Finite Element Analysis of Knee Joint with Ti6Al4V

Prof. Vijay Parmar[1], Prof. Unnati Parmar[2]

[1] Assistant Professor, Mechanical Engineering Department, Vadodara Institute of Engineering, Kotambi, Vadodara,Gujarat, India
[2] Assistant Professor, Mechanical Engineering Department, ITM Vocational University,Raval, Vadodara,Gujarat, India

ABSTRACT

Knee joint is the most important joint in the human body. Various stresses and strain produce in the joint in static and dynamic loading condition. To calculate stress and strain in joint we first have to create model of the knee joint. This 3D model is created using reverse engineering concept. There is various software used to create 3D model from the CT scan images and also model can generate using laser scanner and CMM. By using medical imaging software like MIMICS we can easily visualize 3D model which is the part of reverse engineering. After creating the 3D image it is analyzed using analytical software like ANSYS. For the analysis we give different loads on the model so we can analyses different results. The result gives an idea about effect of loading on knee joint.

Keywords—*Knee Joint, MIMICS, ANSYS, Reverse Engineering, Loading Condition*

I. INTRODUCTION

The knee is the largest joint in the body and it is also one of the most complex joints. The knee joint is made up of four bones: femur, tibia, fibula and patella. The articulation of these bones forms the knee joint, and is shown in Figure 1, which is adopted from website http://www.aclsolutions.com/default.php. The two major articulations within the knee are the tibia-femoral and patella-femoral joints.

Fig. 1 knee joint

The knee joint contains four bones. These are the femur and the tibia. The femur is the bone of the thigh and is the longest bone in the body; the tibia is the larger and the medial of the two bones in the lower leg. The other two bones of the knee joint are the fibula, and the patella. The fibula is the lateral and more slender of the two bones in the lower leg. This bone has its function mostly during rotation along the longitudinal axes of the leg. The other functions of the fibula can be adopted by the other bones, mostly by the tibia.

II. MATERIALS IN BIOMECHANICS

Biomaterials have had a major impact on the practice of contemporary medicine and patient care in both saving, and improving the quality of lives of humans and animals. Modern biomaterial practice still takes advantage of developments in the traditional, nonmedical materials field but is also aware of, and concerned about, the biocompatibility and bio functionality of implants.

Metal	Ceramics	Polymers
Ti6A14V	Alumina	Polyurethane (PE)
CO-Cr alloys	Zirconia	Ultra-high molecular weight polyethylene(UHMWPE)

Table 1 Materials

Properties of biomaterials

- strength, bending strength and fatigue resistance
- corrosion resistance
- durability
- biocompatibility
- shear strength

Properties/material	Ti-6Al-4V
Density, kg/m^3	4430
Young modulus, GPa	120
Poisson's ratio	0.34
Yield strength, MPa	900

Table 2 Material properties of Ti6Al4V

III. REVERSE ENGINEERING TECHNIQUES

There are mainly two types of reverse engineering techniques.

1) Contact type (CMM)
2) Non-contact type (Using software (MIMICS), laser scanner, online technique etc.).

In contact type technique, Coordinate measuring machine (CMM) is used to measure outer dimensions of the geometry and from that geometrical data 3D CAD model is generated.

In non-contact technique, there are different software like (MIMICS, XOR etc.), laser scanner machine and online techniques are available to generate 3D CAD models using CT scan data of the patient.

IV. MODELING

There is software MIMICS 16.0 by which the 3D CAD model is generated using CT and MRI data. In this technique first the CT or MRI data is taken and that data is imported into the software in DICOM format. Thresholding is done for selecting the area of interest of model generation seen with green color. Region growing is done to select such area which we want to generate 3D model seen with yellow color. Mass filling is done to fill the material in remaining area which was not selected in previous step. Then 3D calculation is done for the selected area to generate 3D model and finally the 3D model is displayed on the screen. We observe that model generated is not smooth so the smoothing is done so the perfect model is generated then this model is exported to .stl file for further analysis.

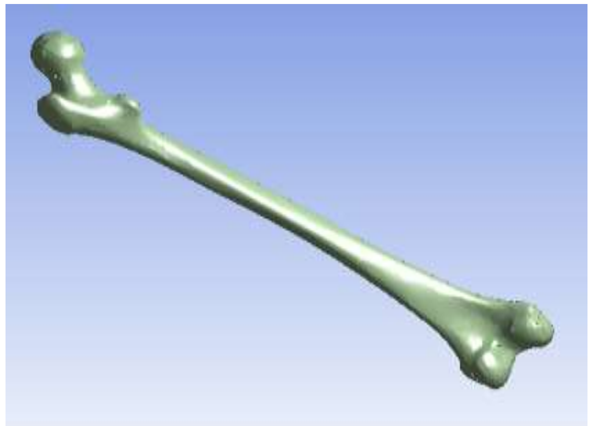

Fig 2 MIMICS model

File format conversion

We saw two different techniques to generate 3D CAD model. In both the technique the model is in .stl which is not supported in analysis software. So this .stl file is imported into hyper mesh or pro-E and it is exported as .iges format which is supported in ansys, abacus and hyper mesh. I have done this in hyper mesh.

V. FINITE ELEMENT ANALYSIS

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 Ti6Al4V. 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.

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 = 35k ⇒ W = 343.35 N

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

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

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

Weight, kg	Half weight, kg	Half load, N
60	30	294.3
65	32.5	319
70	35	343.35
75	37.5	368
80	40	392.4
85	42.5	417

Table 3 Load on Knee

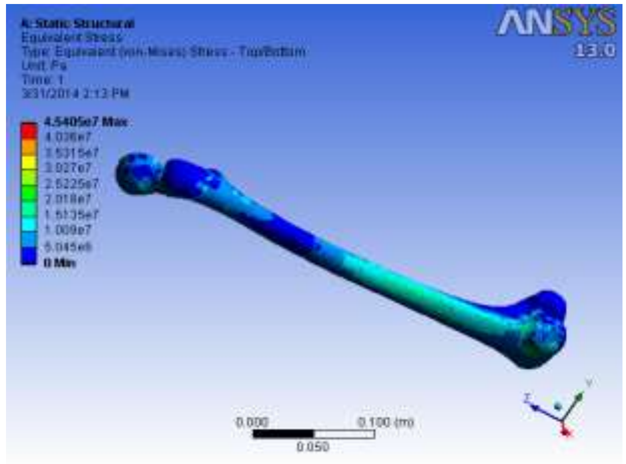

Fig 3 ANSYS Analysis Result for 60kg weight

Weight, kg	Stress, Pa	Weight, kg	Stress, Pa
60	4.54×10^7	75	5.68×10^7
65	4.94×10^7	80	6.11×10^7
70	5.34×10^7	85	6.44×10^7

Table 4 Results with Ti-6Al-4V

VI. Conclusion

From the above results we can conclude that the increase in stress with the increase in load is very much low and hence this material is mostly used for knee implant.

VII. References

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