GAIT CYCLE 3-D CAD MODEL LOAD ANALYSIS OF HUMAN KNEE JOINT FEMUR

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ABSTRACT

Knee joint is a very complex structure in the body which is an indispensable part during variety of locomotion's carried out in a lifetime of a human being .It can take place from standing, walking and running to doing variety of mechanical work. However, gait cycle analysis primarily focuses on studying the motion of leg through cyclic divisions or stride and step of two multi-segmented body limbs and total body mass. Major part in knee joint is femur, tibia, patella and meniscus. It has two articulation or we may say rotating portion between femur and patella. Knee joint is a flexible joint which permits rotation in variety of ways and direction. In the distal end of femur there is a possibility of a horse- shoe shaped bend in front end of the femur. The two ends of the femur extend backward and forward and are called medial and lateral condyles . Knee joint is blended and flexed to compensate for incongruence of bone in motion. In this experiment we have primarily focused on stress, strain, displacement and load calculation mainly for, femur at pressure angle in x, y and z direction of the plane.

Keyword : - *Knee joint, femurs ,3-D CAD Model*

1.Introduction

.Gait is the way locomotion can be achieved through the human body.Walking is the mostcommon gait used for the study.it is affected by mainly shape, position and function of neuromuscular and musculosk Based on CT scanning pictures from a volunteer's knee joint, a three-dimensional finite element model of the healthy human knee joint is constructed including complete femur,tibia, fibular, patellar and the main cartilage and ligaments. This model was validated using experimental and numerical results obtained from other authors. The pressure distribution of contact surfaces of knee joint are calculated and analyzed under the load action of 'heel strike', 'single limb stance' and 'toe-off'. The results of the gait cycle are that the contact areas of medial cartilage are larger than that of lateral cartilage; the contact force and contact areas would grow larger with the load increasing; the pressure of lateral meniscus is steady, relative to the significant variation of peak pressure in medial meniscus; and the peak value of contact pressure on all components are usually found at about 45% of the gait cycle. Femur and patella have to face largest load brunt in gait cycle .

1.2 Aim of experiment

In this project we have validated the procedure to build 3-D model of knee joint femur from CT scan data and carry out simulation at all the three important phases of gait cycle and balanced standing posture to obtain different pressure,stress,strain and displacement distribution in knee carried out at different pressure and stress angles.

2. METHOD USED FOR ANALYSIS

2.1 LITERATURE REVIEW

Stress analysis is a discipline under engineering, an effective method to determine the strains and stress acting upon any material. Those materials are subjected to any particular load and forces in any direction. Stress analysis is used for keeping any specific structure in a functional state and maintaining its structure, with that investigating the causes which may lead to the failure and damage to that structure[1]. Stress analysis is done in any geometrically described structure with that checking the properties of the material used in that specific structure, where the loads being applied. Stress analysis can be done through computational analysis, mathematical techniques, and analytical, mathematical approach or combination of two three methods. Mechanical behavior of knee joints is a complex system. There are two states of mechanics in which the body behaves: one is the static state where body in a system is acting on a constant motion, it's either at a rest state or moving with a constant velocity[2]. The other state of the body is dynamic, in which the body in the system is in motion where there is a presence of acceleration and the study of the body in that state is studied according to time, velocity, displacement, speed of the body in a particular linear direction or in any certain direction, with an involvement of forces acting on the body or any applied load.

