10 May 2021

Socket Sense

Progress Report – Week 1: Preliminary Study

A Preliminary Study on the Finite Element Analysis (FEA) of transfemoral amputees is required to clearly understand the prerequisites – geometry, material properties, contacts, loads and boundary conditions; before proceeding to the complex FEA of pressure distribution in soft tissues of the stump.

1. Geometry

The geometry of socket fit on a transfemoral amputee is simplified by approximations as explained below.

1.1 Femur

The femur bone is simplified to a cylinder with a height of 370 mm and a diameter of 25 mm.

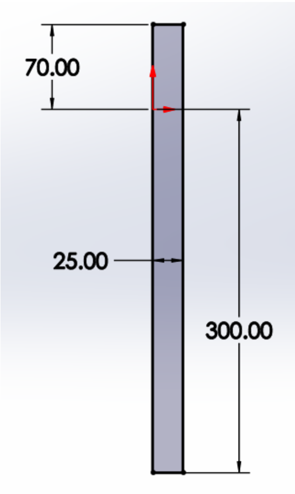


Fig 1. Sketch of CAD model of femur

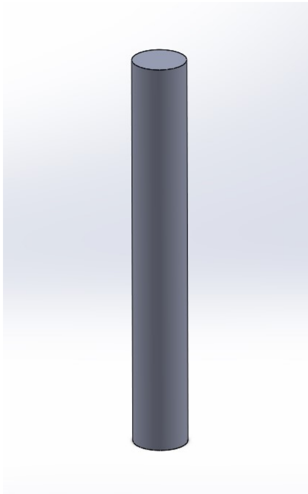


Fig 2. CAD model of femur

1.2 Stump

The stump is approximately simplified to an inverted cone with a depth of 350 mm and a radius of 110 mm.

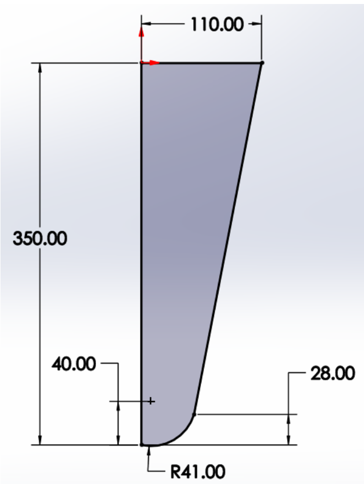


Fig 3. Sketch of CAD model of stump

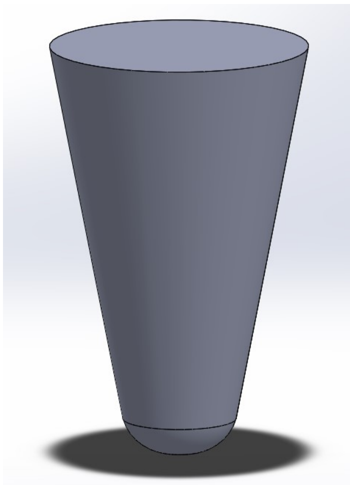


Fig 4. CAD model of stump

1.3 Socket

The socket is designed to exactly fit the simplified stump with a thickness of 10 mm.

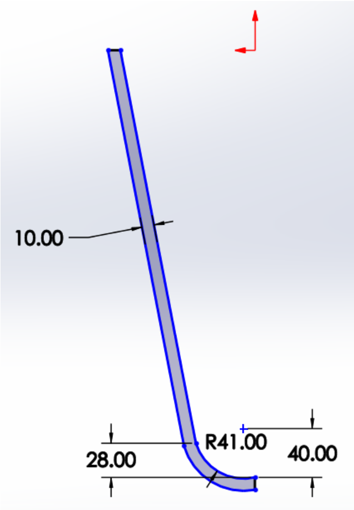


Fig 5. Sketch of CAD model of socket

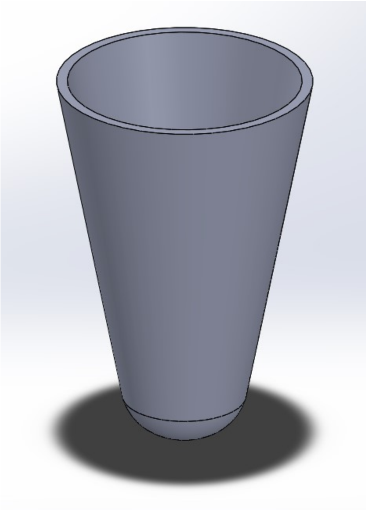


Fig 6. CAD model of socket

1.4 Assembly

Assembling all the components in for FEA.

