

Socket Sense

Progress Report – Week 4: FEA of Transfemoral Amputee

Finite Element Analysis (FEA) of transfemoral amputees is required to study the pressure distribution at the socket-stump interface. FEA results provide a better understanding of the loading on stump for the design of better transfemoral sockets.

1. Geometry

The geometry of transfemoral amputee for FEA is constructed using MeshMixer, FreeCAD and SOLIDWORKS as explained in detail in Progress Report – Week 2. The assembly of all components is shown in Figure 1.

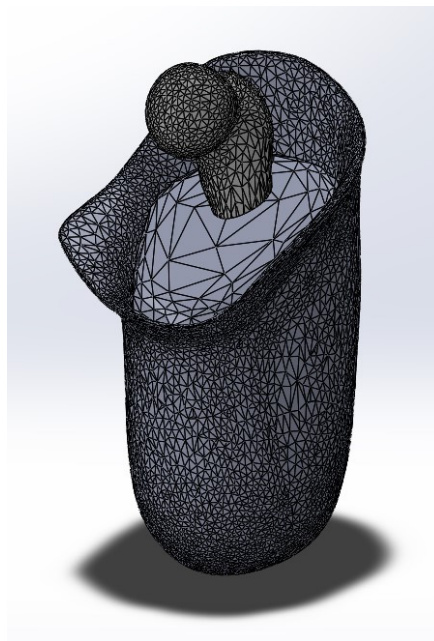


Fig 1. Assembly of components

2. Material Properties

2.1 Femur [3]

Young's modulus = 15 GPa Poisson's ratio = 0.3 Density = 2000 kg/m³

2.2 Stump [3]

Neo-Hookean Hyperelastic model

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

2.3 Socket [3]

Young's modulus = 1.5 GPa Poisson's ratio = 0.3 Density = 800 kg/m³

3. Contacts

3.1 Between Femur and Stump

Bonded contact between the femur and the stump as shown in Figure 2.