The knee joint is one of the most important joints in the human body. The knee joint is also called as the hinge joint which performs lots of activities like standing, walking, sitting, flexion, extension, with bending of knee etc. with different loads acting upon it with a certain pressure[3]. Knee joint in a human body is made up of mainly 3 components those are tibia, femur and patella with a presence of deformed body. People suffering from knee joint pain and any injury to knee risking everyday and in sports activity leads to occurrence of wearing and tearing on the knee joint. Failure and improper functioning of knee joint due to defect occurrence in the knee may lead to operative solution i.e. removal of components of the knee with an artificial implant termed as knee prosthesis. Examination of defect in knee can be done by X-ray and CT scan as well as with MRI imaging. Mostly knee replacement is done through a small incision, small as 3-4'[4]. According to the defect and failure condition total and partial knee replacement is carried out. In total knee replacement a large implant is inserted in place of the knee joint which favors long term durability and biocompatibility. In spite of excellent working

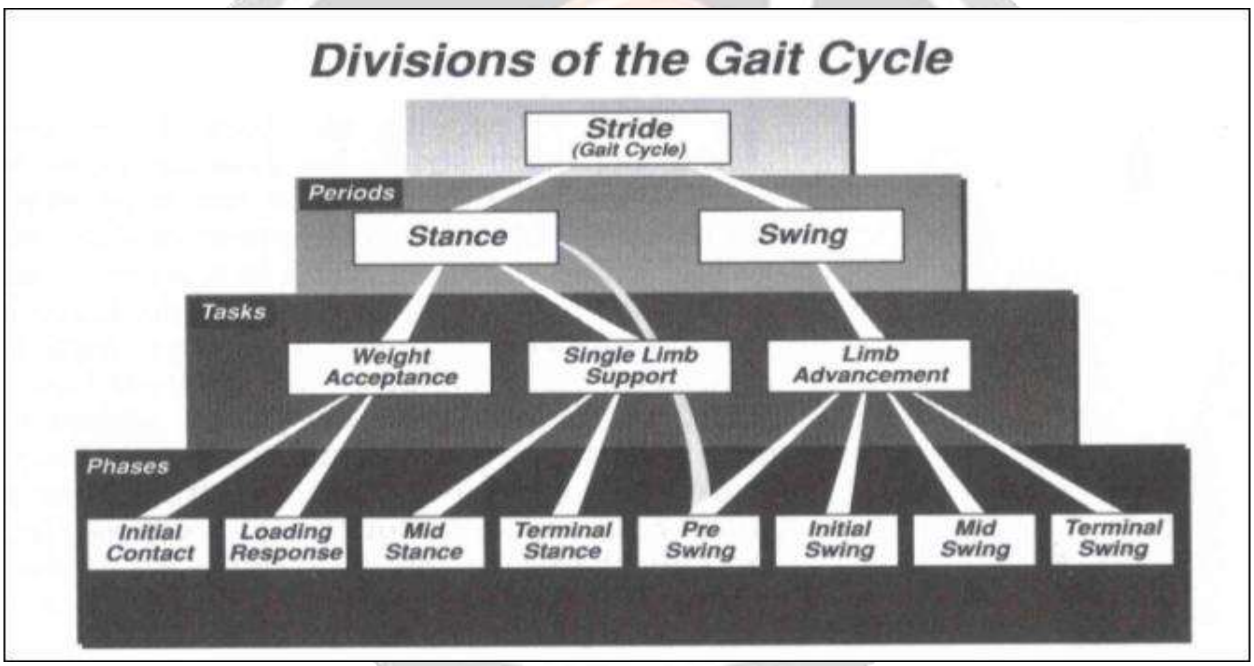

Fig- 1: Division of gait cycle

and result it frequently fails in around 4-5 yrs due to chronic inflammation of generated wear particles which results in implant failure giving defective outcomes. Those wear particles interact with the immune system leading to toxicity affects in in- vivo[5]. Due to this hypersensitivity reaction occurred from immunotoxic. Ni, Co, Cr are common sensitizer but when comes in contact with Ti and its alloy they show hypersensitive reaction leading to corrosion and wear of metal implant. The usefulness of material tested according to hypersensitivity of the material as respect to the sensitizers CoCrMo towards the implant material and checking its reliability of the properties of the implant in the target site and its compatibility and durability checking its toxicity rate. Partial knee replacement is done by two methods i.e. unicompartmental partial knee replacement and tri/bicompartmental partial knee replacement. In unicompartmental partial knee prosthesis a Unicondylar fixed bearing knee implant, which is the most commonly used modeled prosthesis or a mobile bearing knee implant. Bi or Tricompartmental partial knee implant consists of one or more component of knee causing less damage [6].

