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STRUCTURAL AND MODAL ANALYSIS OF KNUCKLE JOINT AND FRAME TYPE MACHINE FOUNDATION

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Abstract : Finite element method (FEM) is a numerical method for solving a differential or integral equation. It has been applied to a number of physical problems, where the governing differential equations are available. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution. In this article, a brief introduction to finite element method is provided .The aim of the present paper is to study and calculate the stresses in knuckle joint using steady state analysis for different material and the knuckle joint is analyzed for structural steel , aluminium alloy. The knuckle joint is proposed to develop in the present study is for an applied force of 150 KN. also find out natural frequency of frame type machine foundation using modal analysis in ANSYS.

Keywords : FEM , Knuckle joint , Stress Analysis , Machine Foundation , Modal Analysis.

- **STRUCTURAL ANALYSIS OF KNUCKLE JOINT :**

1. INTRODUCTION :

A knuckle joint is a mechanical joint used to connect two rods which are under a tensile load, when there is a requirement of small amount of flexibility, or angular moment is necessary. There is always axial or linear line of action of load. Knuckle joint is joint between two parts allowing movement in one plane only. It is kind of hinged joint between two rods. Knuckle joint is used for connecting two rods whose axes either coincide or intersect and lies in one plane only. They are widely used in tractor trailer, tie rod in roof truss, joint between the links of suspension bridge and also used in steering system in between the steering rod and pinion of the steering gear .The common examples of the knuckle joints are link of a roller chain, tension link in a bridge structure, tie rod joint of roof truss, tie rod joint of jib crank, etc.

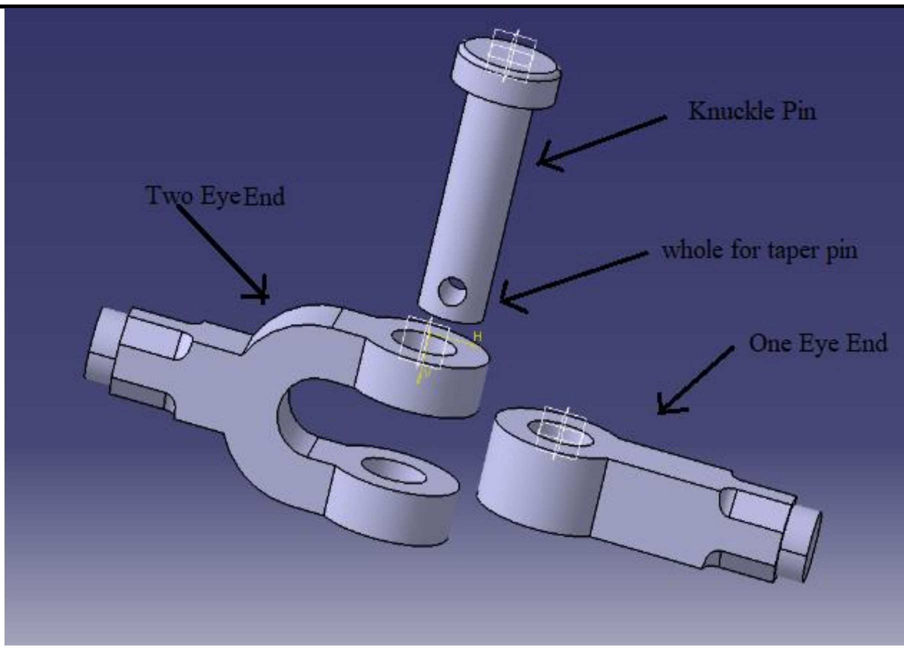

Fig 1. Knuckle Joint Diagram

The knuckle joint assembly consists of following major components:

1. Single eye.
2. Double eye or fork.
3. Knuckle pin.
4. Collar.
5. Tapper pin.

A typical knuckle joint consists of three parts: an eye, a fork, and a knuckle pin. The end of one rod is formed into an eye and the end of another rod is formed into fork with an eye in each of the fork leg. The eye is inserted into the fork and after aligning the holes in the eye and fork, the knuckle pin is inserted through them. The knuckle pin has a head at one end and at the other end it is secured by a collar and a taper pin or split pin. The simple definition of stress is that force divided by area. If the force is perpendicular to the area and pulling away from it, the stress is tensile. If the force is perpendicular to area and pushing towards it, the stress is compressive.

II) PROBLEM IDENTIFICATION:

a) To decide the best suitable material for Knuckle joint from available materials for same load carrying capacity.

b) To analyze the stresses using ANSYS software.

III) METHODOLOGY:

A. Designing Knuckle Joint:

Nomenclature:

P=Tensile load acting on the rod,
d =Diameter of the rod,
d1=Diameter of the pin,
d2=Outer diameter of eye,
t =Thickness of single eye,
t1=Thickness of fork

Calculations :

Outer diameter of eye	48 mm
Diameter of knuckle pin	24 mm
Thickness of single eye (t)	28 mm
Thickness of fork (t1)	18 mm

The material selected in the present investigate on Structural Steel, Aluminium and Cast Iron. The pin is having 24 mm diameter and the thickness of the fork-end is 18mm

Following material properties have been considered for the FEM analysis of Structural Steel:

1. Young's Modulus = 200000 Mpa
2. Poisson's Ratio = 0.3
3. Yield Strength = 250 Mpa
4. Factor of safety (F.O.S.) = 3

Permissible stress = Syt/F. O. S

= 83 MPa

Following material properties have been considered for the FEM analysis of Aluminium Alloy :

1. Young's Modulus = 71000 Mpa
2. Poisson's Ratio = 0.3
3. Yield Strength = 280 Mpa
4. Factor of safety (F.O.S.) = 3

Permissible stress = Syt/F. O. S

= 93 MPa

B. Meshing of Knuckle Joint:

The basic need for ANSYS analysis is to divide the whole section into many tetrahedral elements. This will enable us to analyze the stress of the components at distinct locations. A typical drawing of the meshing of the knuckle joint is shown in Figure 2.

Figure 3. represents the boundary conditions applied to the knuckle joint. The fork end is fixed and an axial load of 150 KN has been applied at the eye end.

