Static structural & Additive simulation analysis of human femur bone using Ansys and Simu fact tool

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***Abstract*—The applications of Additive Manufacturing have increased extensively in the area of orthopedics. AM provides a perfect fit implant for the specific patient by unlimited geometric freedom. Various scanning technologies capture the status of bone defects, and printing of the model is done with the help of this technology. It gives an exact generation of a physical model which is also helpful for medical education, surgical planning and training. The purpose of this paper is to identify the best possible usage of additive manufacturing applications in orthopedics field. It also presents the steps used to prepare a 3D printed model by using this technology and details applications in the field of orthopaedics. AM gives a flexible solution in orthopaedics area, where customized implants can be formed as per the required shape and size and can help substitution with customized products. A 3D model created by this technology gain an accurate perception of patient's anatomy which is used to perform mock surgeries and is helpful for highly complex surgical pathologies. It makes surgeon's job accessible and increases the success rate of the operation. In our study we model 3D human femur bone of specific patient was developed using patient CT scan images. Investigated mechanical properties of femur bone along with topology optimization with different materials. The result is correlated with some other papers and also, we reduced mass.**

***Keywords*—Additive Manufacturing (AM), Computer tomography (CT), Femur bone, orthopaedics**

I. INTRODUCTION

In the last decade, the biomedical field has witnessed massive and sustain growth in various facets of human tissue regeneration, this process is concerned with cell growth and reconstruction of organs, since the regeneration of tissue is an immense interest for scientists and academicians globally. Based on recent years research in the field tissue implants and transplantation, it can be understood that its substitution, and fixation are the practical alternatives for patients with injured or damaged organs, but with some difficulties and limitations in conventional surgical procedure, An extreme need of unconventional procedure for tissue regeneration, Here's is an best fabrication method for tissue regeneration with additive manufacturing technology also known as 3D printing, has emerged during recent years as it is flexible and powerful technique for advanced manufacturing in healthcare. 3D printing machine allows for obtaining the 3D physical parts directly from CAD file, it means by adding the material successively layer-by-layer on substrate.

Biomechanics is the application of mechanical principles on living organisms. Finite Element Method (FEM) is widely accepted as a power tool for biomechanics modelling. Irregular geometry, complex microstructure of biological tissues and loading situations are specific problems of the FEM in biomechanics and are still difficult to model. In human anatomy, the femur is the longest and largest bone but strongest under compression only. The femur at its bottom portion meshes with the tibia bone to create the knee joint. At its top end, the femur meshes with the acetabulum to create the hip joint. The femur is responsible for bearing the largest percentage of body weight during normal weight-bearing activities.

II. IMPLANTS

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. Despite great number of metals and alloys known to man, remarkably few warrants Preliminary consideration for use as implant materials. The relatively corrosive environment combined with the poor tolerance of the body to even minute concentrations of most metallic corrosion products eliminate from discussion most metallic materials. Compared to other metallic implant materials. The biocompatibility of implant quality stainless steel has been proven by successful human implantation for decades. Composition, microstructure and tensile properties of titanium, cobalt chrome, zirconium and stainless steel 316 used for internal fixation is standardized in IS and ASTM material specifications. Metallurgical requirements are stringent to ensure sufficient corrosion resistance, nonmagnetic response. Composition, microstructure and tensile properties of titanium, cobalt chrome, zirconium and stainless steel 316 used for internal fixation is standardized in IS and ASTM material specifications. Metallurgical requirements are stringent to ensure sufficient corrosion resistance, nonmagnetic response.

Dimensions(millimetres)	Mean
Femoral Length	443.6
Femoral Head Offset	47.0
Femoral Head diameter	43.4

Femoral Head position	56.1
Canal Width (lesser trochanter+20)	43.1
Canal Width (lesser trochanter)	27.9
Canal Width (lesser trochanter-20)	21.0
Endosteal width at the isthmus level	13.1
Periosteal width at the isthmus level	26.7
Isthmus position	105.7
Neck Shaft Angle(degrees)	122.9
Canal Flare Index	3.36

Table 1.1: Dimensions of Femur Bone

III. MODELLING OF FEMUR BONE

Femur bone is modelled using ANSYS Workbench student version R1. The following flow chart represents step by step modelling of bone.

