FINITE ELEMENT ANALYSIS OF POLYMERS COMPARING WITH SS316L USED AS ORTHOPAEDIC IMPLANTS

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Abstract
In human anatomy, the femur is the longest and largest bone. The average adult male femur is 48cm (18.9 in) in length and 2.34cm (0.92 in) in diameter and can support up to two times the weight of an adult. Being longest and heaviest in size, failure of femur neck is the most common among bone failures in human. With increased incidence of hip fracture risks in osteoporotic patients, it is important to develop preventive treatment options including bone strengthening implants. Analytical and experimental techniques are used to optimize material and design of orthopaedic implants.

In the present work, a finite element analysis was used to evaluate the stress distribution in the proximal region of femur implant of polymer material (polyurethane, PEEK, PEEK 30C) and SS316L under dynamic loading condition. Since each femur carries full weight of the body, analysis done for 25kg, 50kg, 75kg, 100kg, including the cases of patient carrying certain weight.Thus it is concluded that polymer is a low density material it makes the patient to feel comfort to move his leg and the stresses obtained are within the allowable stress. A polymer material has high corrosion resistance, wear resistance and also it is more bio-compatible to human body. So it is suggested that polymer material is suitable for the femur implantation.
Keywords: orthopaedic implants, PEEK, SS316L

1. Introduction

The *Femur* the longest and strongest bone in the skeleton is almost perfectly cylindrical in the greater part of its extent. In the erect posture it is not vertical, being separated above from its fellow by a considerable interval, which corresponds to the breadth of the pelvis, but inclining gradually downward and medial ward, so as to approach its fellow toward its lower part, for the purpose of bringing the knee-joint near the line of gravity of the body. The degree of this inclination varies in different persons and is greater in the female than in the male, on account of the greater breadth of the pelvis. The femur, like other long bones, is divisible into a body and two extremities.

The Upper Extremity (proximal extremity,).The upper extremity presents for examination a head, a neck, a greater and a lesser trochanterThe Head (caput femoris).—The head which is globular and forms rather more than a hemisphere, is directed upward, medial ward, and a little forward, the greater part of its convexity being above and in front. Its surface is smooth, coated with cartilage in the fresh state, except over an ovoid depression, the fovea capitis femoris, which is situated below and behind the center of the head, and gives attachment to the ligamentumteres.

1.1 IMPLANTS

Definition: - An object made from non living material that is deliberately inserted by a surgeon into the human body where it is intended to remain for a significant period of time in order to perform a specific function.

Figure 1 Femur Bone Implant

FEMORAL HEAD

This is the uppermost part of the femur implant. It is spherical in shape connected to neck. Its rolling moment causes the free movement of leg. Femoral head offers large range of offsets.

TAPERED WEDGE

The tapered wedge design of polymer femoral component provides firm mediolateral stability within the femoral canal. This design philosophy is supported by extensive long term clinical experience. This part is inserted into the hollow bone and fitted to bone by screws and nuts. This low profile, bone sparing design easily accommodates either a standard or small incision approach.

OFFSET OPTIONS

An offering of standard (132 degrees) and extended (127 degree) offset options enhance soft tissue tensioning without significant affecting leg length when adjusting joint stability. The offset is chosen suitably.

NECK

This is the part connecting tapered wedge and femoral head of the implant. Proportional neck lengths relative to body geometry, neck lengths grow proportionally in size to accommodate a wide patient population using a standard femoral head. This is the area where maximum deformation takes place.

1.2 Properties Of Materials

Table 1. Mechanical and physical properties

Material	Density (kg/m^3)	Young's Modulus 'E' (GPa)ratio'γ'	Poisson's
PEEK	1310	3447.38	0.39
PEEK 30C	1410	9652.66	0.40
POLYURETHANE	1200	0.025	0.50
SS316L	7900	595	0.33

1.3 Finite element analysis of femur bone implant

Femur bone is the longest bone in human body subjected to maximum compressive stresses and hence deformation. It's important to find out the stress concentrations and deformation zones of implant of femur bone. So FEA using ANSYSis the best method for analysis of stresses and deformations.

Procedure

- To prepare solid model of femur implant using Solidworks.
- Finite Element Analysis using ANSYS and NASTRAN.
- Results.