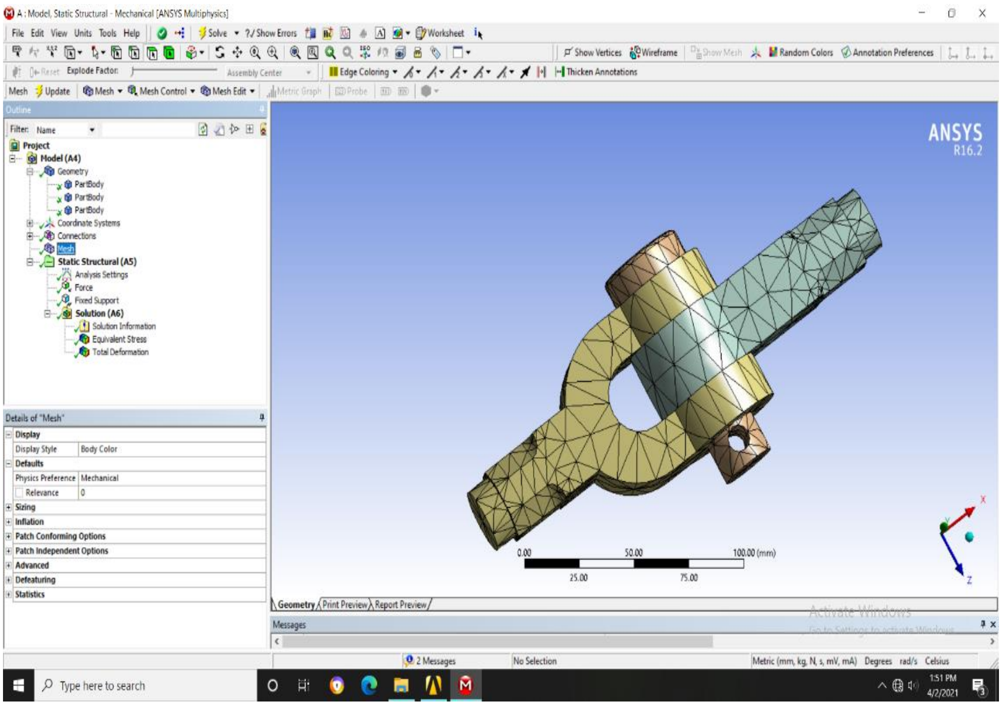

Fig 2. Meshing with Relevance size

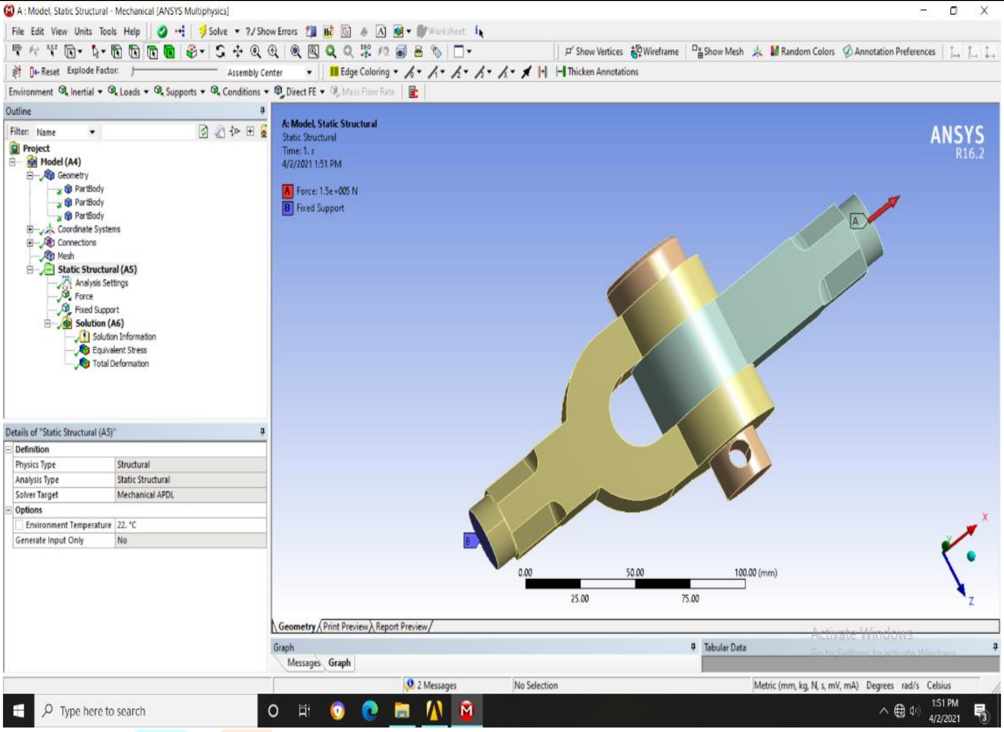

Fig 3 . Boundary Condition

C. Total Deformation of Knuckle Joint :

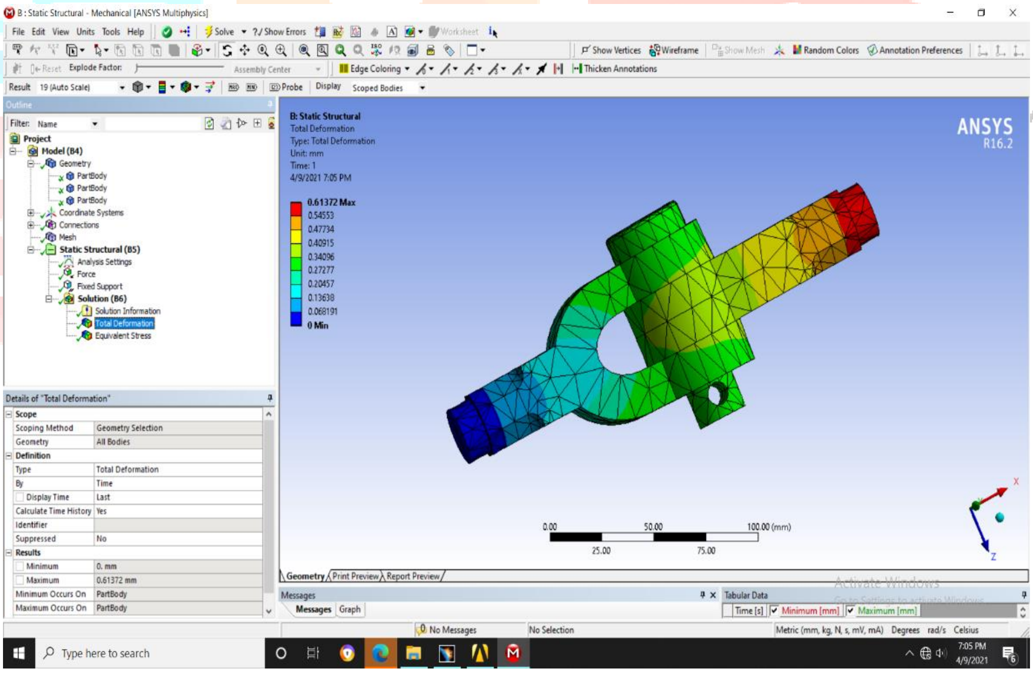

Fig 4. Deformation : Aluminium

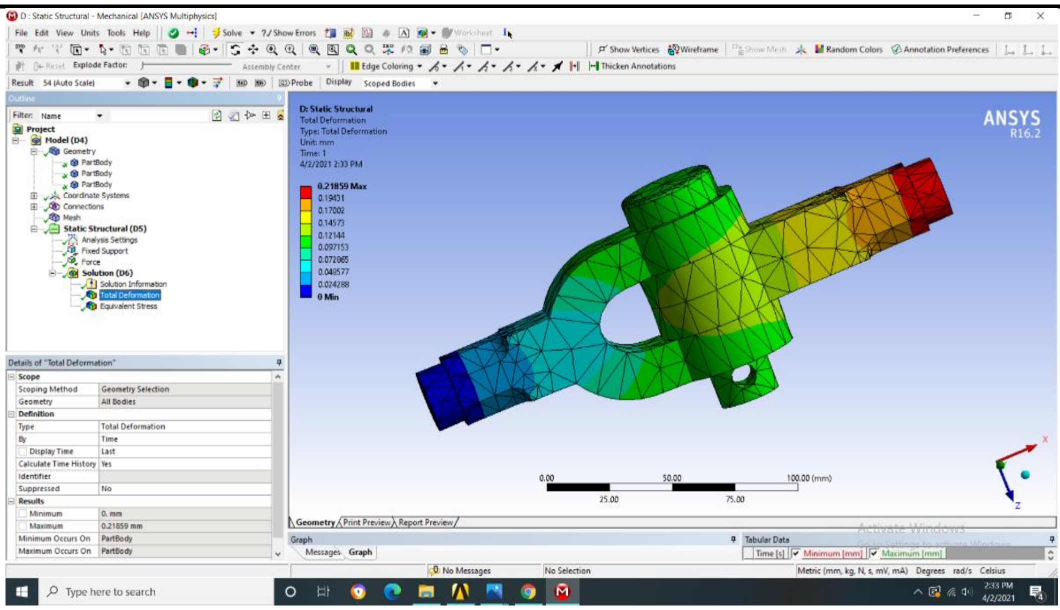

Fig 5. Deformation: Structural Steel

Knuckle joint is a part which experiences maximum stress. The material selection depends upon the fact that it could withstand the stresses develop in the joint and could deform elastically during its operation. ANSYS software has a unique module which can measure the amount of deformation i.e. change in length of the joints. Fig. 4, Fig. 5 show a typical diagram depicting the deformation in each part of the knuckle joint. It may be mentioned that maximum deformation is experienced at the two ends of the joints and minimum elongation occurred around the pin section.
The above results show that the maximum elongation at the two ends of the joints is as follows:

1) 0.61372 mm for Aluminium alloy
2) 0.21859 mm for Structural steel

The minimum elongation which is found around the pin is 0mm for all the materials.
Hence the elongation experienced by the components are less and can be used safely for the application.