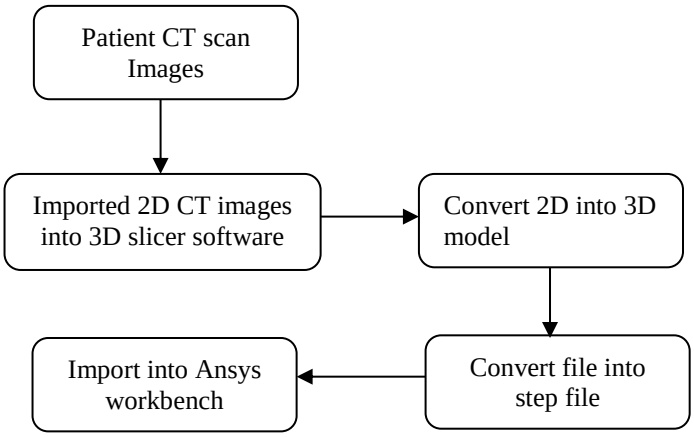


Fig 2.1: 3D model flow chart

Fig.2.2: Femur bone modelled in Catia

IV. MATERIAL ASSIGNMENT AND BOUNDARY CONDITIONS

Materials	**Young's Modulus(GPa)**	**Poisson's ratio**
Ti-6Al-4V	113	0.3-0.33
Zirconium	100-250	0.22-0.32
Cobalt Chromium	210	0.28
Stainless Steel 316	190-205	0.265-0.275

Table 4.1. Material properties

Human bone is highly heterogeneous and nonlinear in nature, so it is difficult to assign material properties along each direction of bone model. In biomechanics study, material can be assigned in two ways, either in Mimics or in Finite element module. Here material properties are directly assigned in ANSYS. The following properties of Density, Young's Modulus and Poisson's Ratio are as follows.Boundary conditions of femur bone is solid and inflexible. The three-dimensional Finite element model of femur bone with

volumetric mesh was imported in ANSYS. Since the femur bone model is nonlinear and highly heterogeneous in nature, model is first imported in Finite Element Modeler then transfer to static structural module in ANSYS 2022 R1. An eccentric and concentrate loads of 55kg,60kg,70 kg applied at the head of femur bone and hinged support is provided at lateral condyle, medial condyle and patellar surface.

V. RESULTS

The simulation part of the study was focused on the chance to form crack initiation and propagation processes in the femur bone specimens under different loading configurations and different materials. The simulations were performed at quasi-static conditions using the ANSYS workbench and results are compared.