2.2 CT SCAN DATA SELECTION

The legs were scanned using a Siemens 3 Tesla MRI scanner (Siemens, Trim Trio Erlangen, Germany)., field of viewFoV) of 224 mm x 224 mm, matrix size of 448 x 448 pixel size. The Slice thickness was 0.75 mm and data was taken in transversal Plane.

CT scan data was obtained for an patient from an authorized medical professional to carry out this project after his due permission. This data was converted into 3-D CAD model using balanced standing posture . Further, the gait phases will be modeled in MIMICS software and results have been discussed.

Steps :

1)Obtain CT scan data from authorized personnel of patient having pathological or non-pathological condition.

2)Convert 3-D CAD model of this data using CAD modeling software such as Solidworks , Inventar,etc. .This data can be further analyzed for different loading and pressure angles in CAD modeling software such as Solidworks , Inventar,etc.

3)This data can be further analyzed in software such as MIMICS for actual modeling and getting effect of different gait phases in different materials.

4)This data can be compared with normal weighted person and results be discussed.

5)This data can be further analyzed for different weighted and age group person.

3. ANALYSIS OF 3-D CAD MODEL USING ANSYS WORKBENCH 12

Analysis is the main part in which we get aware about different stresses, strain and displacement. In our analysis the stress is calculated at different loading condition with different biomaterials. The analysis is done in **ANSYS Workbench 12.** In this software first the project with static structural is selected as our aim is to do static analysis. Geometry is imported which is in .iges (initial graphics exchange system) format. Then material properties are added in the current project. Then model is generated and surface is converted into solid and material is added. Meshing is done with the tetrahydel triangles with medium mode. Fixed support is given at particular surface area. Loading is applied at that area where it actually applies. After importing all required data the solution for stress, strain and deformation is selected and finally the solution is done. Now results can be seen on screen.

3.1 Analysis steps

a) Importing geometry

For FE analysis of femur bone, firstly the three dimensional model of femur was developed. In the present study we have used an ideal femur bone model as presented. The model used represented an ideal human reconstructed from CT (DICOM) images. The model was received as (.stl) file then it was converted into .iges imported to ANSYS Workbench 12.

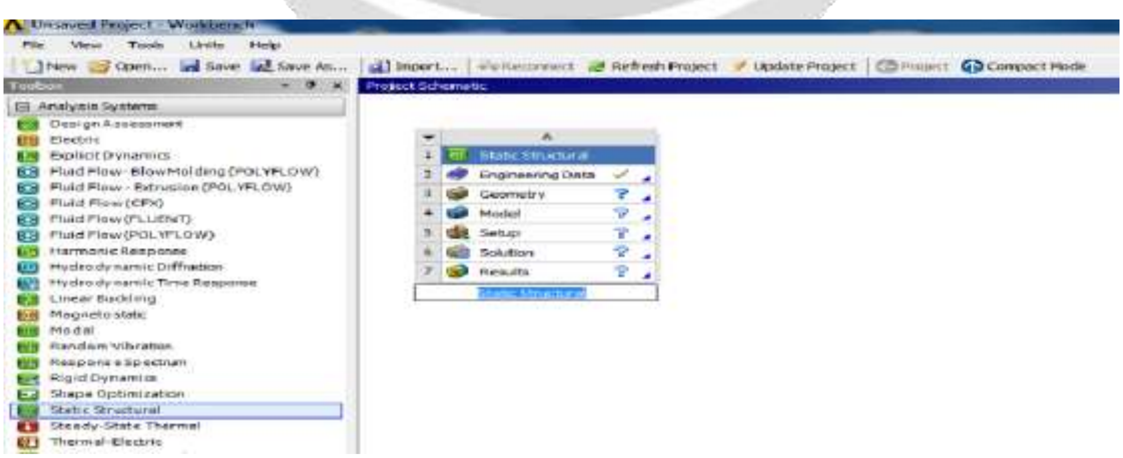

Fig- 2: Importing geometry

b) Adding material properties

Material properties like density, young modulus, yield strength and Poisson's ratio are given to the project.