D. Stress Analysis Knuckle Joint :

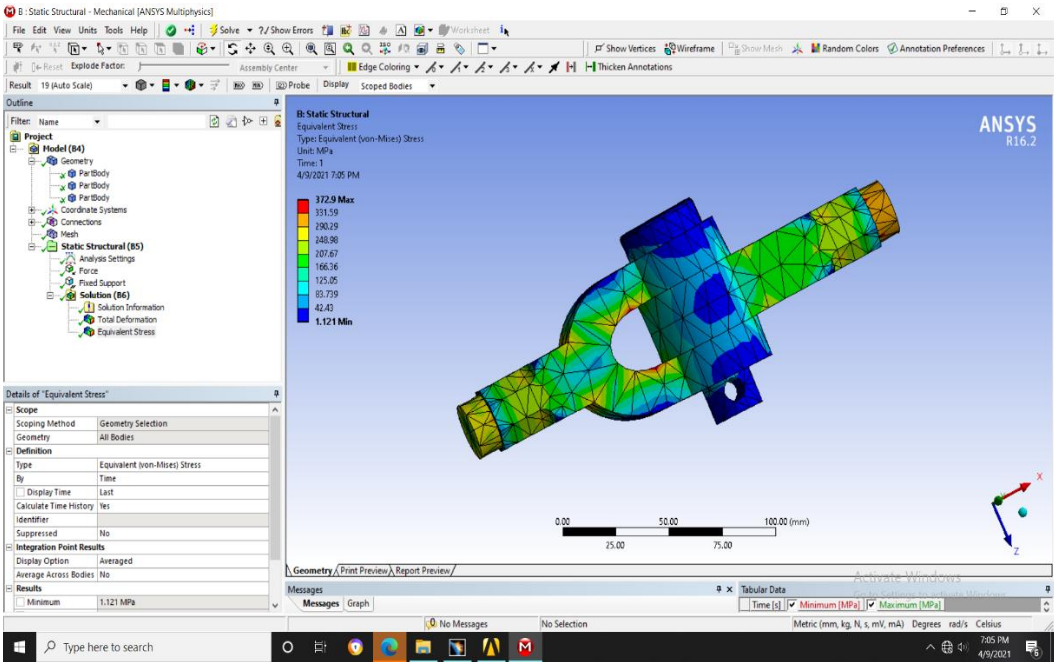

Fig 7. Max. Stress: Aluminium

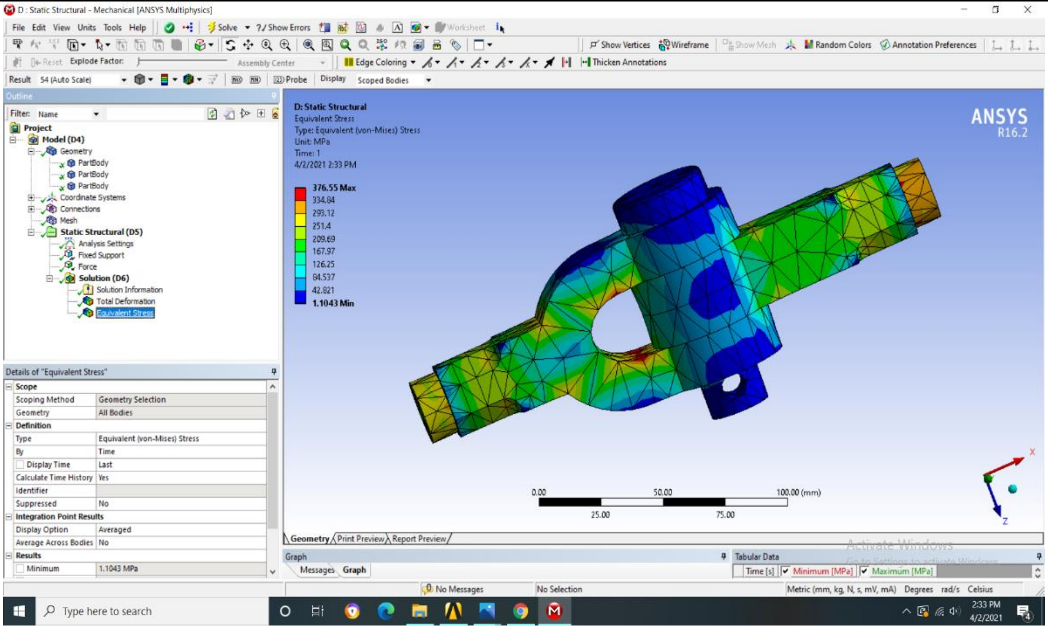

Fig 8. Max. Stress: Stainless Steel

When a load of 150 KN is applied in the system, the ANSYS analysis depicts that the maximum stress experience in the pin is as follows:
1) 372.9 MPa for Aluminium
2) 376.55 MPa for Structural steel

The ANSYS analysis indicated the maximum stress experiences at the interface between the pin, eye-end and the fork end.
It is evident from the aforementioned literature that Aluminium, Structural steel with maximum yield strength 280 Mpa and 250 Mpa, this clearly states from the analysis that pin of 24 mm diameter cannot sustain an applied load of 150 KN and hence the design for all the two materials are unsafe.

IV) RESULTS :

Material	Total Deformation (mm)	Maximum Stress (Mpa)
Aluminium	0.61372	372.9
Structural Steel	0.21859	376.55

- **MODAL ANALYSIS OF FRAME TYPE MACHINE FOUNDATION :**

MODAL ANALYSIS : Modal analysis helps to determine the vibration characteristics (natural frequencies and mode shapes) of a mechanical structure or component, showing the movement of different parts of the structure under dynamic loading conditions, such as those due to the lateral force generated by the electrostatic actuators. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions.

I) FRAME TYPE MACHINE FOUNDATION :

This type of machine foundation consists of vertical columns with horizontal frame at their tops. It is used for larger machines. The machines are rested on the top of frames. The vertical and horizontal members of this foundation can be constructed by different materials.

- **Categories of machine foundations :**

1. **Reciprocating machines :** It produces periodic unbalanced force and operating frequency is 600rpm. For designing unbalanced force is taken as varying sinusoidally.
2. **Impact machines :** It produces impact loads at an operating frequency of 60-150 blows/min. Dynamic load attends the peak within short duration and then die out quickly. Designed as over tuned.
3. **Rotary machines :** These are high speed machines with high operating frequency. Hence the foundations are designed as under tuned.

- **Types of machine foundation :**

1. Wall type
2. Block type
3. Caisson type

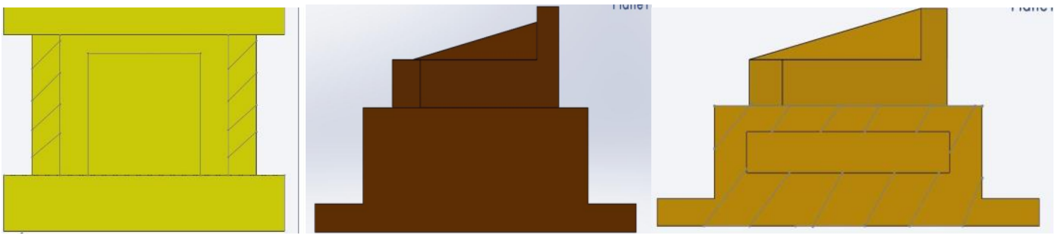

Fig 1. Types of machine foundation

- **Criteria for the Design of Machine Foundations :**

1. Static Loading

- Without shear failure.
- Without any excessive settlement.

2. Dynamic loading

- No resonance

As per 2974 part1, r<0.5 (under tuned)
r>0.5 (over tuned)

- The amplitude of motion should not exceed limiting amplitude. Permissible amplitude is 0.2mm.
- Vibrations must not be annoying to the persons working in factory or surroundings.

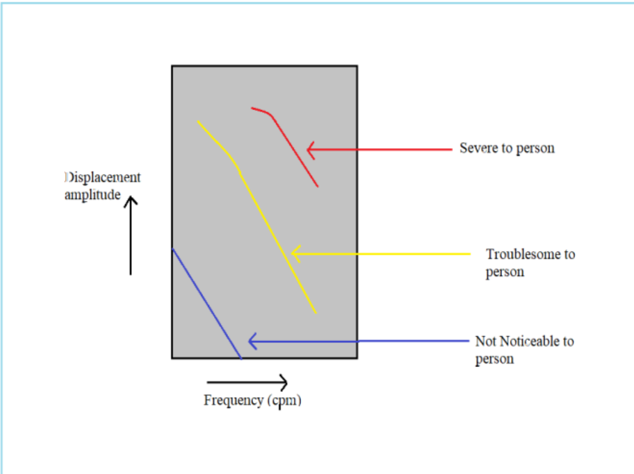

Fig 2. Displacement amplitude vs. frequency

II) MODEL UNDER STUDY:

1. **Design of Machine Foundation :**
   - **Material : Concrete**
   - **Dimensions : 6 * 6 mm**

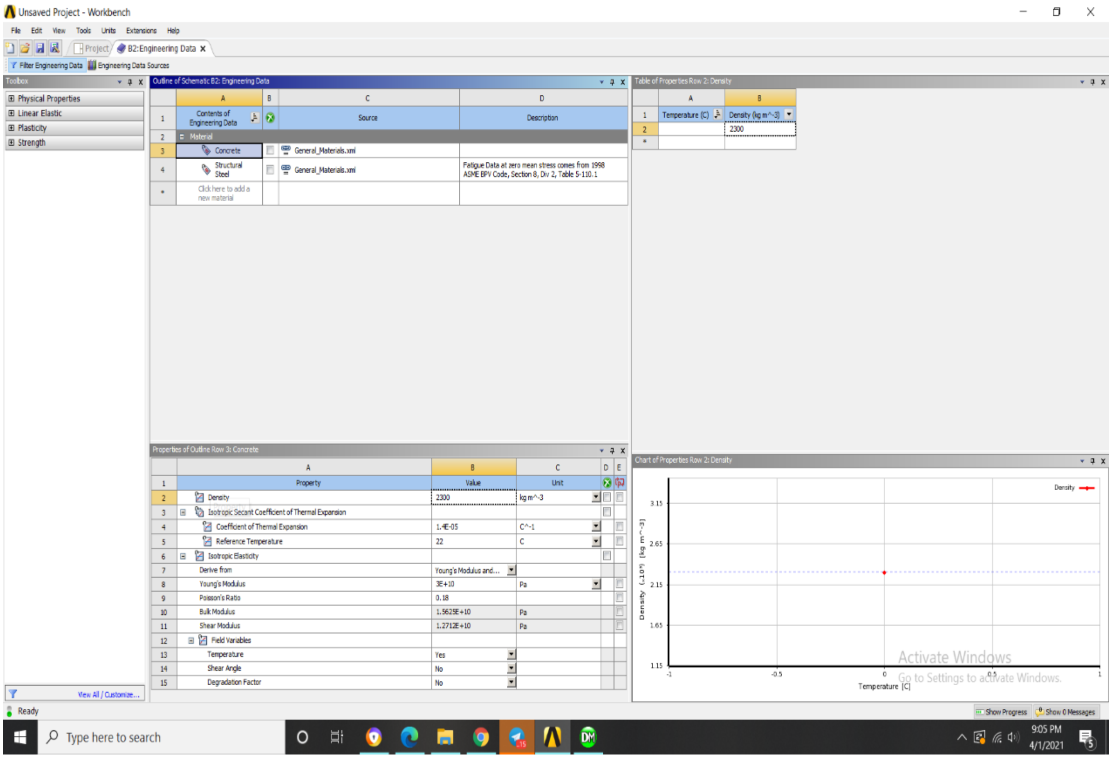

Fig 1. Basic Details of geometry

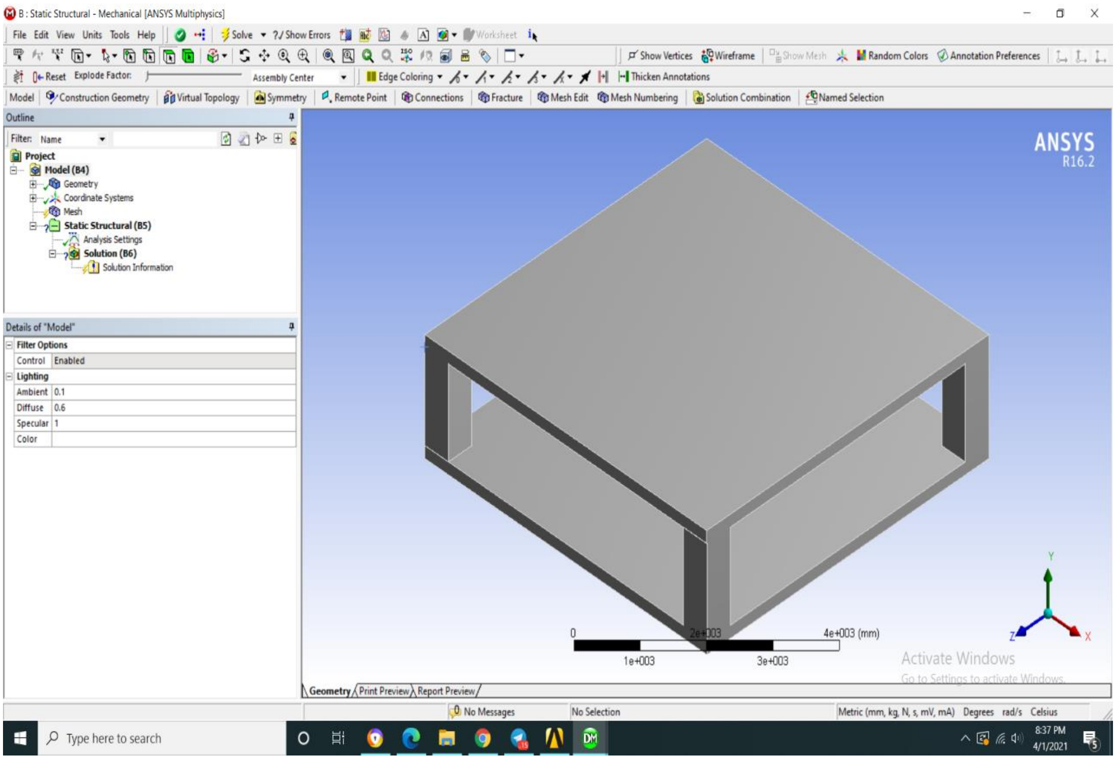

Fig 2. Geometry of frame type machine foundation

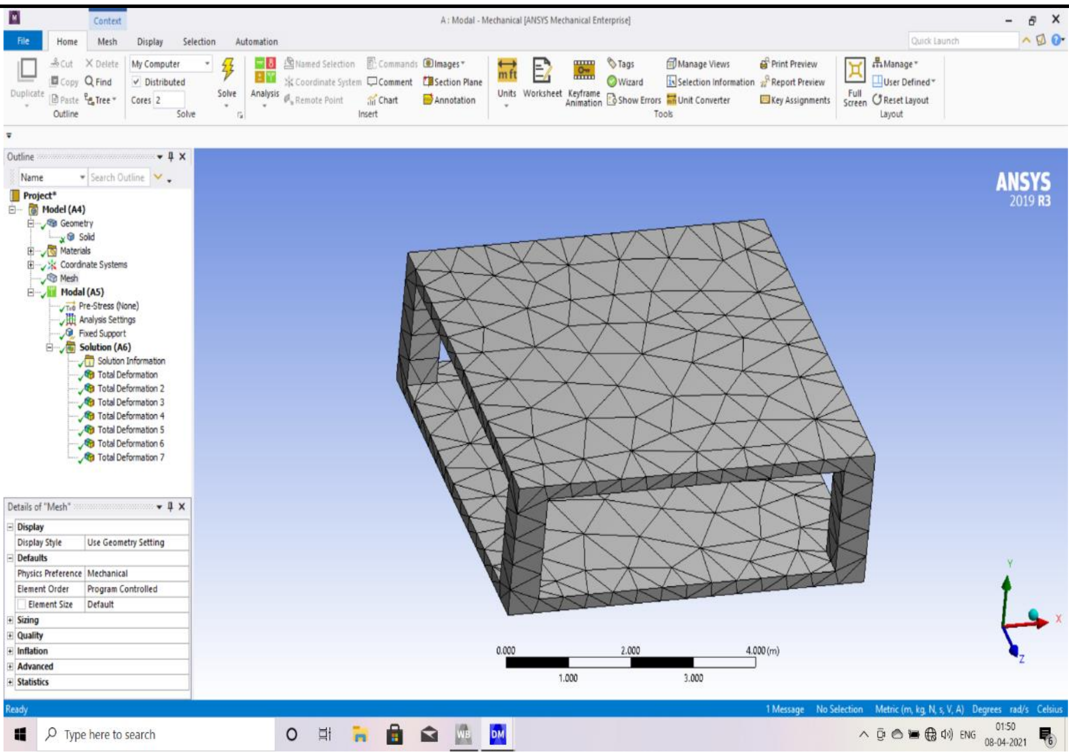

Fig 3. General meshing

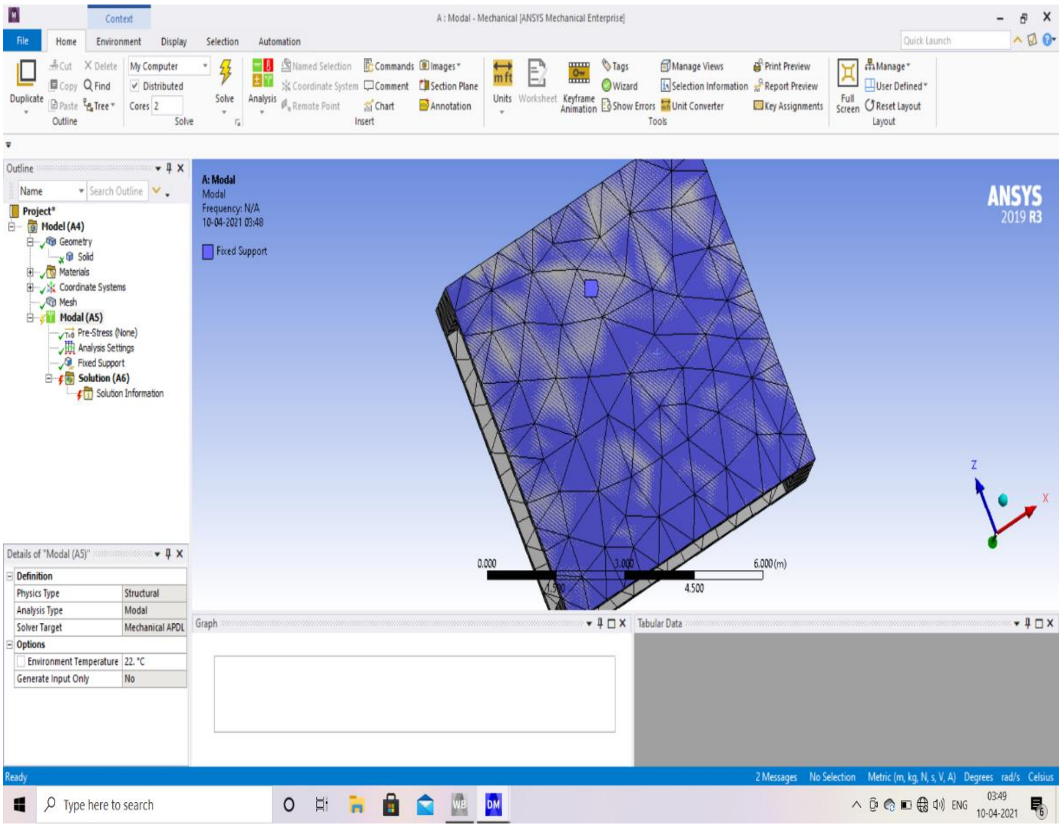