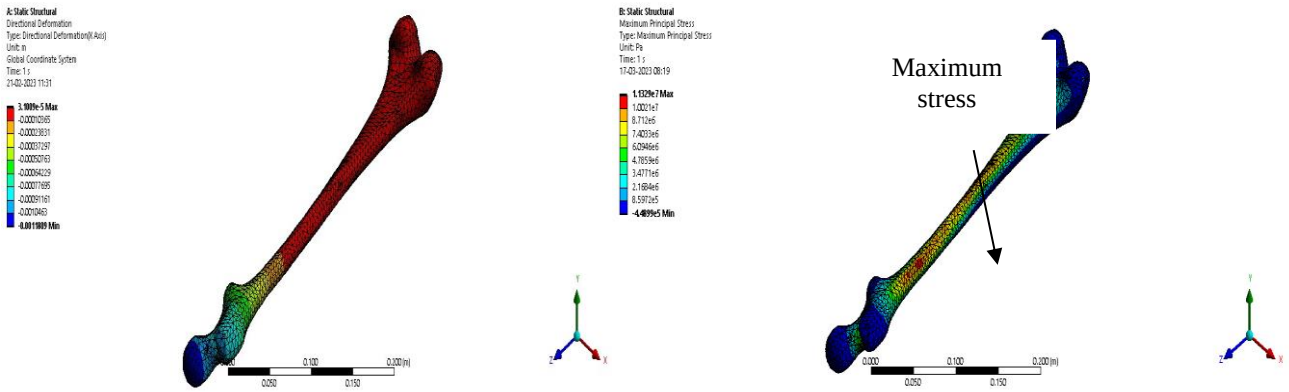


Fig 5.1. Total deformation and Equivalent stress structural steel

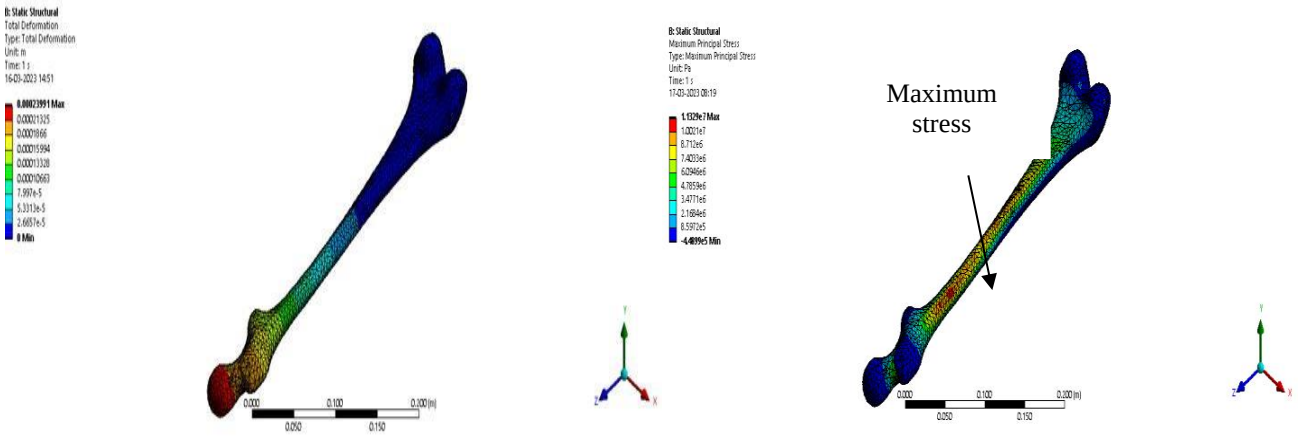


Fig 5.2. Total deformation and Equivalent Stress of Cobalt Chromium

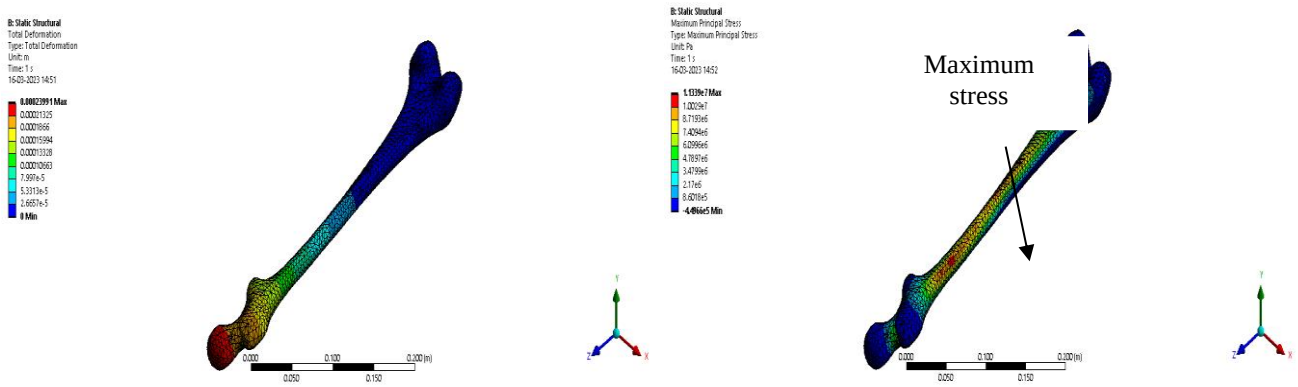