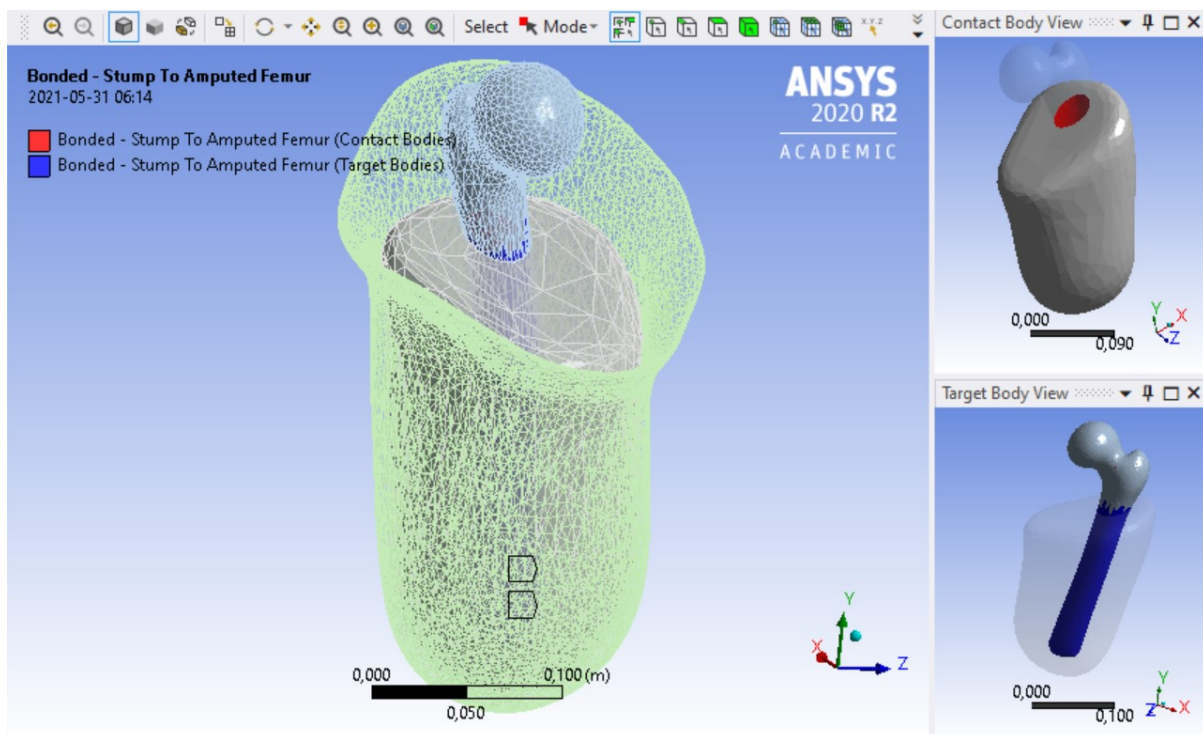


Fig 2. Bonded contact

3.2 Between Stump and Socket

The frictional contact between the stump and socket has a coefficient of friction [3], $\mu = 0.37$

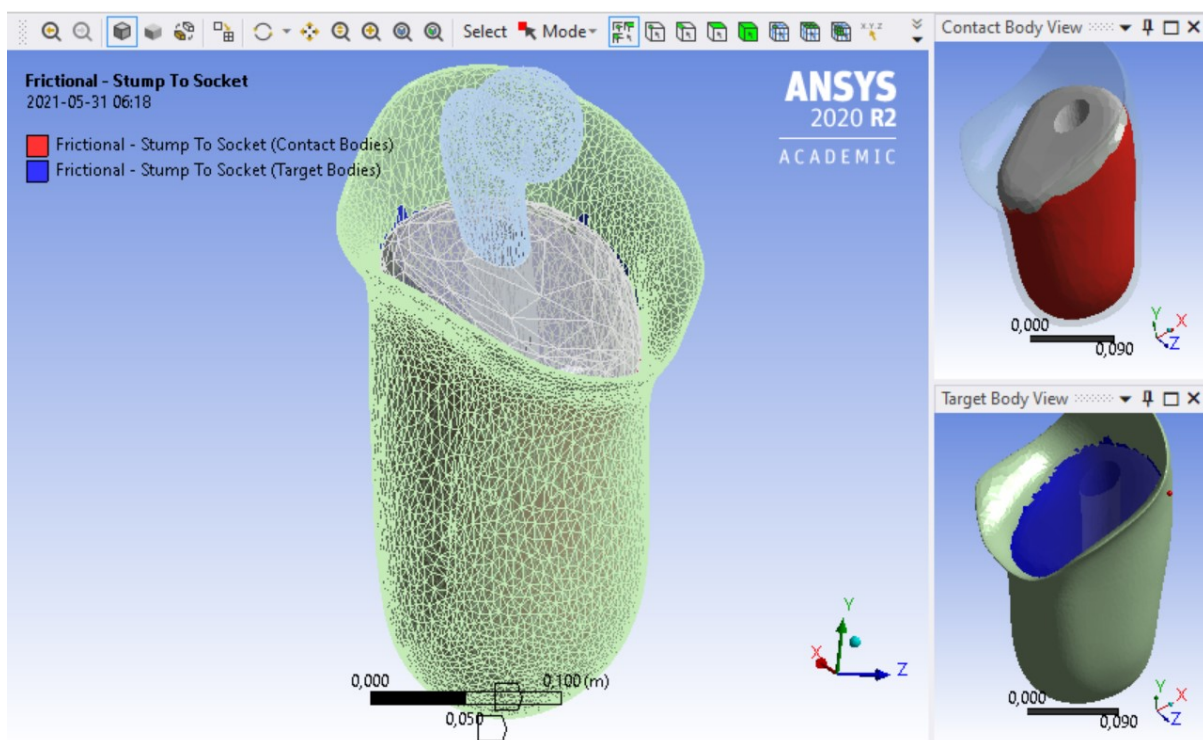


Fig 3. Frictional contact

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. The force of 350 N is applied in 4 steps of 10 N + 50 N + 120 N + 170 N to help the ANSYS solver converge.

5. Boundary Conditions

A fixed support is applied on the head of femur in contact with acetabulum at the hip joint.

6. Results of Static Structural analysis in ANSYS Mechanical

6.1 Force Convergence

The runtime of ANSYS Solver is 2 hours 19 mins, using AMD Ryzen Threadripper 2950X 16-Core Processor 3.50 GHz and 16 GB RAM, Windows 10 Education 64 bits OS.