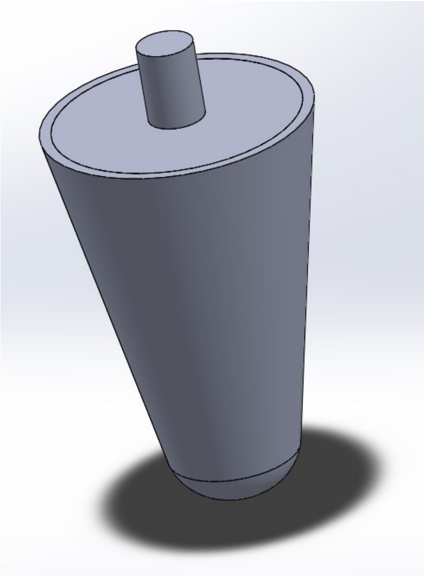


Fig 7. Assembly of components

2. Material Properties

According to Henao *et al.,* (2020)

2.1 Femur

Young's modulus =15 GPa Poisson's ratio = 0.3 Density = 2000 kg/m^3

2.2 Stump

Neo-Hookean Hyperelastic model

C_{10} = 11.6 kPa and D_1 = 11.9 MPa^{-1}

2.3 Socket

Young's modulus = 1.5 GPa Poisson's ratio = 0.3 Density = 800 kg/m^3

3. Contacts

3.1 Between Femur and Stump

Bonded contact between the femur and the stump.

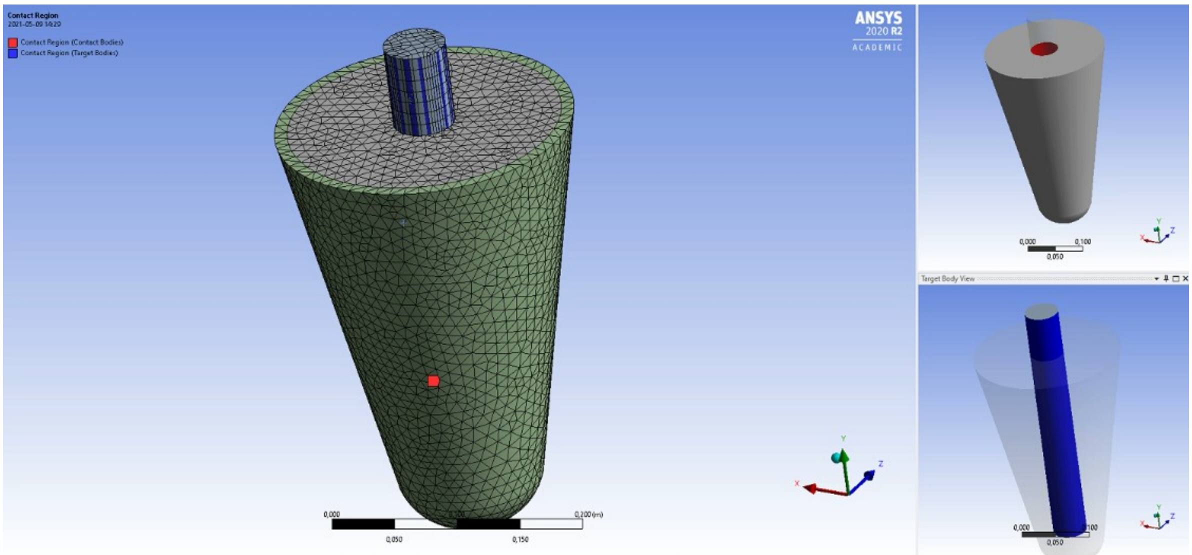


Fig 8. Bonded contact

3.2 Between Stump and Socket

According to Henao *et al.,* (2020) the frictional contact between the stump and socket has $\mu = 0.37$