Fig 5.3. Total deformation and Equivalent Stress of Zirconium

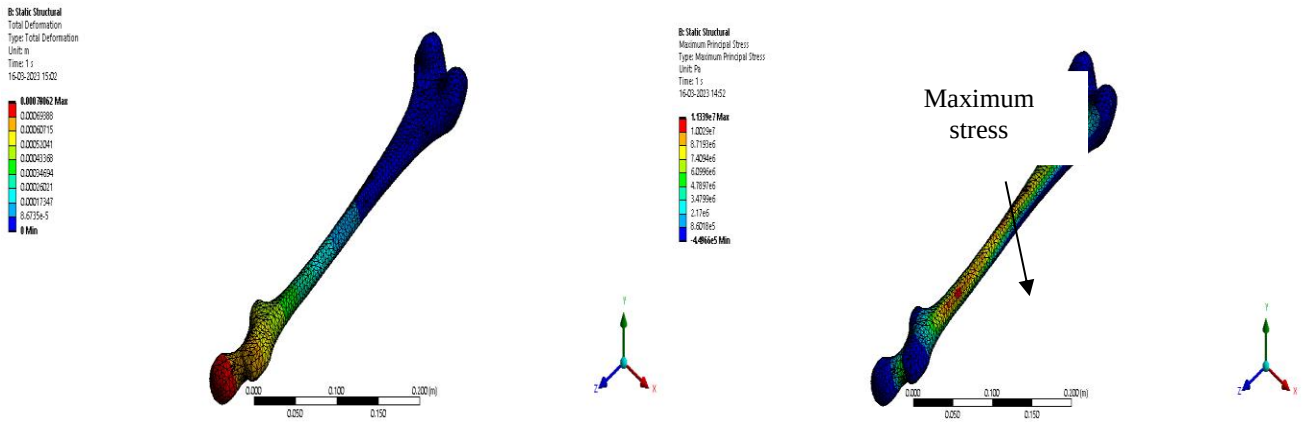


Fig 5.4. Total deformation and Equivalent Stress of Titanium

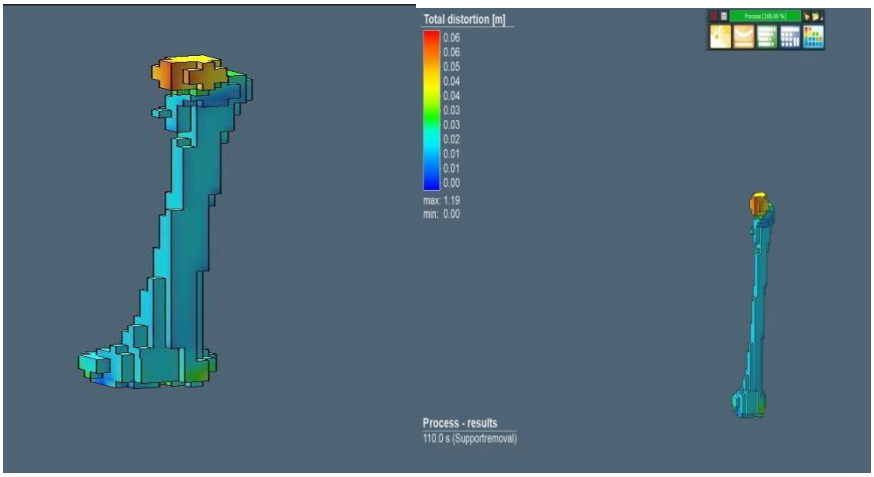
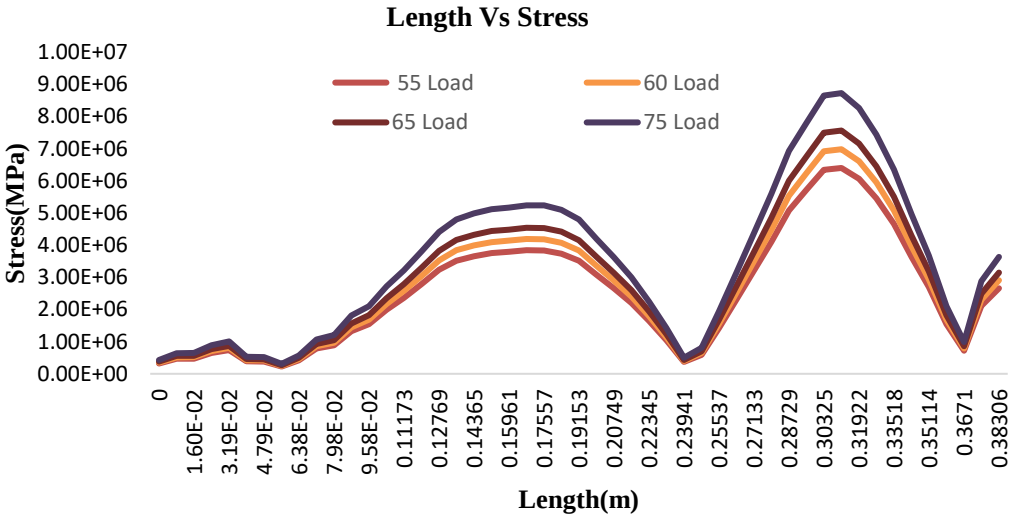