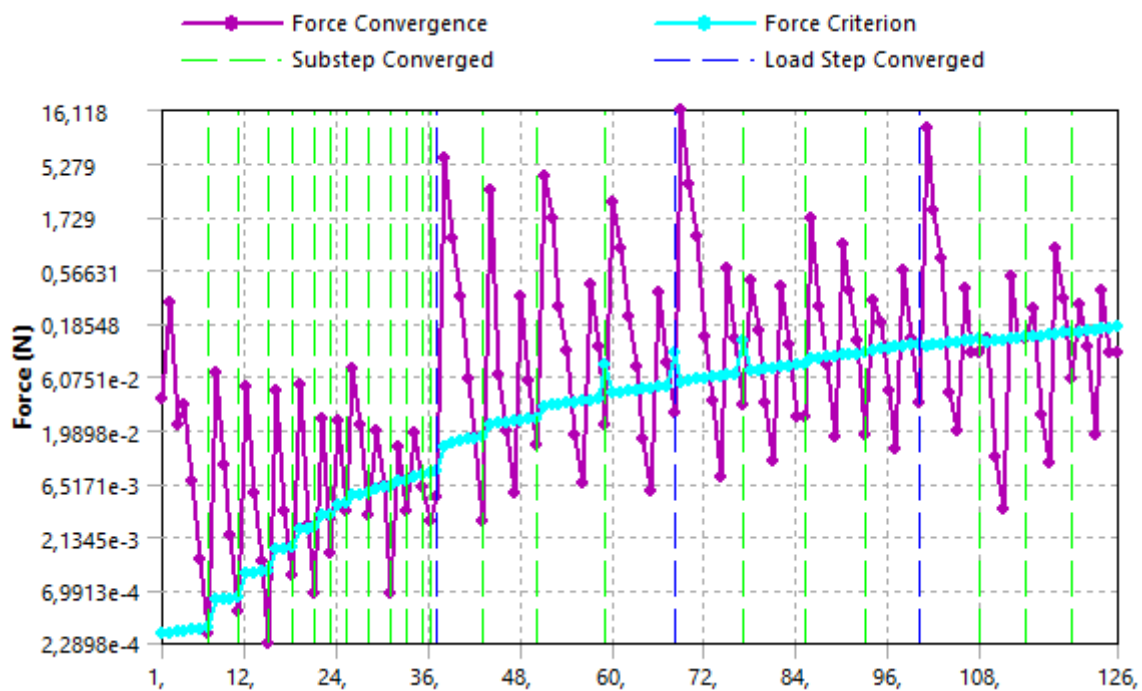


Fig 4. Force Convergence plot

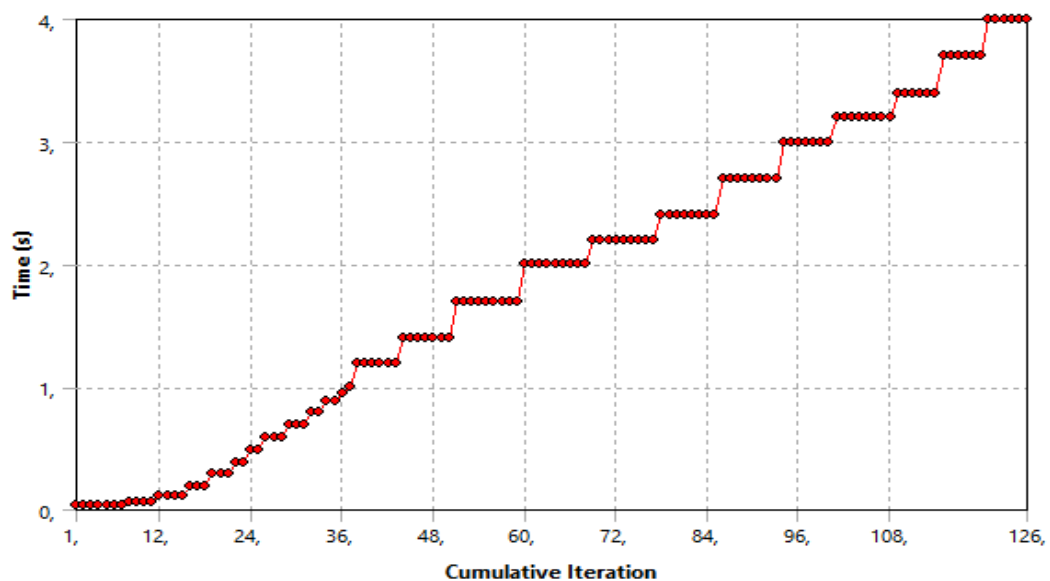
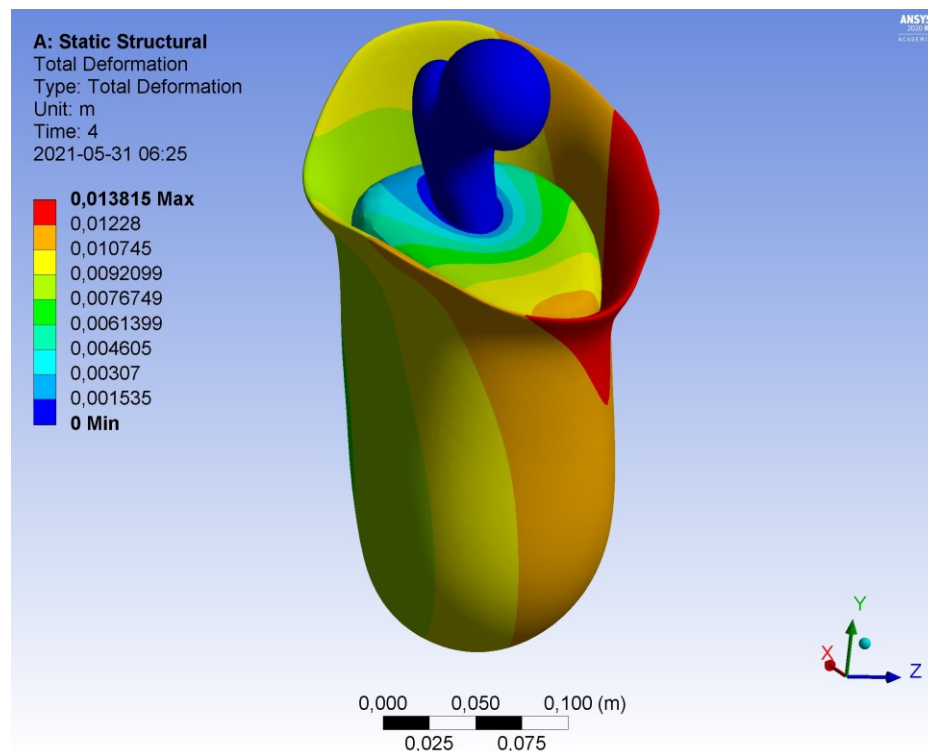


