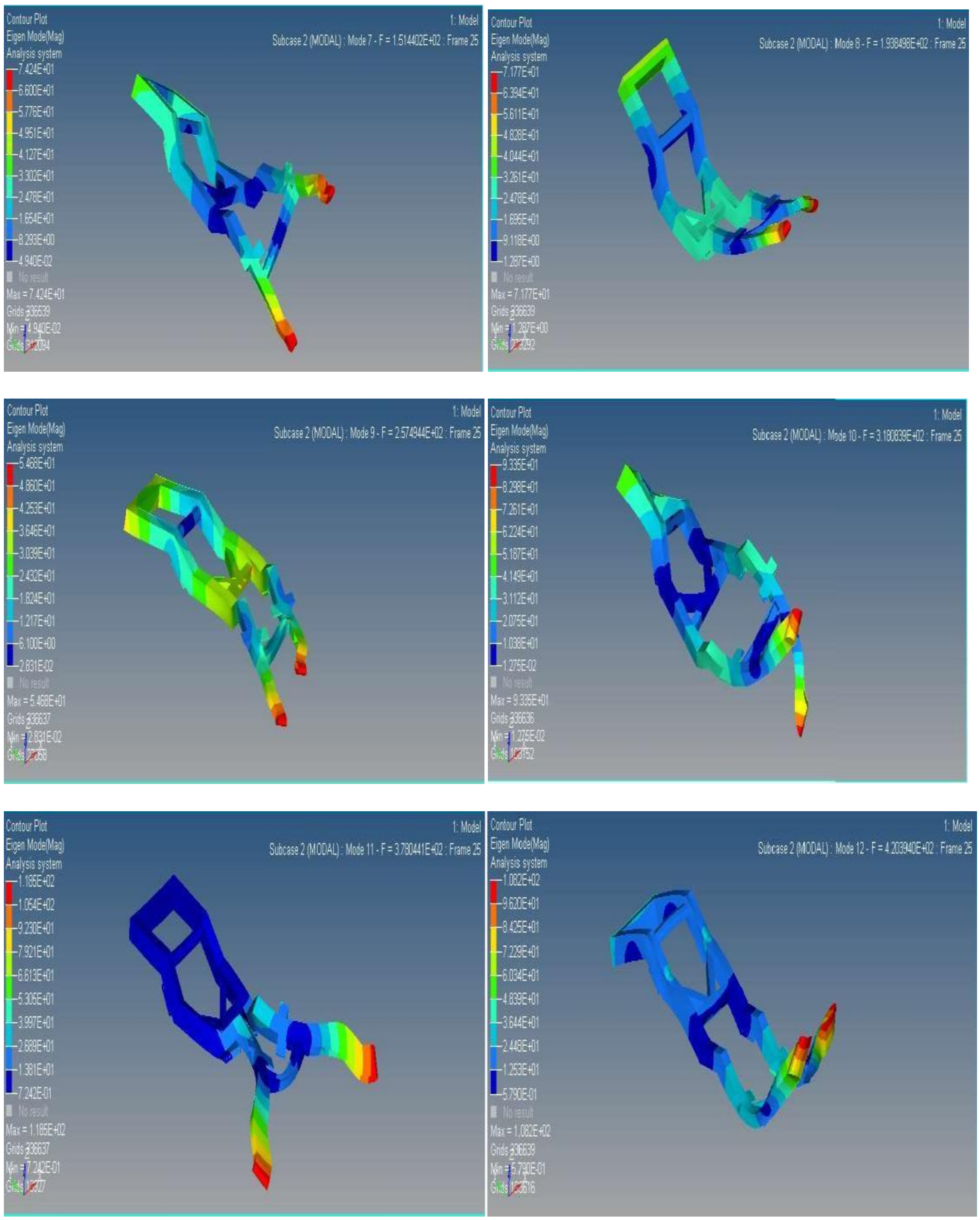


Fig 10.4 Modal frequency of different mode shapes of Q235 steel chassis

Material: CAST IRON

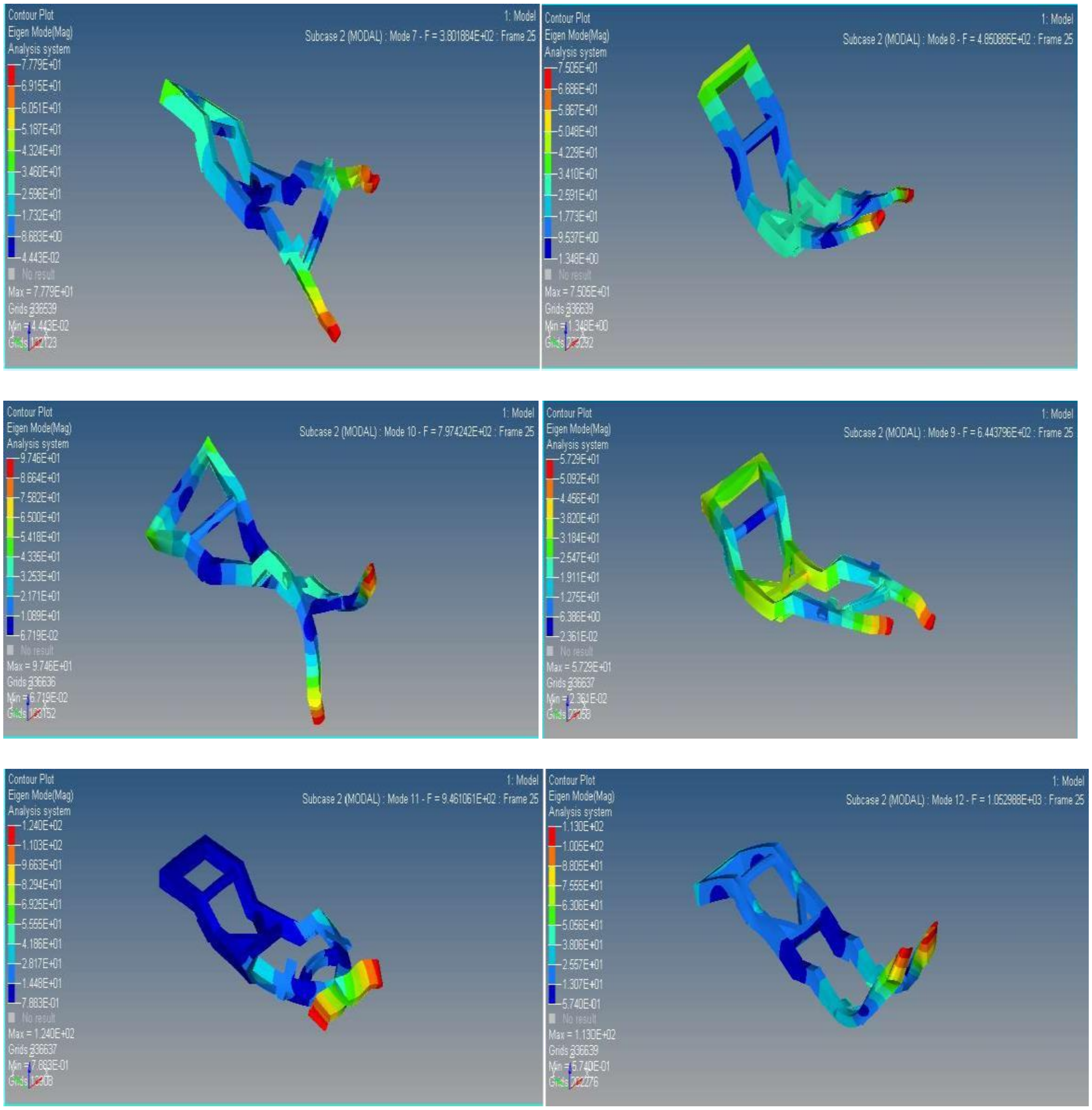


Fig 10.5 Modal frequency of different mode shapes of cast iron chassis

Material: Aluminum alloy

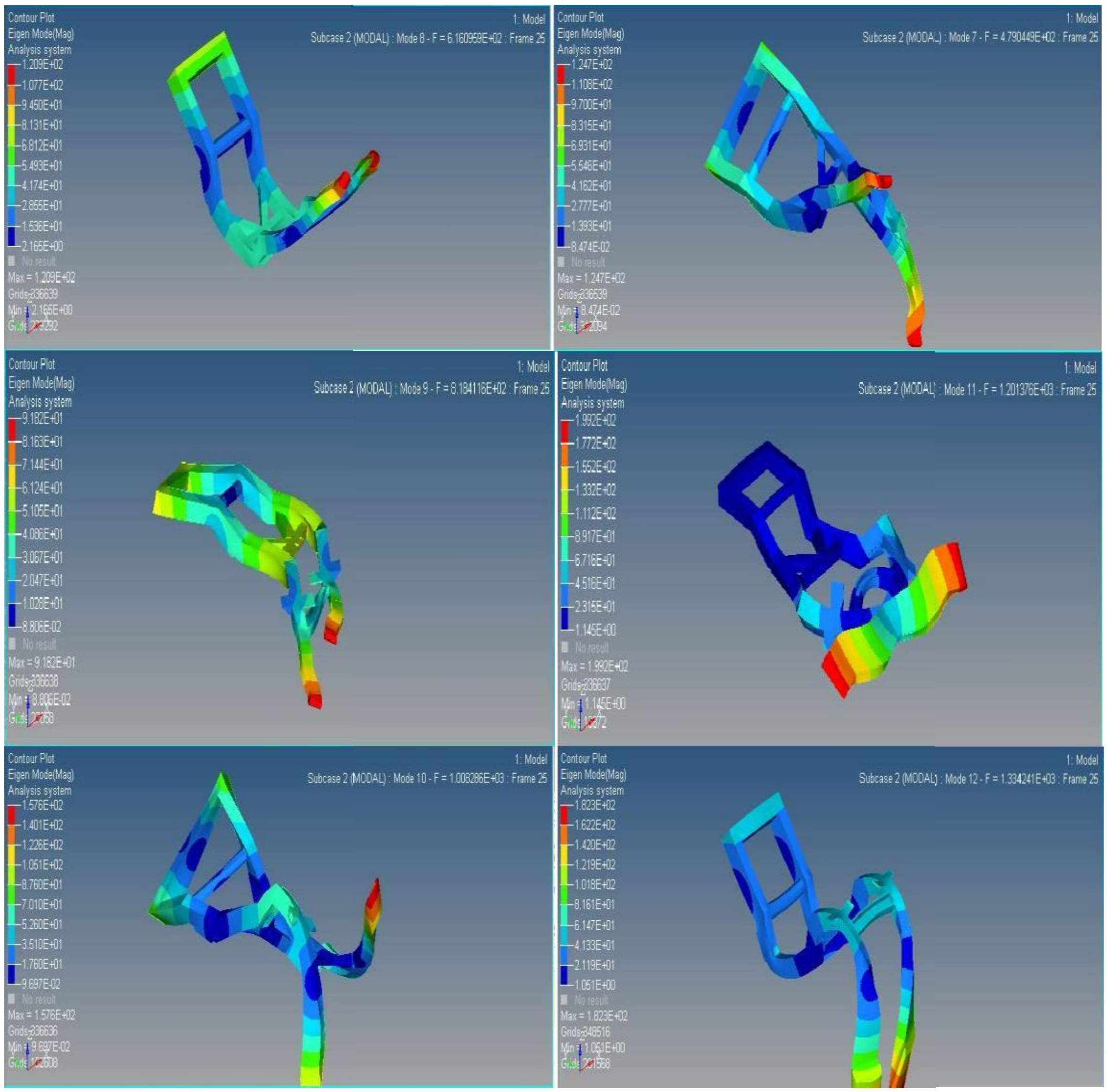


Fig 10.6 Modal frequency of different mode shapes of aluminium alloy chassis

CHAPTER 11

DYNAMIC ANALYSIS

The dynamic response of simple structures, such as uniform beams, plates and cylindrical shells, may be obtained by solving their equations of motion. However, in many practical situations either the geometrical or material properties vary, or the shape of the boundaries cannot be described in terms of known mathematical functions. Also, practical structures consist of an assemblage of components of different types, namely beams, plates, shells and solids. In these situations it is impossible to obtain analytical solutions to the equations of motion. This difficulty is overcome by seeking some form of numerical solutions and finite element methods.

11.1 PURPOSE OF DYNAMIC ANALYSIS

Static analysis does not take in to account variation of load with respect to time. Output in the form of stress, displacement etc. wrt time could be predicted by dynamic analysis (i.e. say what would be the magnitude of stress at 3 sec. or 10 sec.).

In static analysis velocity and acceleration (due to deformation of component) are always zero. Dynamic analysis can predict these variables wrt time/frequency.

During dynamic analysis the load applied on the chassis and momentum given to the wheel side is as shown in below figures.