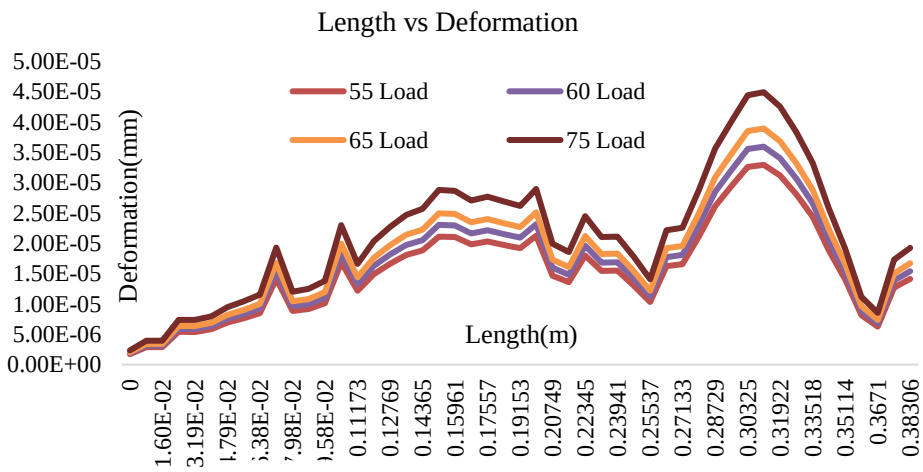
Fig: Simufact simulation of femur bone

VI. Discussions

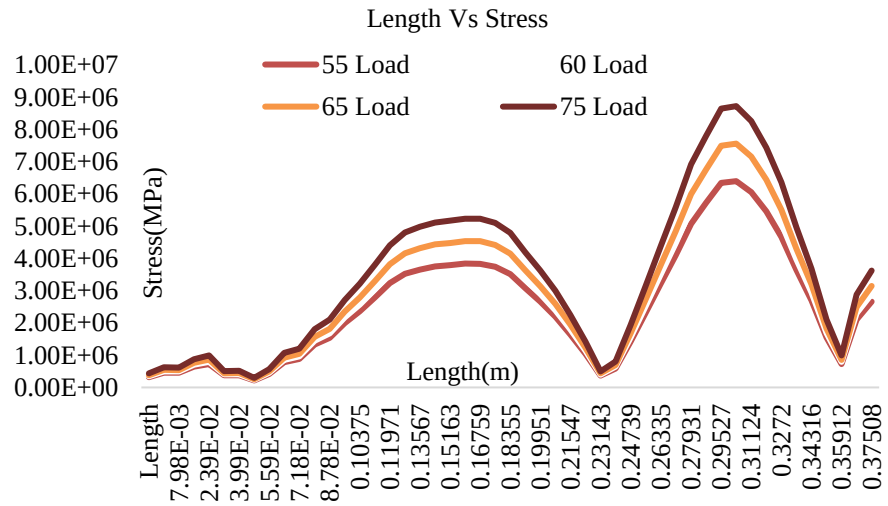
Maximum stress appeared at distance of 0.31124 m and second highest stress appeared at 0.17557 m irrespective of load conditions, and maximum deformation appeared at distance of 0.31124 m and second highest stress appeared at 0.19153 m irrespective of load conditions.



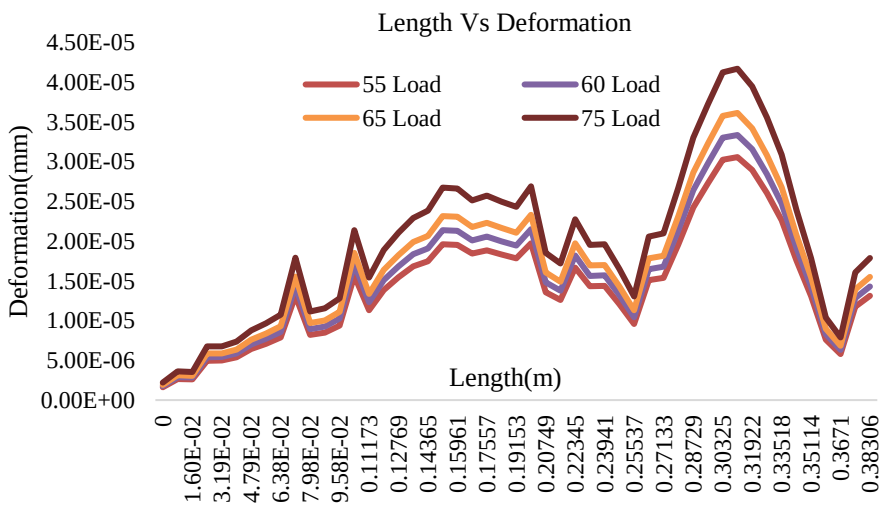
Graph 6.1. Stainless steel Equivalent Stress