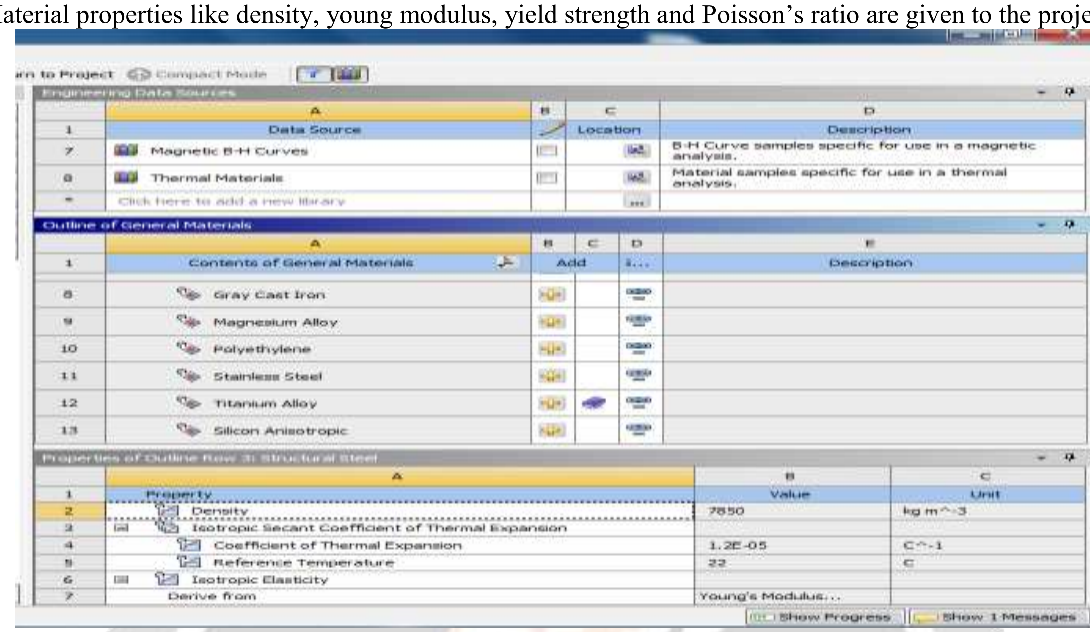

Fig- 3: Material addition

c) Model generation

Model is generated after importing geometry and giving material properties.

