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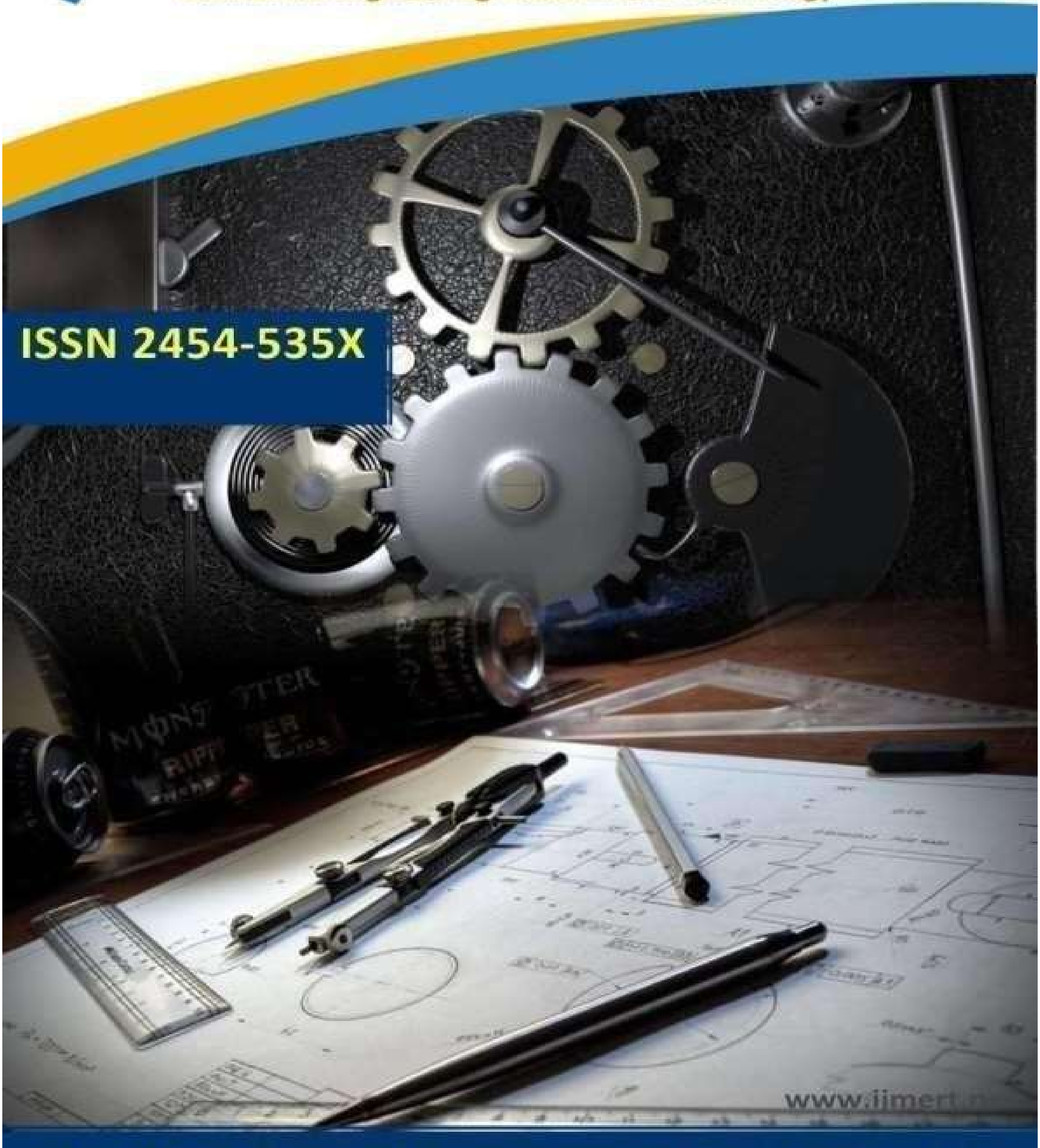

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DESIGN AND STATIC MODAL ANALYSIS OF ARTIFICIAL KNEE PROSTHESIS USING FEM

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ABSTRACT:

The generally acknowledged effective surgical method for treating osteoarthritis and other degenerative disorders of the knee is total knee arthroplasty (TKA). Nonetheless, current data on low patient satisfaction and survivability highlights the need of receiving the best possible endoprosthetic treatment. Artificial components are used to replace the natural joint surfaces in an effort to alleviate pain, restore function, and enhance the quality of life associated with health. Lightweight, high-load-bearing construction is the main need for this. The project's goal is to develop and evaluate a flexible prosthetic knee joint and identify options and strategies to meet the need for a well-thought-out replacement for a lightweight, readily operable prosthetic knee joint. Ansys software is used to analyse the knee dimensions, which are derived from measurements of the human body. This study examines the suitability of materials with characteristics such as low cost, great lifespan, and no maintenance for use in prosthetic knees. The improvement of knee prostheses over the last ten years has been significant, allowing individuals to continue engaging in numerous activities even after experiencing age or injury. The human knee-joint is a complicated system with a complexly structured femoral condoyle that glides over the complexly curved meniscus of the tibia bone, absorbing different critical stresses during different gait, movement, and sitting activities. Since the beginning of orthopaedic surgery, metal alloys have been the preferred materials. TI-6AL-4V, TI-6AL-7NB, ABS, and stainless steel are the materials that are most often used as biomaterials for knee implants. This project aims to create a 3D CAD model of prosthetic knee joint implants by allocating load combinations of biomaterials to the femoral and tibia components and analysing the distribution of von-misses stresses, total deformation, shear stress, and strain. 3D modelling programs ANSYS 15 finite element analysis software and Catia are used to simulate knee implants in three dimensions and determine the best material for knee prostheses.

Keywords: femoral and tibia components, biomaterials, FEA (Finite Element Analysis), prosthesis, von-misses stresses, total deformation, shear stress.

I. INTRODUCTION

A prosthesis, prosthetic, or prosthetic limb is an artificial device extension used in orthopaedic medicine to replace a missing body component. It falls under the umbrella of biomechatronics, which is the study of how to replace lost motor control resulting from illness, accident, or deformity using mechanical devices that interface with human muscle, bone, and neurological systems. Prostheses are usually utilised to complement malfunctioning body components or replace damaged or missing portions due to trauma or birth defects. Artificial heart valves are widely used within the body, whereas artificial hearts and lungs are less often used but still undergoing active technological development. Artificial eyes are among the other medical equipment and tools that fall under the category of prosthetics. Although in certain situations a prosthesis may wind up fulfilling some or all

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of the same functional advantages as an orthotic, prosthetics are expressly not the same as orthotics. In a technical sense, prostheses, often known as prostheses, are the completed articles. A C-Leg knee, for example, is only a prosthetic component and not a prosthesis in and of itself. The whole prosthesis would be made up of the attachment hardware components all the way down to and including the foot, as well as the stump attachment mechanism, which is often a "socket". Depending on the memory database, because terminology is often altered.

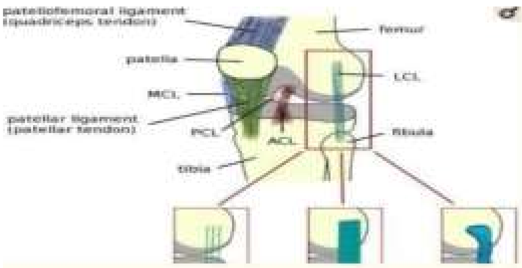

Figure1: parts of knee joint

In the world of medicine, a prosthesis is an artificial device that is used to replace a bodily component that is damaged or missing due to an illness, accident, or congenital condition. There are primarily two kinds of prostheses in use: somato (body) and craniofacial. There are two categories of craniofacial prostheses: extra oral prostheses and intra prostheses. On the other hand, somato prostheses come in many different forms, such as limb prostheses, ear prostheses, and replacements for any damaged body parts with artificial organs.

Objectives:

- General evaluation of mechanical reliability for knee implants in terms of stress concentration Determining the proper material using FEM.
- Analyzing the stress concentration on femur and tibia knee implants prosthesis geometry.
- Finally find out stresses, total deformation, shear stress, strain in static analysis
- Recommending the geometry and the suitable material we should be using in future implant surgery.