Fig 4.Fixed support

2. Total deformation of machine foundation with frequency :

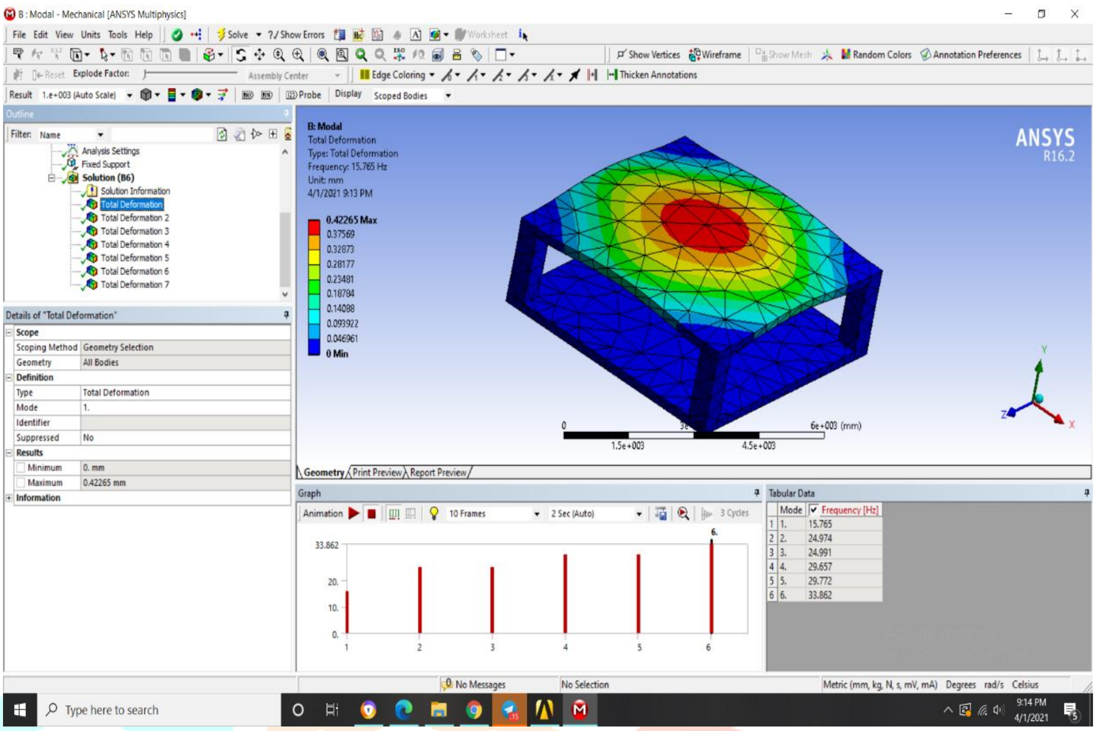

Fig 5. Mode 1 with frequency 15.765 HZ

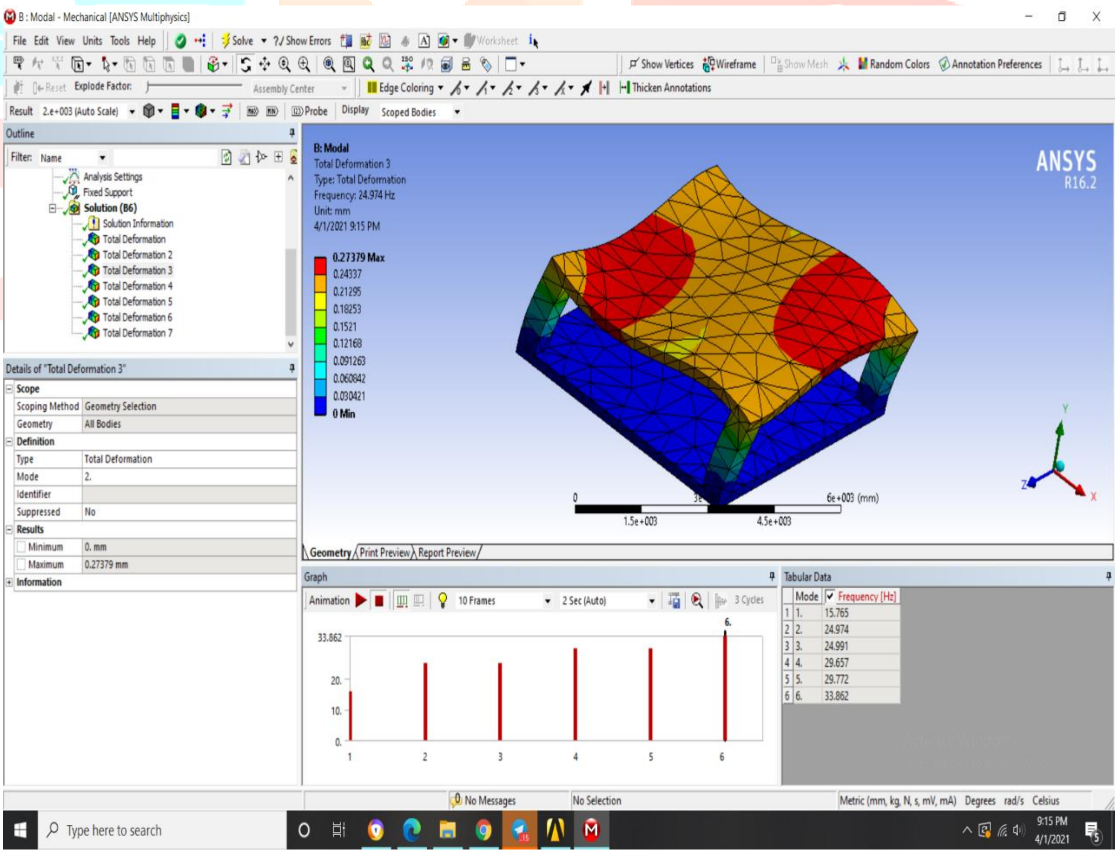

Fig 6. Mode 2 with frequency 24.974 HZ

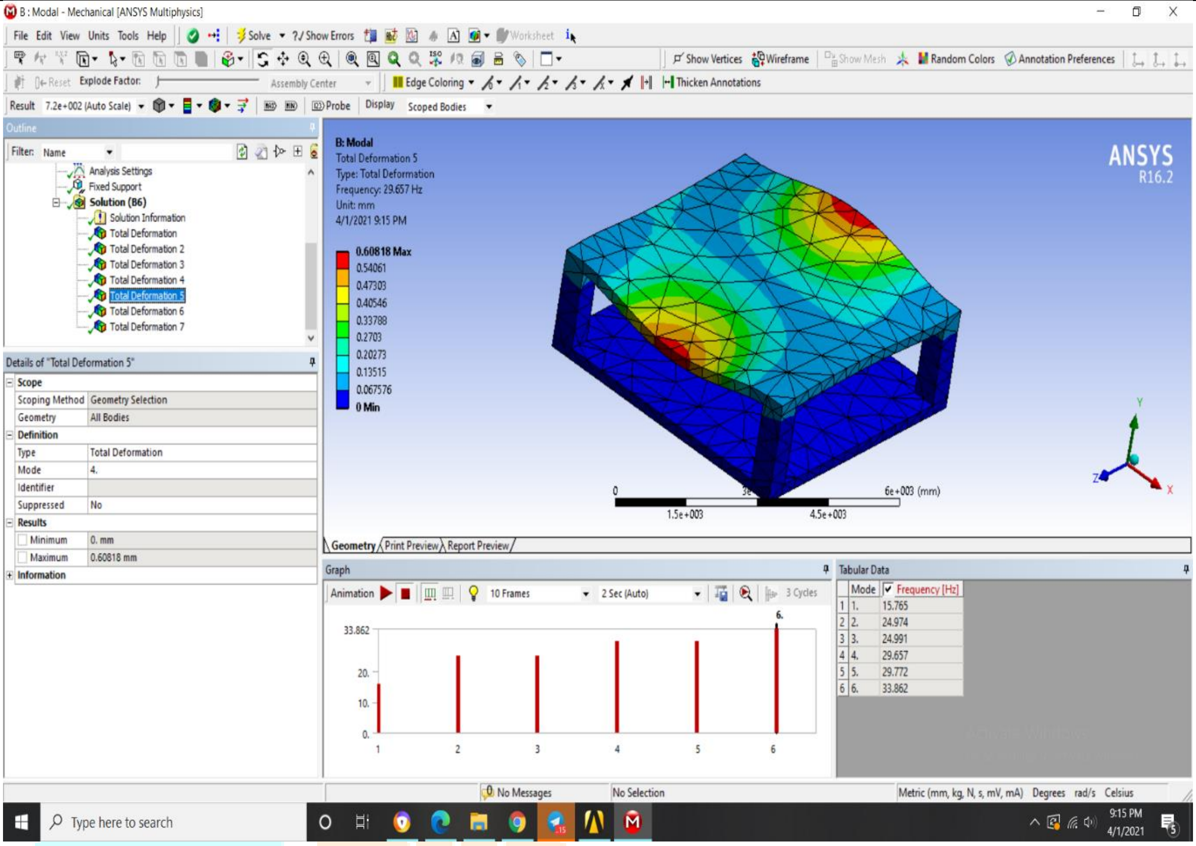

Fig 7. Mode 4 with frequency 29.657 HZ