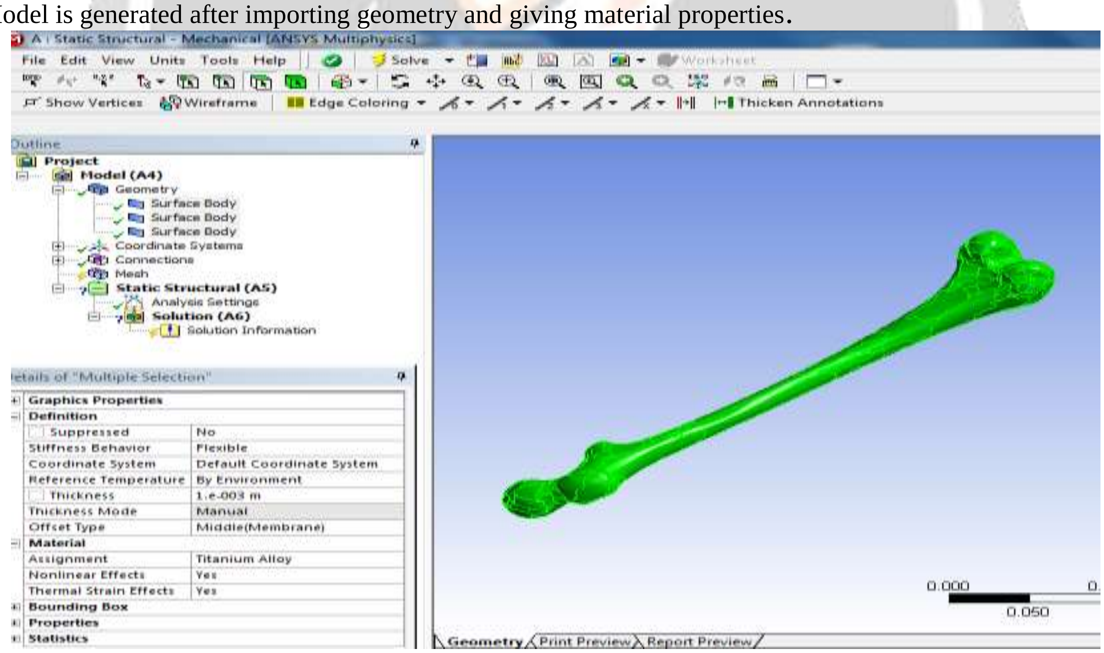

Fig- 4: Model generation

d) Meshing

After importing complete geometry meshing is done. For this model tetrahydel meshing is created with minimum element size 0.25 mm and maximum element size 1.25 mm. after generating meshing 36065 nodes and 35205 elements are created in the geometry.

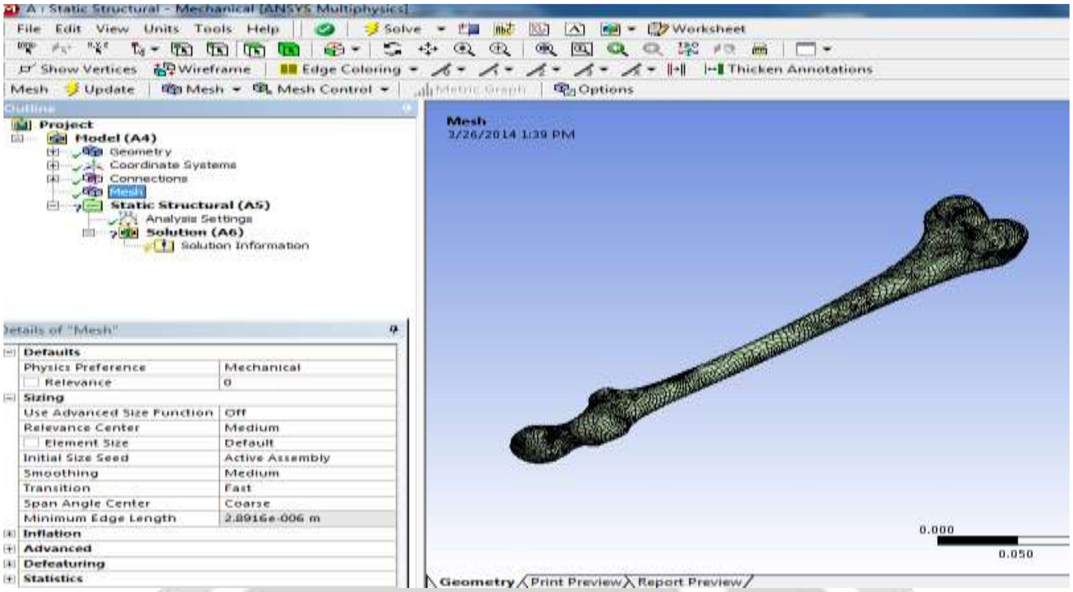

Fig- 5: Meshing

e)Fixed support

Fixed support is given to model to constrain movement of the model and displacement. The fixed support is given at the bottom of the femur.