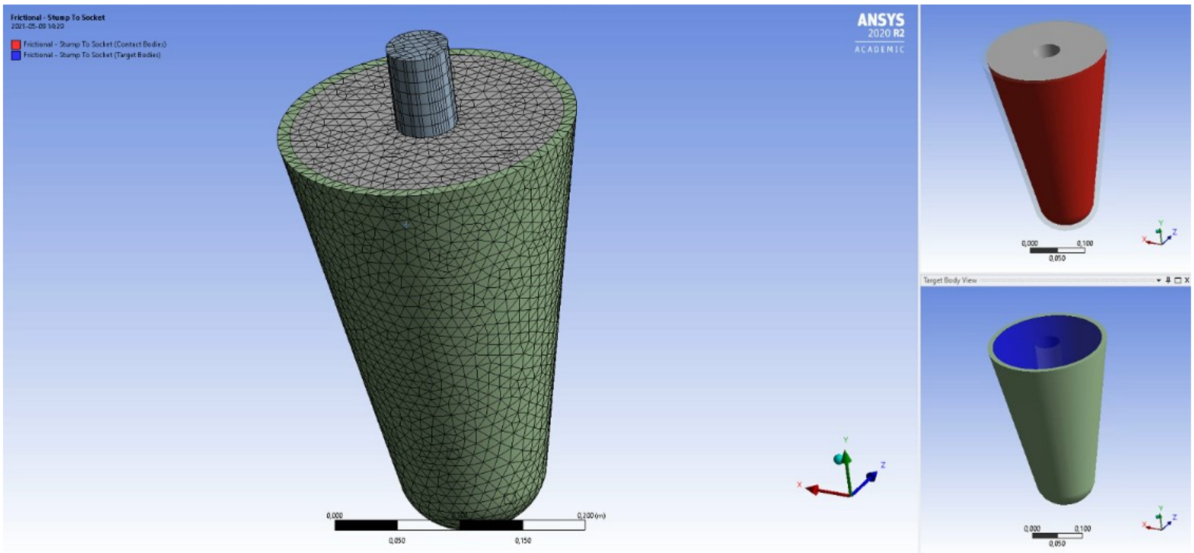


Fig 9. Frictional contact

4. Load

A force of 350 N is approximated for a 70 kg individual in standing position. The load is applied on the bottom face of the socket in +Y direction.

5. Boundary Conditions

A fixed support is applied on the top face of femur as an approximation of the hip joint.

6. Results of Static Structural analysis in ANSYS Mechanical

6.1 Total Deformation

The deformation of assembly under a load of 350 N.