II. LITERATURE REVIEW

Osteoarthritis and rheumatoid arthritis cause 44.7% of the pain experienced by humans, and hinder daily activities such as walking and stair climbing. [[1]]. Total knee replacement (TKR) surgery was first performed in 1968. In this surgery, part of the damaged bone was excised and replaced with a metal joint implant [[2]]. The use of TKR to address knee disease has grown exponentially in the past 60 years and is expected to continue increasing by 601% from 2005 to 2030 in the USA [[3]]. Improvements in surgical materials and techniques have significantly enhanced the effectiveness of this procedure. However, 11–19% of primary TKR patients reportedly remain dissatisfied with the surgical outcome, and ∼6% require revision surgery owing to operative complications and failure of the implant [[4], [5]]. Although in vivo clinical testing provides the most realistic information regarding the biomechanics of the TKR knee, certain types of experiments or data collection methods are difficult or unethical to complete on human subjects. In addition, applying clinical testing for prosthesis evaluation is difficult during the design stage. Therefore, various types of in vitro knee simulators have been developed to predict the joint kinematics during the design of the knee prosthesis [[6]-[11]]. However, the number and type of experimental tests are limited because they require physical parts and cadaveric specimens and are very time-consuming. Therefore, experimental analysis of component geometry during prosthesis design is in general difficult in terms of cost

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Vol.16 Issue 4, 2024

and time. Computational knee simulations provide an efficient toolset to overcome the limitations of in vivo and in vitro testing, to accelerate the design, and to improve the quality of the knee prosthesis. These simulations allow the evaluation of a TKR design under various dynamic loading conditions to address clinical design and to evaluate ligament performance, laxity, kinematics, wear, contact mechanics, cement fatigue, bone remodelling-induced stress shielding, muscle force, and joint loading. The simulations also allow comparative analyses of TKR designs [[10]].

III. METHODOLOGY

Minimization of stress concentration developed on contact surface between the femur and tibia knee prosthesis. Finally Design and analysis selecting the proper prosthetic material.

Step 1: Collecting information and data related to knee Prosthesis
Step 2: A fully parametric model of the Artificial knee created in Catia software.
Step 3: Model obtained in Igs. Analyzed using ANSYS 14.5(workbench), to obtain stresses, deformation, Shear stress,Strain etc.
Step 4: Taking boundary conditions.
Step 5: Finally, we compare the results obtained from ANSYS and compared geometry with different materials.

Knee Replacement Implant Materials:

Stainless Steel (SS):

Most common SS used to design the knee joint implant is 316L SS. It is mainly made up of iron, but has various materials with a composition of metals like chromium more than 11%, molybdenum about 2-3%. It has limited ability to withstand corrosion effect in in-vivo condition, thus it is not preferred frequency while designing of the implant, butt used in designing of knee implant which can be used as temporary implants such as screws and plates.

Ti-6Al-7Nb Material:

Ti-6Al-7Nb (UNS designation R56700) is an alpha-beta titanium alloy first synthesized in 1977 containing 6% aluminum and 7% niobium. It features high strength and has similar properties as the cytotoxic vanadium containing alloy Ti-6Al- 4V. With the aim of applying a novel titanium alloy, Ti-6Al-7Nb, to a Prosthesis casting material, a comprehensive research work was carried out on its characteristics, such as castability, mechanical properties and corrosion resistance in the present study.

Table 1: Material properties

Material Properties	**Abs**	**Stainless Steel 316 L**	**Ti-6Al-4V**	**Ti-6Al-7Nb**
Density(g/cm^3)	1.25	8.0	4.420	4.52
Possion's Ratio	0.38	0.3	0.35	0.35
Young's Modulus (Gpa)	2.5	165	114	117
Ultimate Tensile Strength (Mpa)	40	515	930	980

Walking Condition

Consider the Force = 3000
Gravity =9.81
Mass = weight of the body
3000=305X9.81

Design Procedure in Catia Workbench:

The development of the modern total knee arthroplasty can be dated back to the 1960s. The polycentric knee designed by Frank H. Gunston introduced the use of two cemented polyethylene tibial components articulating on two cemented femoral components. In addition, specialized instrumentation was used to insert the prosthesis. The introduction of a reliable fixation agent, together with a metal on polyethylene articulation, led to a

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Vol.16 Issue 4, 2024

furious development of designs in knee arthroplasties.