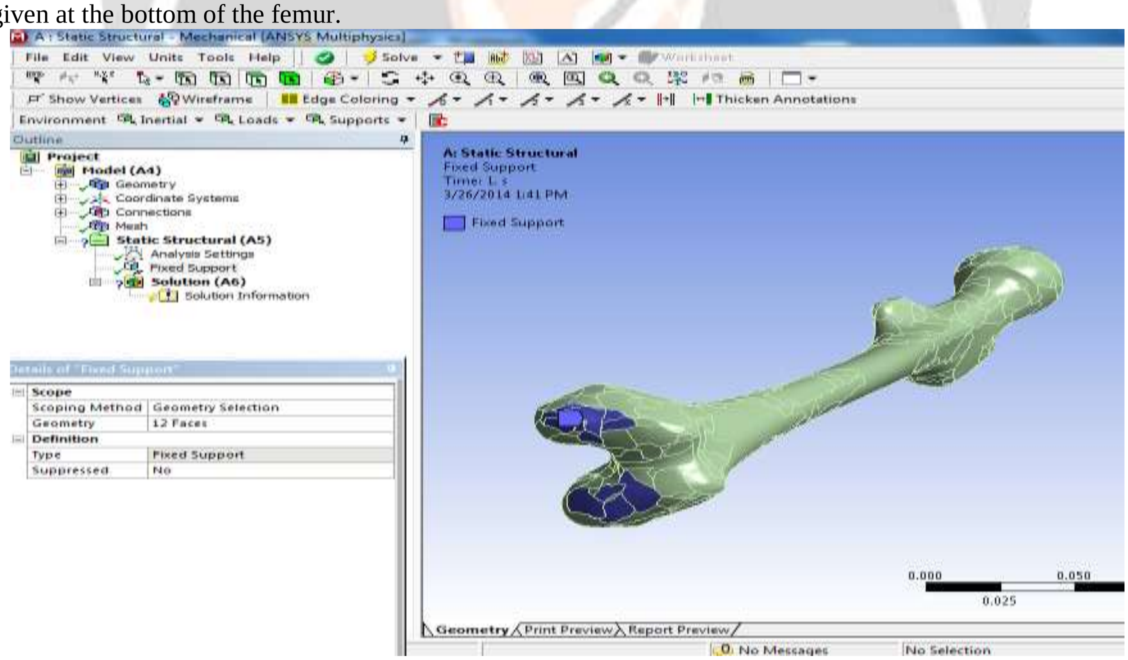

Fig- 6: Fixed support

d) Loading condition

Load is given to the model for stress analysis. Load is applied at the head of the femur model.