1.4 Solid Works Model of the Implant

Solid works is one among the latest modelling software. By this we can create any type of complicated 3D solid models with good quality. With all available dimensions of the implant the 2D model is drawn in sketcher. Than 3D models created in part body using all the required 3D options of solid works. The same is shown below

(a) 

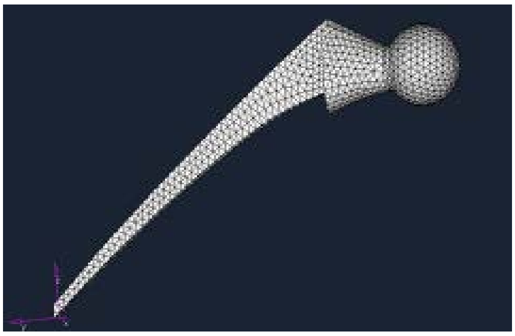
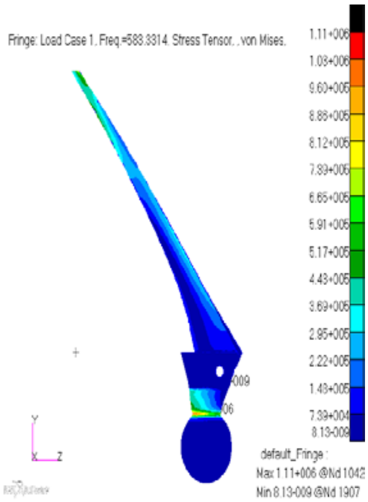
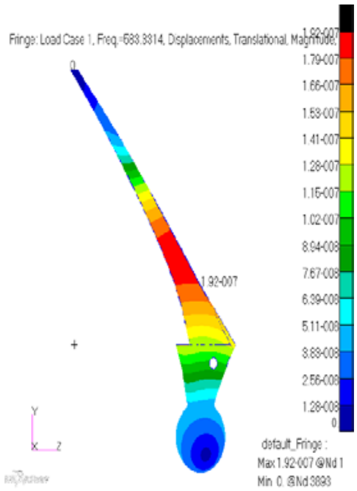
(b) 

Fig. 2. (a) Solid works model of the implant and (b) Element Plot

1.5 Results Of Analysis

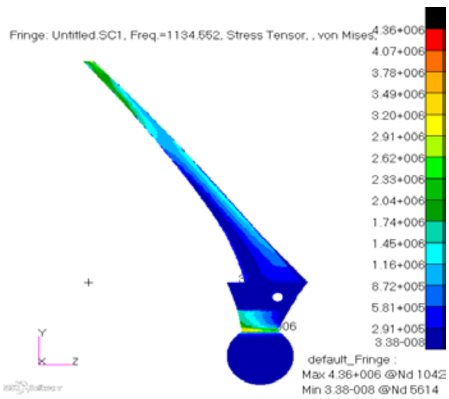


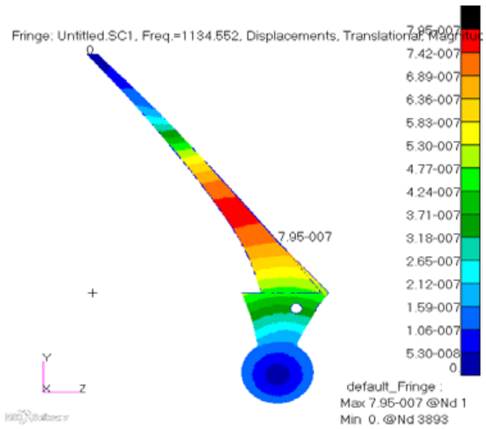
(a)



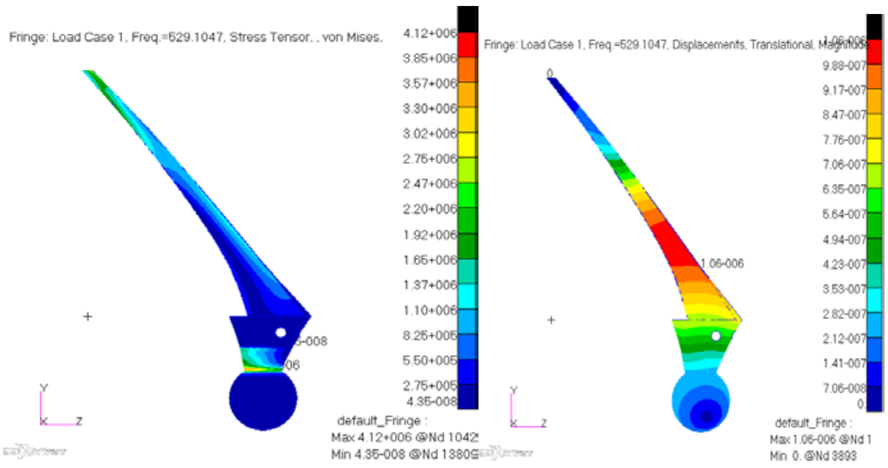
(b)