Fig 5. Cumulative iteration vs time plot

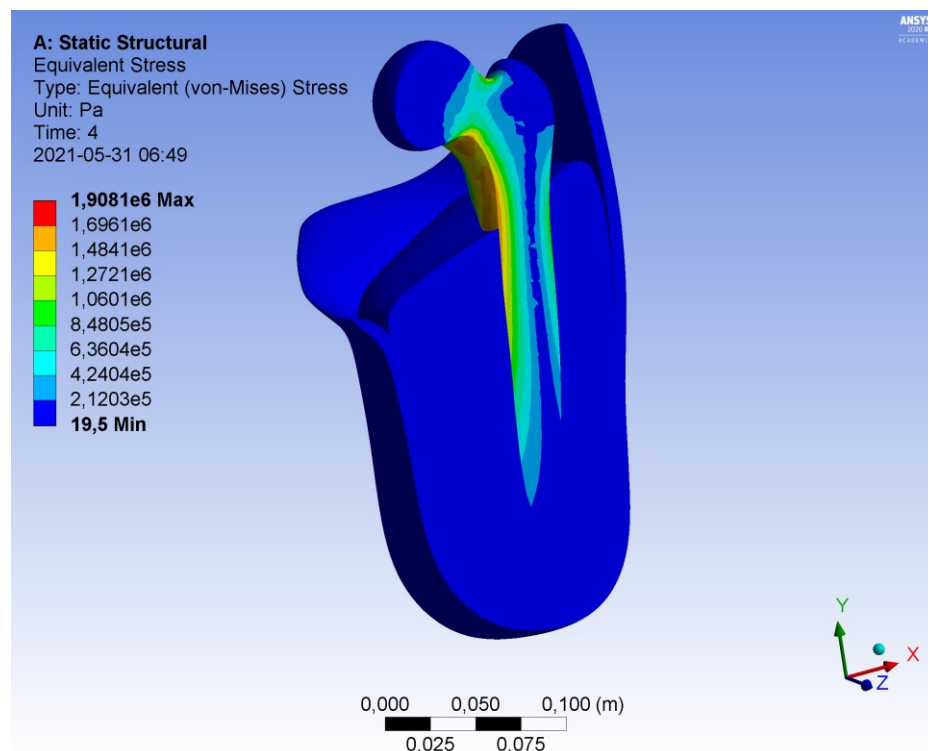
6.2 Total Deformation

The deformation under a load of 350 N is shown in Figure 6.