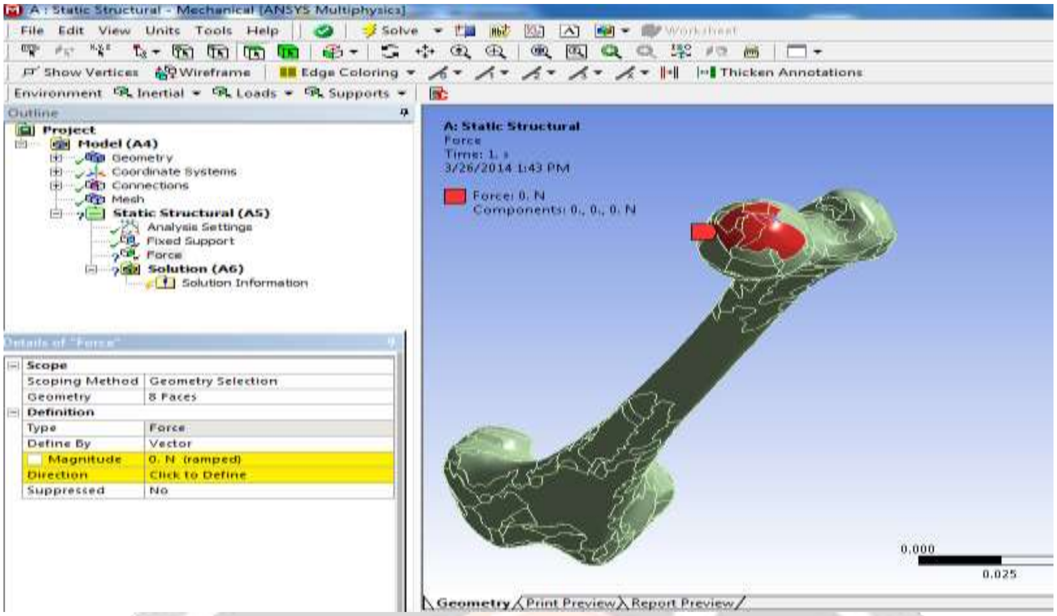

Fig- 7: Loading condition

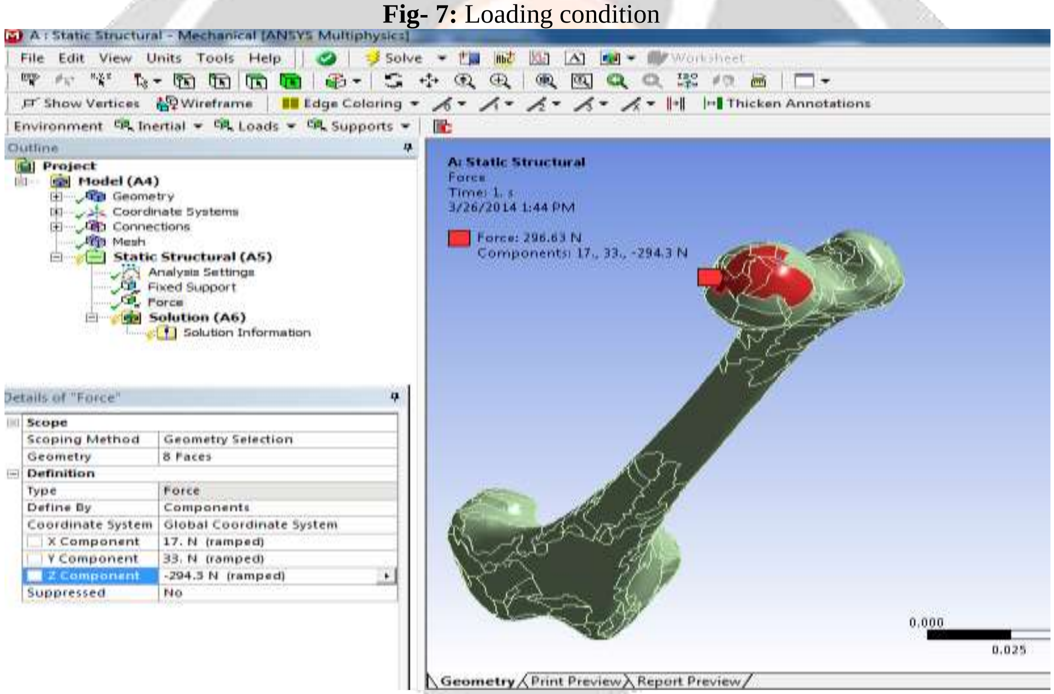

Fig- 8: Loading direction

Result is calculated after giving all the necessary input data. Now, stress for different material and at different loading condition is calculated as follows shown :