Fig. 3. (a) Von- Mises stress Plot of PEEK for 1000N and (b) Displacement Plotof PEEK for 1000N



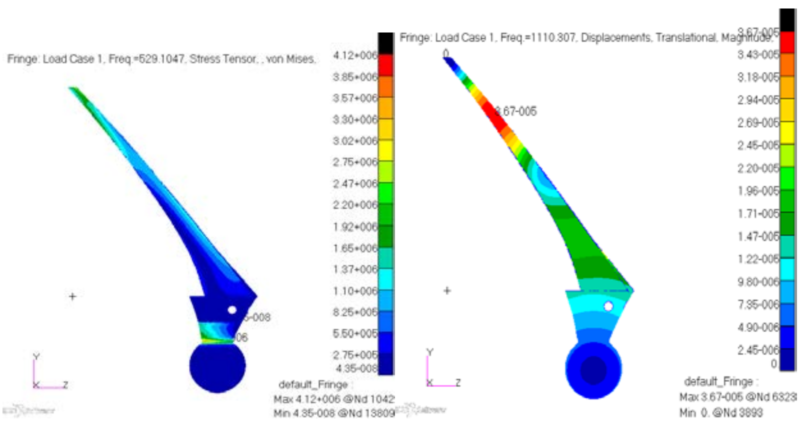


(a) (b)



(c) (d)

Fig .4. (a) Von- Mises stress Plot PEEK 30C for 1000N , (b) Displacement Plotof PEEK 30C for 1000N ,(c) Von- Mises stress Plot of POLYURETHANE for 1000N (d) Displacement Plotof POLYURETHANEPEEK for 1000N



(a) (b)

Fig. 5.(a)Von- Mises stress Plot of SS 316L for 1000N and (b)Displacement Plotof SS 316L for 1000N

1.6 Results summary

Table 2. Result summary of PEEK

Patient weight (kg)	Load(N)	Displacement (max) mm	Von misses stress(max) N/mm^2
25	250	1.92e-07	1.11e+06
50	500	3.83e-07	2.22e+06
75	750	5.75e-07	3.32e+06
100	1000	7.67e-07	4.43+06

Table 3. Result summary of PEEK 30C

Patient weight (kg)	Load(N)	Displacement (max) mm	Von misses stress(max) N/mm^2
25	250	7.95e-07	1.09e+06
50	500	1.59e-06	2.18e+06
75	750	2.39e-06	3.27e+06
100	1000	3.18e-06	4.36e+06

Table 4. Result summary of POLYURETHANE

Patient weight (kg)	Load(N)	Displacement (max) mm	Von misses stress(max) N/mm^2
25	250	2.65e-07	1.03e+06
50	500	5.29e-07	2.06e+06
75	750	7.94e-07	3.09e+06
100	1000	1.06e-06	4.12e+06

Table 5. Result summary of PEEK 30C

Patient weight (kg)	Load(N)	Displacement (max) mm	Von misses stress(max) N/mm^2
25	250	9.18e-06	1.19e+07
50	500	1.84e-05	2.38e+07
75	750	2.76e-05	3.56e+07
100	1000	3.67e-05	4.75e+07

1.7 CONCLUSION

In the present work conclusions regarding the results of FEA analysis under dynamic loading conditions of femur bone implant materials can be summarized as followes

- The stresses are formed at the neck and head are of very low values for polymer material compared to SS316L
- The displacements values of nodes in implants are very low for polymer materials compared to SS316L, carrying no considerable effect on implant.
- The PEEK, PEEK 30C, polyurethane are low density material compared to SS316L .Its light weight enables the patient to lift their leg with greater comfort.
- The PEEK,PEEK 30C, polyurethane are highly biocompatible to human body, which makes the material to suitable for implantation.

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