6.3 Von-Mises stress

The equivalent stresses according to von-Mises theory is shown in Figure 7.



6.4 Total Deformation of stump

The total deformation of stump is shown in Figure 8.

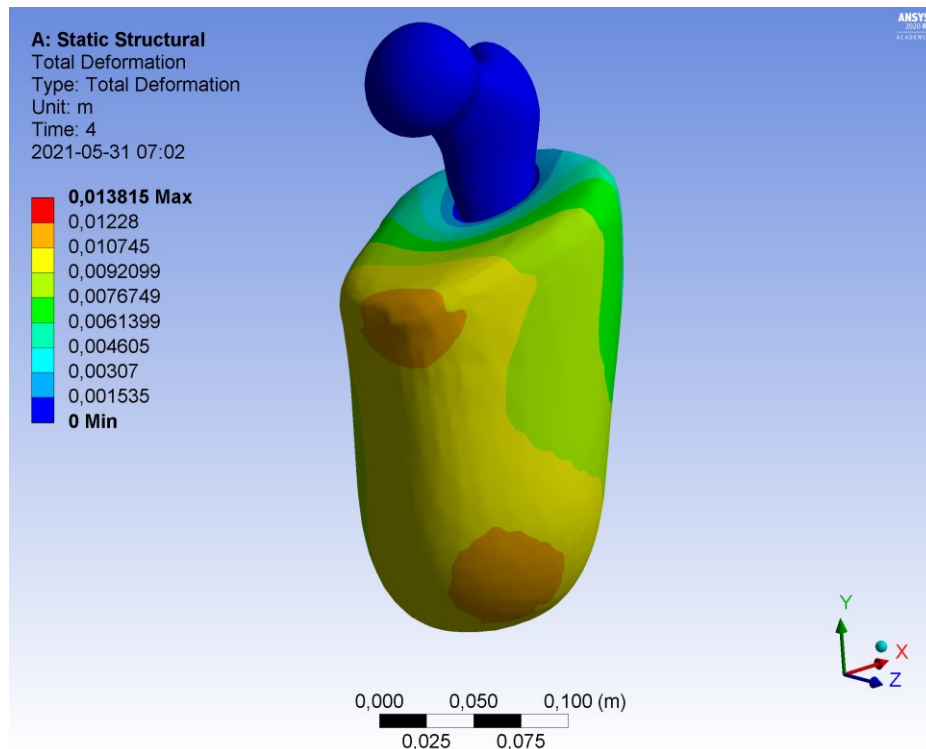


Fig 8. Total deformation of Stump

6.5 Pressure at contact of socket and stump

The pressure at the contact of Socket and Stump is shown in Figure 9.