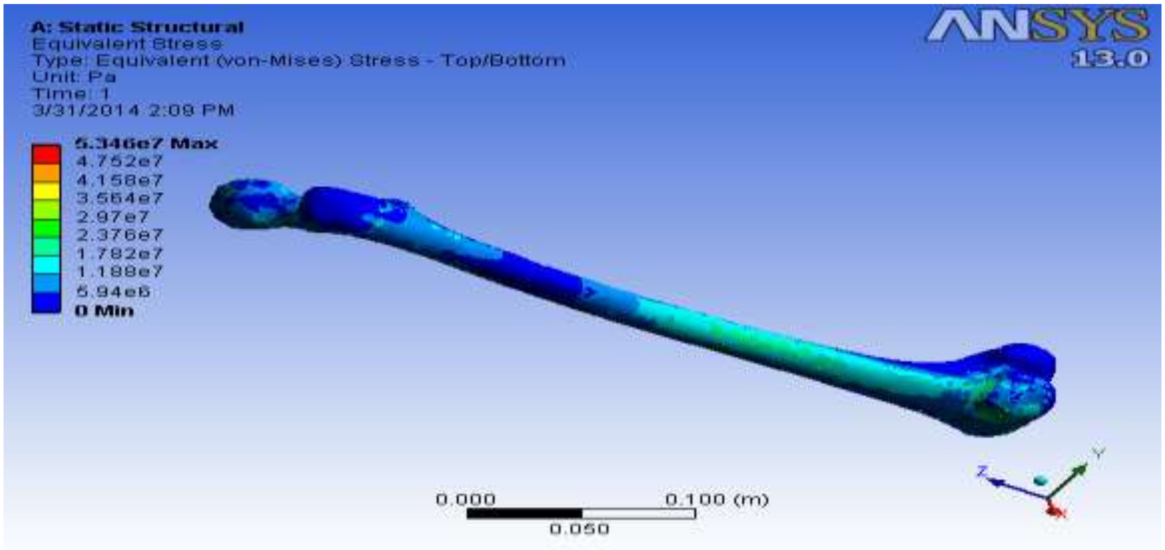

Fig- 9: ANSYS result

3.2) Material properties

There are different types of material which is used in biomedical engineering. So,we have chosen three materials which are highly applicable in bone implants.

Properties/material	Ti-6Al-4V	UHMWPE	Co-Cr-Mo
Density, kg/m^3	4430	945	8290
Young modulus, GPa	120	1.2	225
Poisson's ratio	0.34	0.46	0.3

TABLE 1 : Material properties

3.3 Load calculation

The different biomedical material is taken for the analysis. The load is taken for the different weight person. As the total load is equally distributed on both the knee so the load will be half of the total load on each femur.

We know that,

W = m × g Newton. (m= mass of body = 60kg, g= gravitational acceleration = 9.81 m/s2)

W = 60 × 9.81 = 588.6 N

Load on one femur

W = 588.6 / 2 so W = 294.3 N.

Similarly, load on each femur can be calculated as given below.

m = 65kg ⇒ half mass, m = 32.5kg ⇒ W = 319 N

m = 70kg ⇒ half mass, m = 35kg ⇒ W = 343.35 N

m = 75kg ⇒ half mass, m = 37.5kg ⇒ W = 368 N

m = 80kg ⇒ half mass, m = 40kg ⇒ W = 392.4 N

m = 85kg ⇒ half mass, m = 42.5k ⇒ W = 417

For equilibrium condition,

Fy * Z = Fz * Y, Fx * Z = Fz * X.

Let's take the value for 60 kg person,

X= 24mm, Y= 47mm, Z= 410mm and Fz= 294.3 N then

Fy= 33N and Fx = 17 N.

Similarly, we can find three dimensional loads for different weighted person as follows:

Load(N)/weight(Kg)	60	65	70	75	80	85
Fx	17	18.5	20	21.22	22.6	24
Fy	33	36	39	41.5	44.3	47.2
Fz	294.3	319	343.35	365	392.4	417

TABLE 2 : Load angle at different angles

4. CONCLUSION

All pressure angle and loading have soft tissue extension and compression affecting the vertical forces on knee joint components and equal and opposite reactionary forces getting generated at patella, femur and tibia. So, negative forces in the figure could be explained by that. In the balanced standing position, patient's planar stress distribution can be seen representative of hyper pressure, enabling the search for better diagnosis as pressure was localized near the knee joint of the foot. It was very difficult to get displacement of knee joint during CT scan as the alignment of knee joint might not be related to actual modeling. For this case the Ti-6Al-4V material gives the lowest stress in the femur bone with all loading condition. It is beneficial to use this material for bone implants. From the gait cycle analysis it is concluded that in the mid stance phase load value is maximum so the stress produced in this phase is maximum.

6. REFERENCES

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