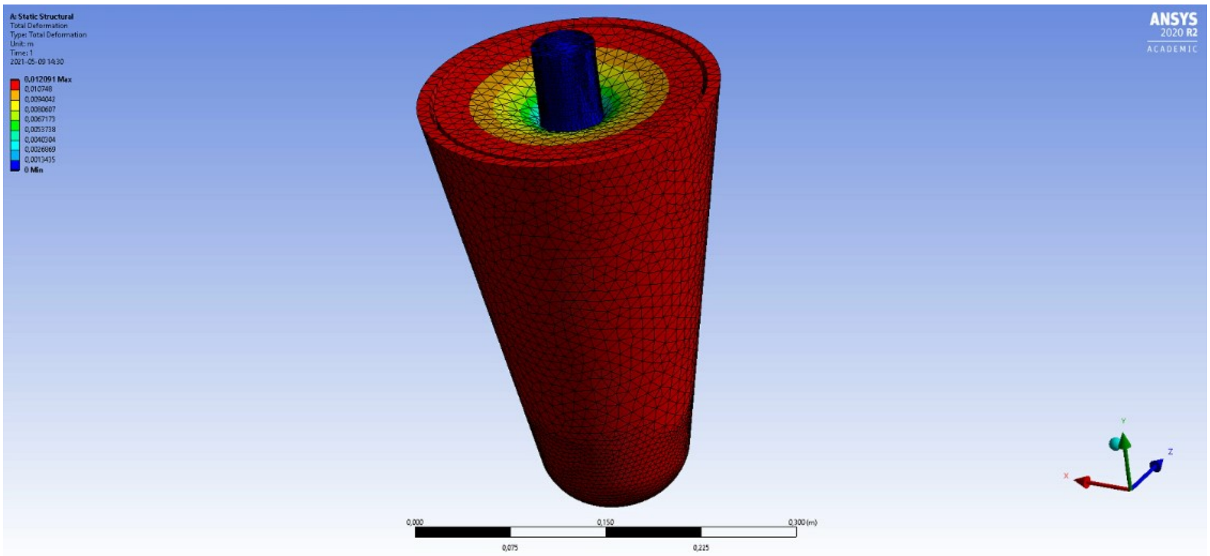
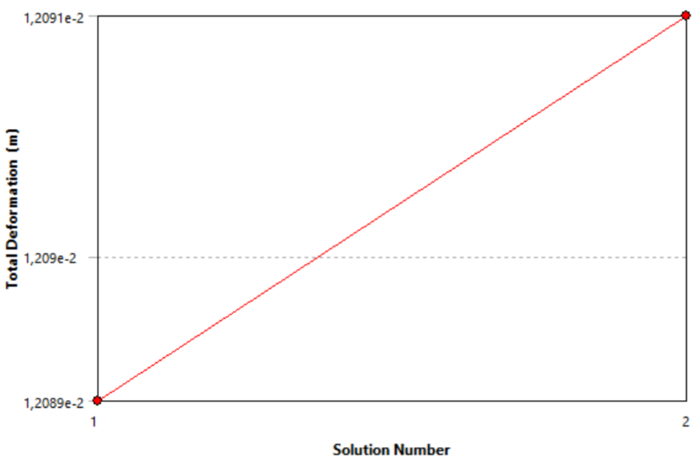


Fig 10. Total Deformation

The results converge with a change of 0.02% at the selected mesh density. Thus, the results can be trusted and will not change with a change in mesh density.



	Total Deformation (m)	Change (%)	Nodes	Elements
1	1,2089e-002		99043	56240
2	1,2091e-002	2,1142e-002	150298	92663

Fig 11. Convergence of Results (Mesh Sensitivity Analysis)

6.2 Von-Mises stress

The equivalent stresses in the model according to von-Mises theory.