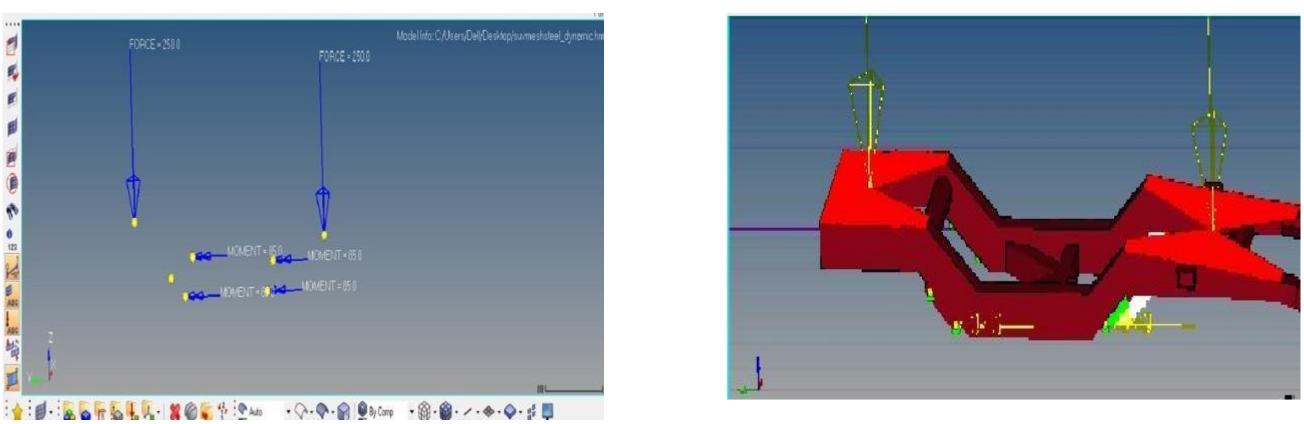


fig 11.1 Chassis with boundary and loading condition

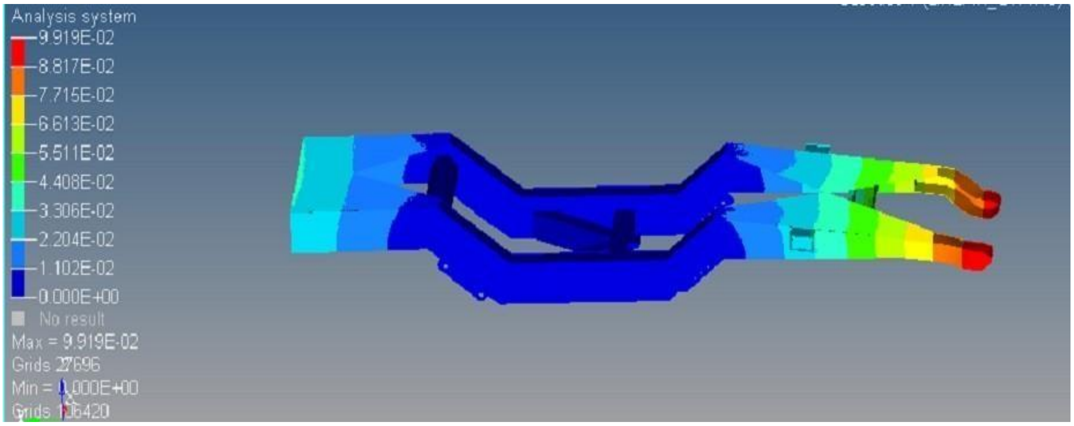


Fig 11.2 Maximum displacement is 0.0991mm under load 250 KN and moment of 85 Nm

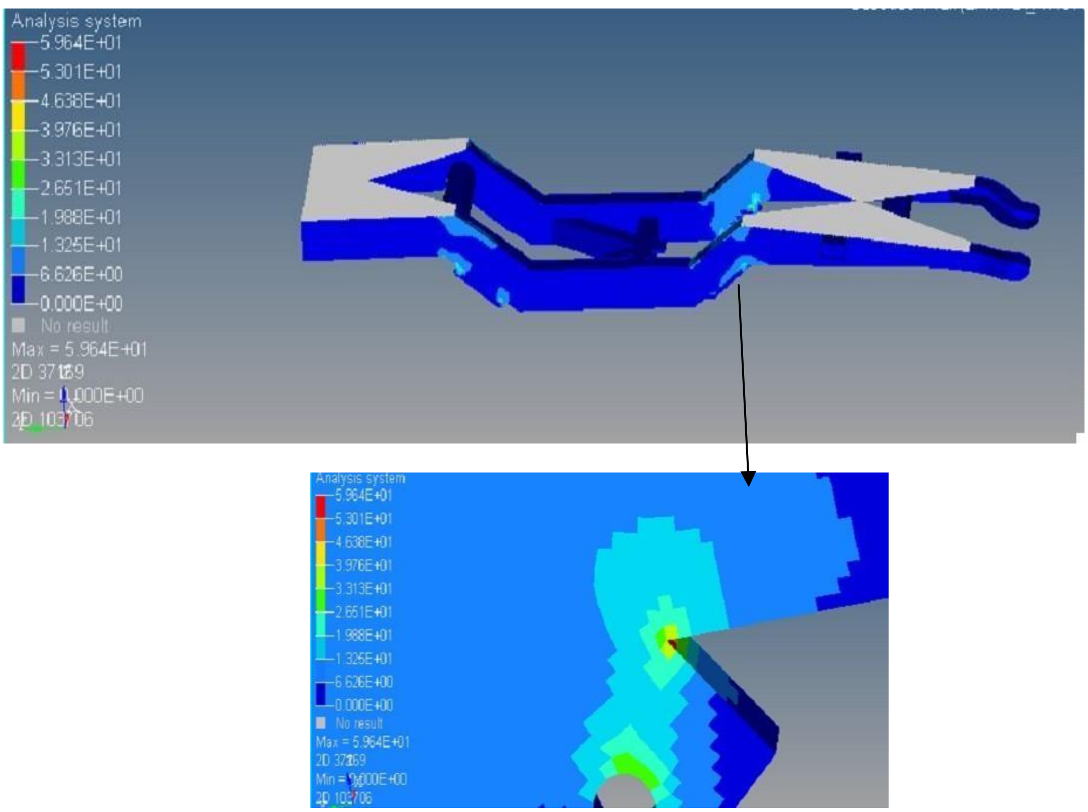


Fig 11.3 Maximum stress value and its region

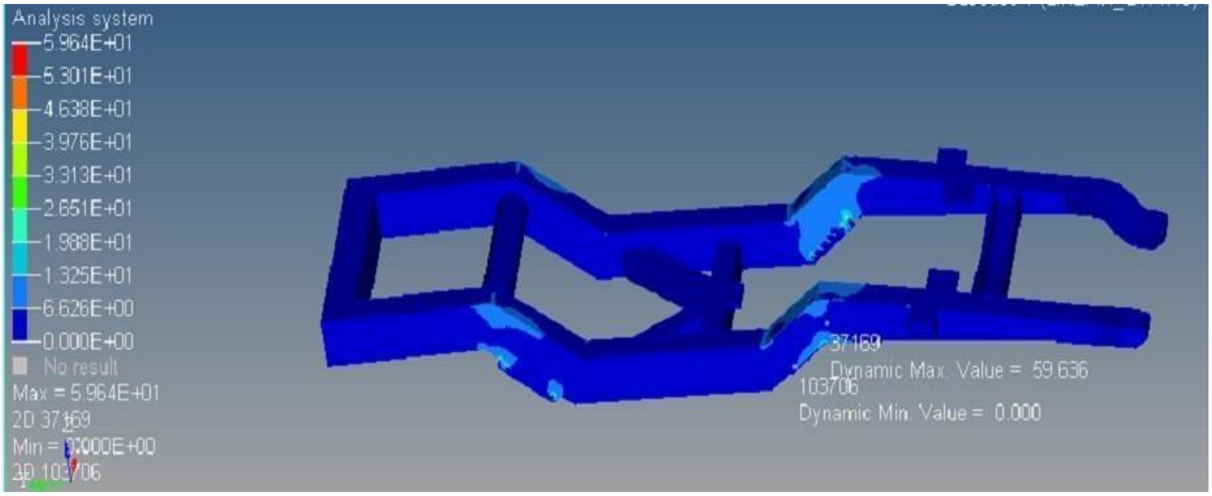


Fig 11.4 Maximum dynamic value is 59.636 N under load 250 KN and moment of 85 Nm

The dynamic analysis on the chassis of material Q235 steel under load of 250 KN and moment of 85 N m, in this loading condition chassis have a maximum displacement of 0.099 mm and with maximum stress value of 59.64 N/mm^2

CHAPTER 12

CONCLUSION