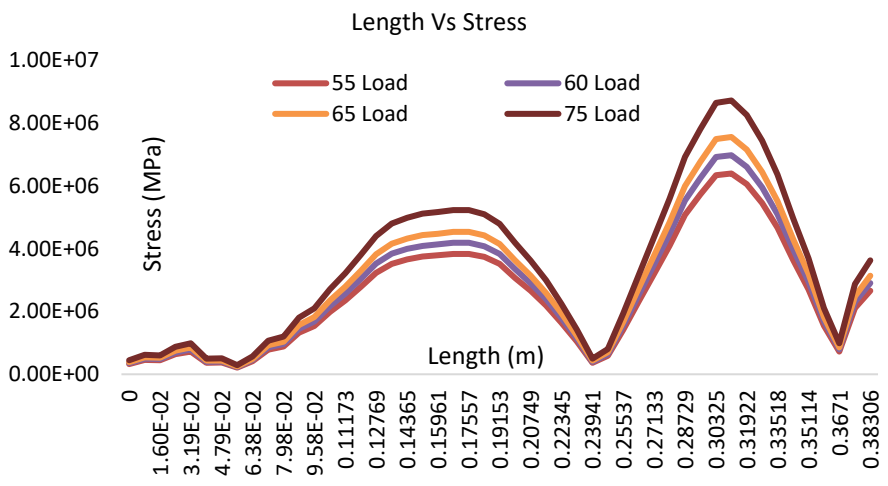
Graph 6.2. Stainless steel deformation



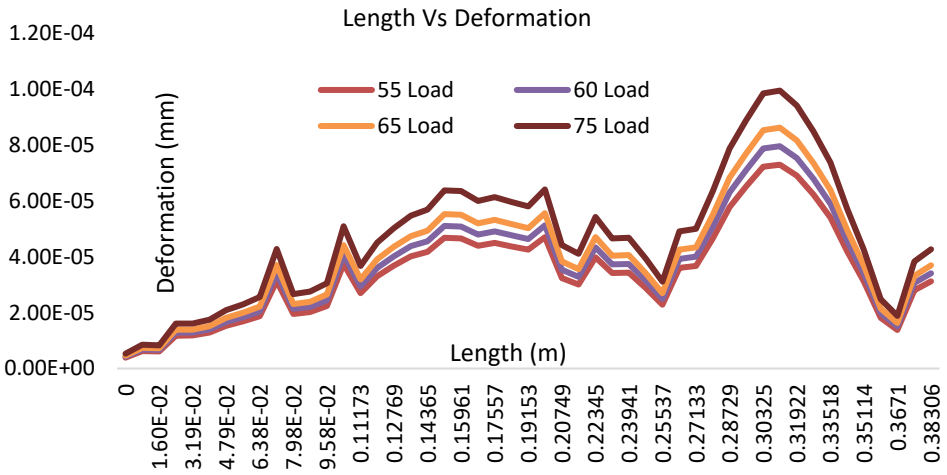
Graph 6.3. Cobalt Chromium Equivalent Stress



Graph 6.4. Cobalt Chromium deformation



Graph 6.6.Ti6Al-4V equivalent stress



Graph 6.6.Ti6Al-4V deformation

Table 6.1: Topology optimization

Minimum	9.4817e-002
Maximum	1.0045
Average	0.87343
Original Volume	2.8404e+005mm^3
Final Volume	2.542e+005mm^3
Percentage volume of original	89.502
Original mass	2.2295
Final mass	1.9955
Percentage mass of original	89.502

10.498 percentage of mass reduced using this topology optimization

VII. Conclusion

Comparison is done between Ti-6Al-4V and Structural Steel implant materials at different load conditions. At each load both stresses and deformations are evaluated. But the stresses of both materials are identically equal. When compared with deformation values Ti-6Al-4V shows less deformation results. hence Ti-6Al-4V is the best material in orthopaedics implant surgeries. The results we have obtained are amazingly satisfactory due to less deformation of Ti6Al-4V alloy. Ti-6Al-4V has excellent Bio-compatible properties along with physical properties which makes it an ideal implant material for fractures, when compared to stainless steel. Ti-6Al-4V

alloy being extremely light with less density does not have any adverse and a 10.498 percentage of mass reduced using this topology optimization.

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