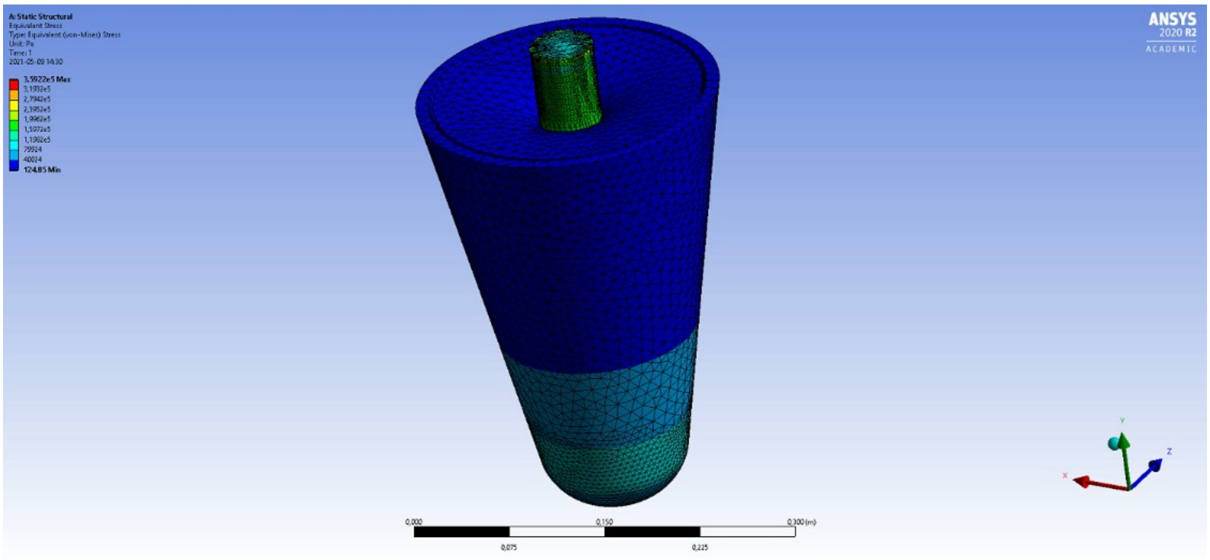


Fig 12. Equivalent Stress

6.3 Normal stress in Y- direction

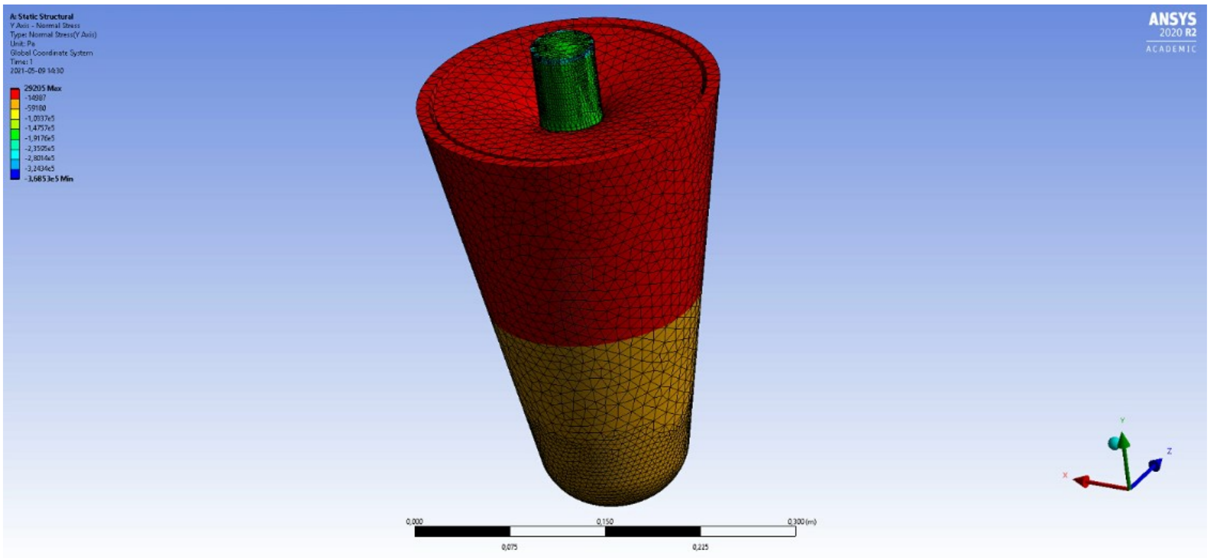


Fig 13. Normal stress in Y- direction

6.4 Normal stress in X- direction

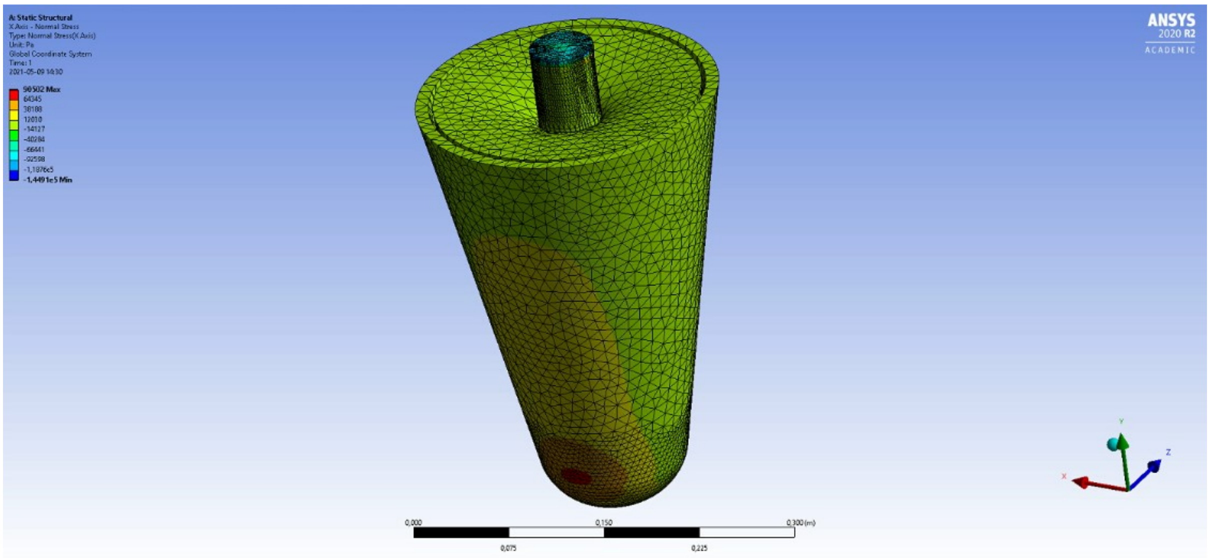


Fig 14. Normal stress in X- direction

6.5 Normal stress in Z- direction

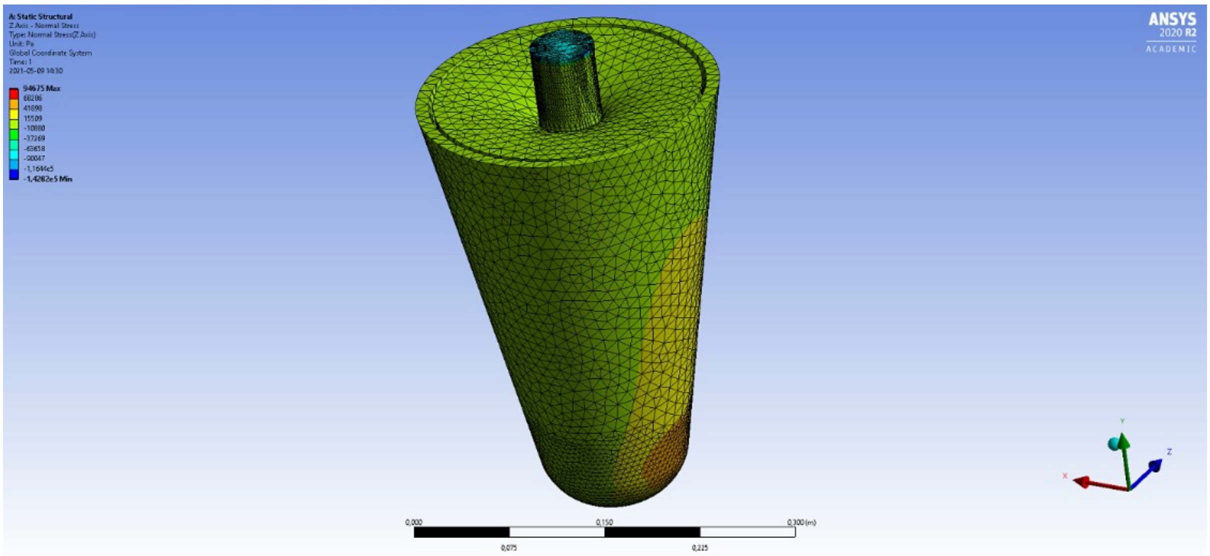


Fig 15. Normal stress in Z- direction

6.6 Shear stress

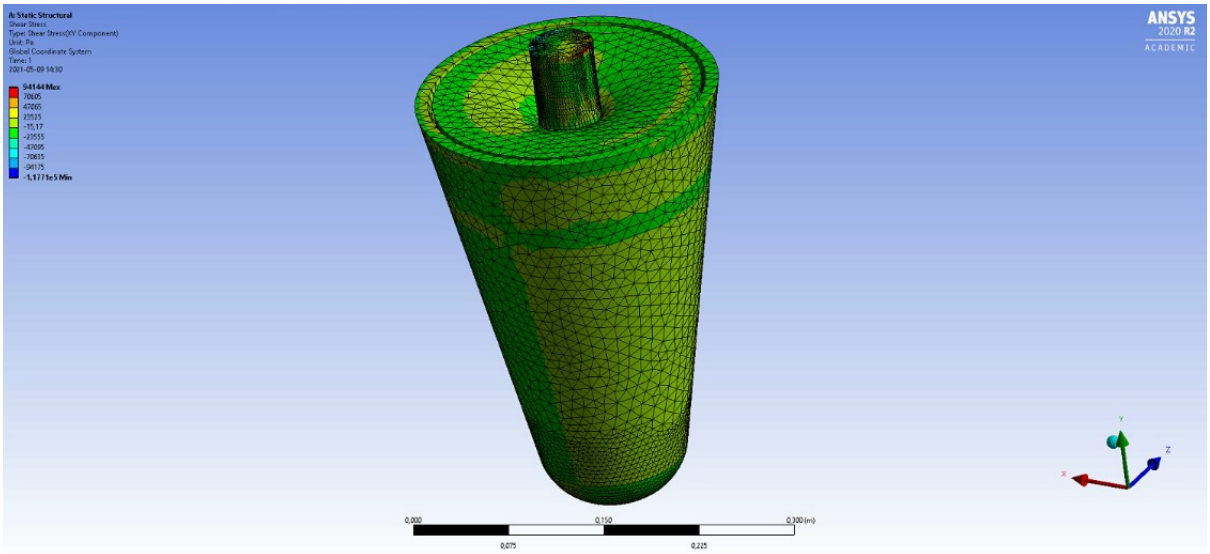


Fig 16. Shear stress