From static, dynamic and modal analysis on the chassis conclude that the chassis design is safe under given loading conditions. The deflection and stress pattern in the model of the chassis is obtained by performing static analysis and dynamic analysis.

Static analysis

Considering a safe load of 100 KN applied on the chassis maximum displacement and maximum stress values and maximum load up to which chassis can withstand are all given below

material	maximum displacement(mm)	maximum stress(N/mm2)	maximum load before yeild (KN)
Q235 STEEL	0.01149	10.54	2260
ALUMINIUM ALLOY	0.021	13.64	1300
CAST IRON	0.01984	11.19	640

Table-10 Static analysis results

Modal analysis

Modal analysis is a powerful tool to identify the dynamic characteristics of structures. Every structure vibrates with high amplitude of vibration at its resonant frequency. It is imperative to know the modal parameters- resonant frequency, mode shape and damping characteristics of the structure at its varying operating conditions for improving its strength and reliability at the design stage.

Q235 STEEL		ALUMINIUM ALLOY		CAST IRON	
mode	frequency(Hz)	mode	frequency(Hz)	mode	frequency(Hz)
1	451.6	1	453.9	1	357.70
2	569.18	2	570.9	2	451.49
3	578	3	581.58	3	457.66
1	1048	4	1054	4	830.87
4	1232.3	5	1239.3	5	975.95
1	1329.2	6	1336.5	6	1052.6

Table-11 Modal analysis results

Dynamic analysis

The dynamic analysis on the chassis of material Q235 steel under load of 250 KN and moment of 85 N m, in this loading condition chassis have a maximum displacement of 0.099 mm and with maximum stress value of 59.64 N/mm^2.

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