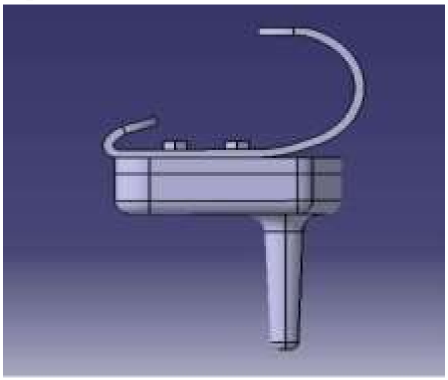

Figure 2: Isometric view

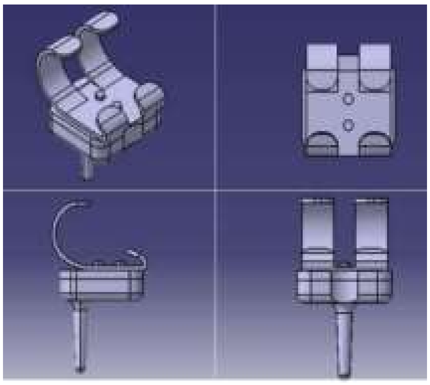

Figure 3: Multi views of Knee Implant prosthesis

IV. RESULTS AND DISCUSSIONS

The designed artificial Knee prosthesis, created in CATIA, undergoes comprehensive analysis in ANSYS 15.0. The analysis includes both static analysis and modal analysis, performed using different materials such as ABS, SS L316, TI-6AL-4V, TI-6AL-7NB. Considering the load distribution on each Knee prothesis, the weight is doubled, resulting in a load of 3000N

The results obtained from the analysis provide valuable insights into the performance and behavior of the Knee prosthesis. These results, including stress distribution, deformation, and natural frequencies, are presented below. The analysis aims to assess the structural integrity, strength, and functionality of the Knee prosthesis design under loading conditions and material choices.