6.7 Solution Convergence

The ANSYS solver is converging (according to force convergence) in the step time.

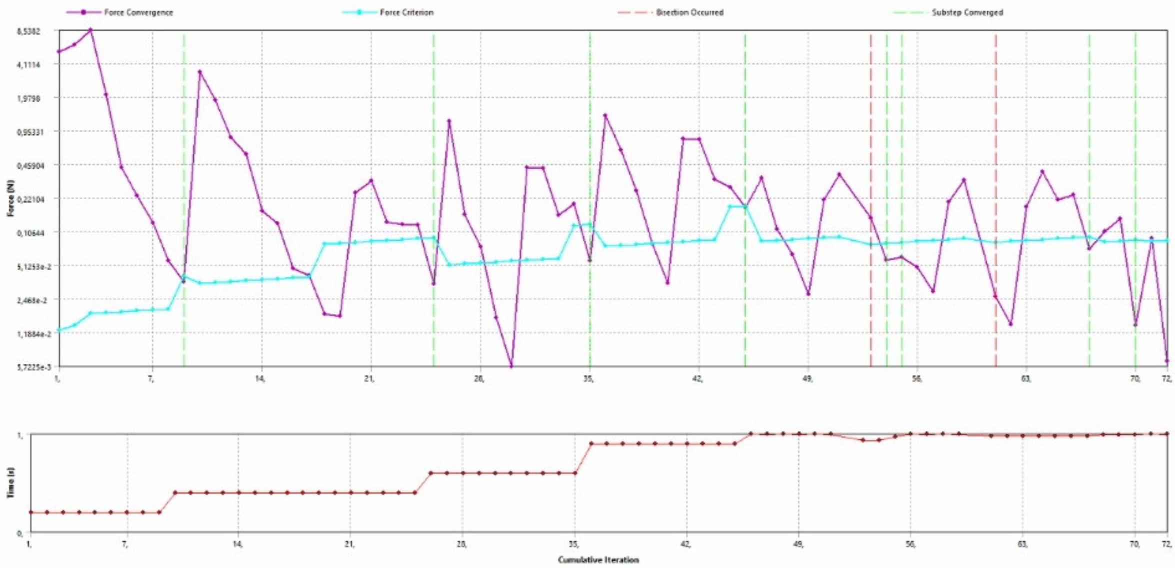


Fig 17. Convergence of Solution

7. Conclusions

This Preliminary Study has helped establish the steps in ANSYS for the FEA of transfemoral amputees.

The following problems need to be solved before proceeding with the actual FEA problem of socket fit on transfemoral amputees:

1. Acquire the CAD model of femur – open source or CT scans
2. Acquire the CAD model of socket – open source
3. Acquire the CAD model of stump – can be generated from the CAD model of socket using MeshMixer.
4. Anatomically position all the components for 3D assembly to get accurate results.

References:

Henao, S.C., Orozco, C., Ramírez, J., 2020. Influence of Gait Cycle Loads on Stress Distribution at The Residual Limb/Socket Interface of Transfemoral Amputees: A Finite Element Analysis. Sci Rep 10, 4985. https://doi.org/10.1038/s41598-020-61915-1