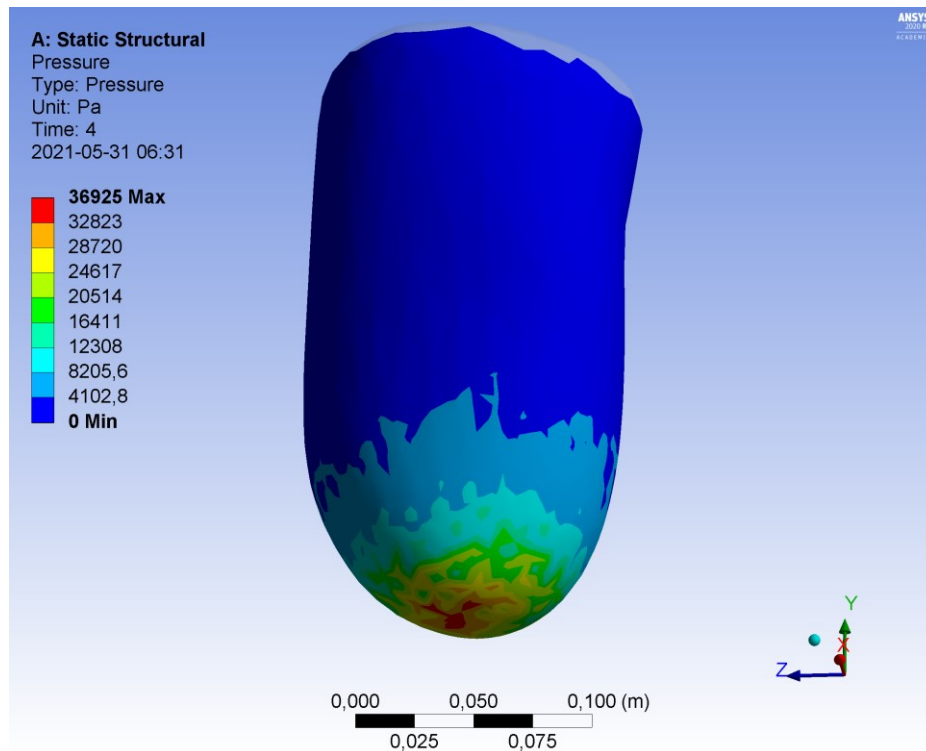


Fig 9. Pressure at contact

6.6 Frictional Stress at contact of socket and stump

The frictional stress at the contact of Socket and Stump is shown in Figure 10.

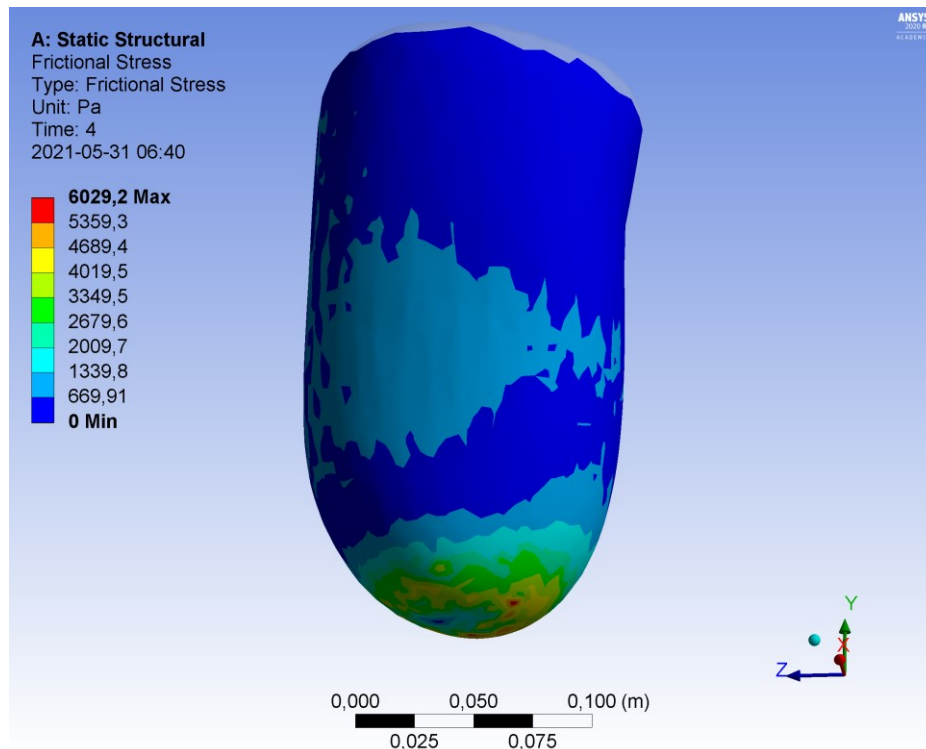


Fig 10. Frictional Stress at contact

7. Conclusions

Convergence issues have been resolved and the ANSYS solver is converging to a solution at a load of 350 N, assumed for a 70 kg man standing.

References:

1. HUMAN LEGS | 3D model (2021). BRO1977. [online] CGTrader. Available at: <https://www.cgtrader.com/free-3d-models/character/anatomy/human-legs--2> [Accessed 18 May 2021].
2. Thingiverse.com (2021). Transfemoral (above-knee) Quadrilateral Prosthetic Socket Pack 2 by MakisB. [online] @thingiverse. Available at: <https://www.thingiverse.com/thing:3233555> [Accessed 18 May 2021].
3. 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>