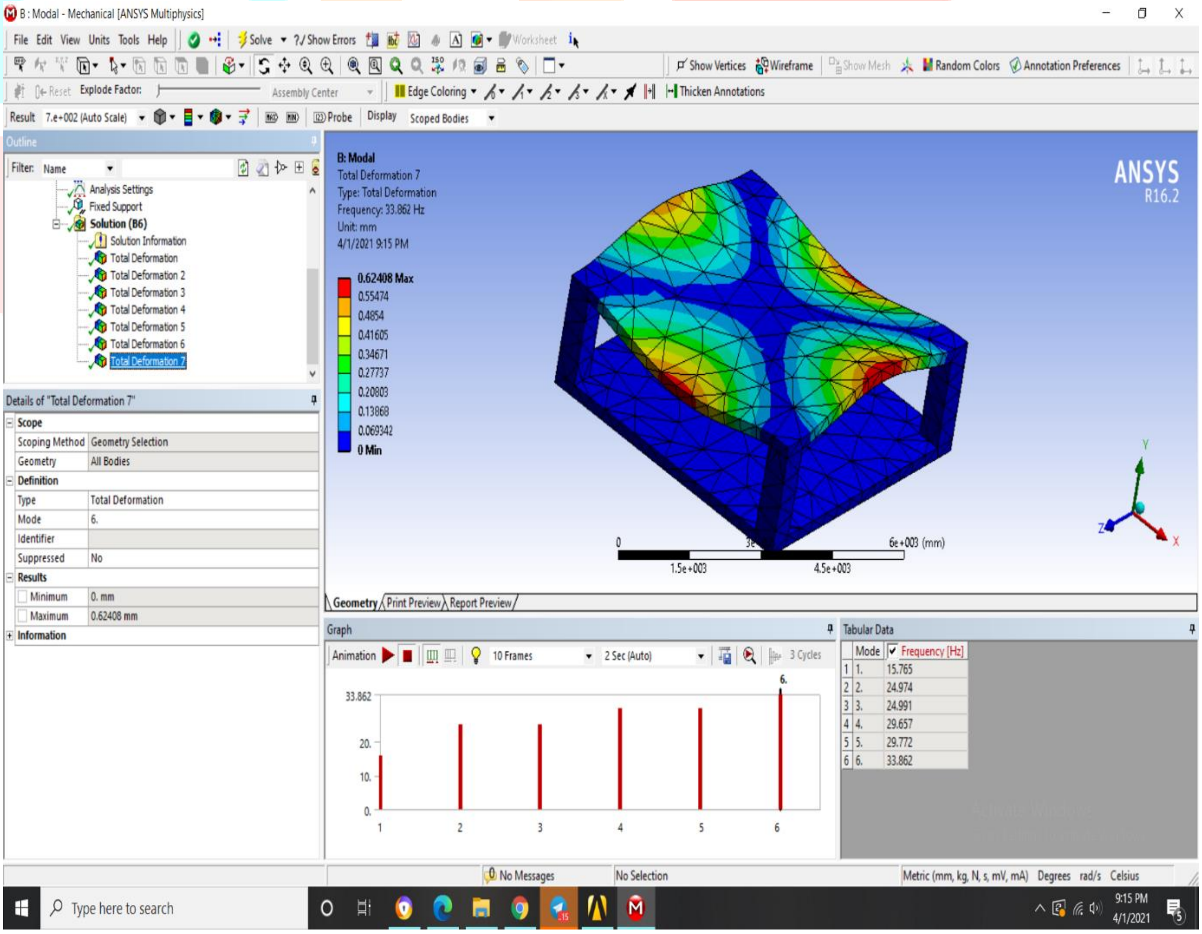

Fig 8. Mode 6 with frequency 33.862 HZ

II) RESULTS :

MODE	FREQUENCY(HZ)
1	15.765
2	24.974
3	24.991
4	29.657
5	29.772
6	33.862

CONCLUSIONS :

- It has been observed that stresses developed for knuckle joint made of aluminium and knuckle joints made of structural steel can sustain maximum tensile load without failure.
- Aluminium alloys weigh lighter than other materials. The total deformation is aluminium alloy is also negligible.
- For modal analysis as we increases the number of modes the frequency of modes increases.

FUTURE SCOPE :

- Research can be carried out on Steering knuckle joint which is used in automobiles.

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