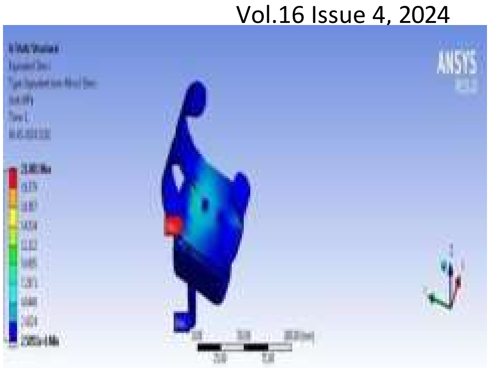

Figure 4: Von-misses stress of TI-6AL-7NB Material

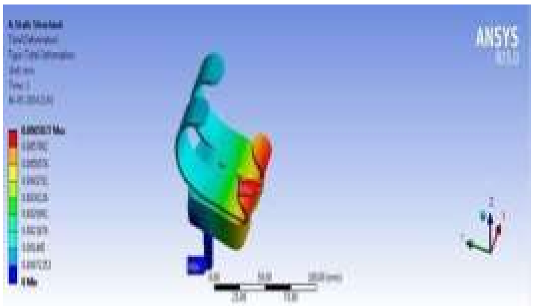

Figure 5: Total deformation of TI-6AL-7NB Material

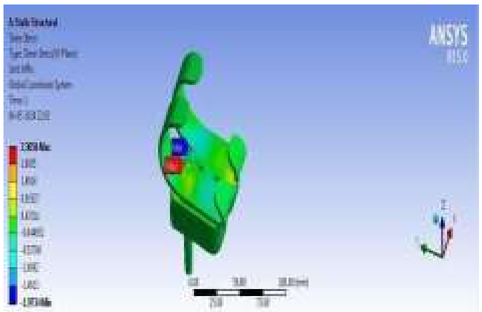

Figure 6: Shear stress of TI-6AL-7NB Material

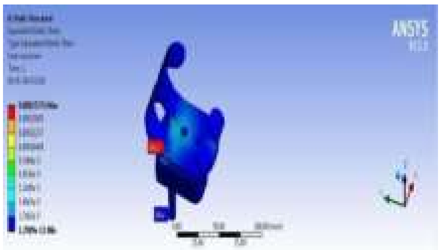

Figure 7: Strain stress of TI-6AL-7NB Material

TI-6AL-4V Material

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Vol.16 Issue 4, 2024

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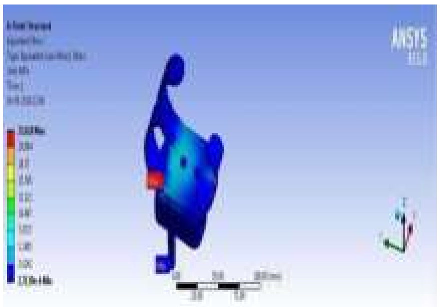

Figure 8: Von-misses stress of TI-6AL-4V Material

Figure 9: Total deformation of TI-6AL-4V Material

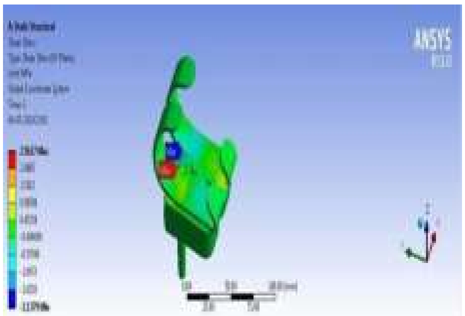

Figure 10: Shear stress of TI-6AL-4V Material

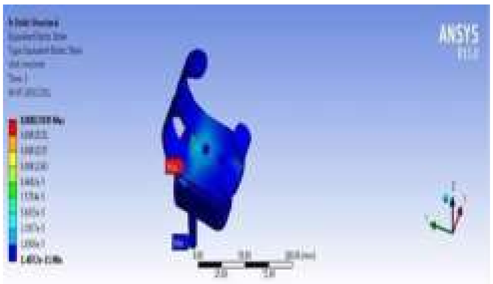

Figure 11: Strain stress of TI-6AL-4V Material

SS L 316 Material

Figure 12: Von-misses stress of SS L 316 Material

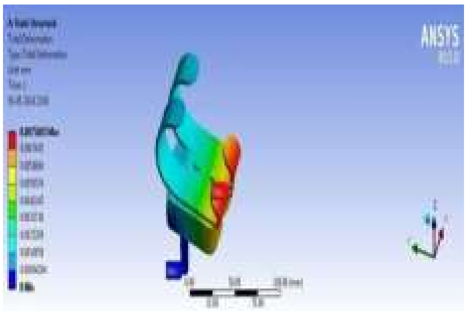

Figure 13: Total deformation of SS L 316 Material

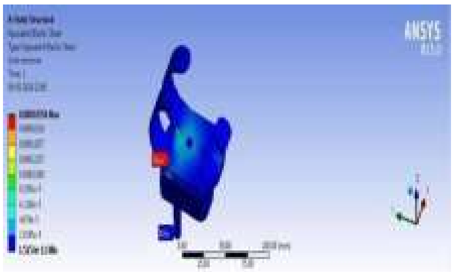

Figure 14: Strain stress of SS L 316 Material

ABS Material:

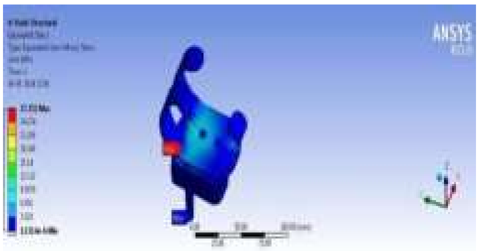

Figure 15: Von-misses stress of ABS Material

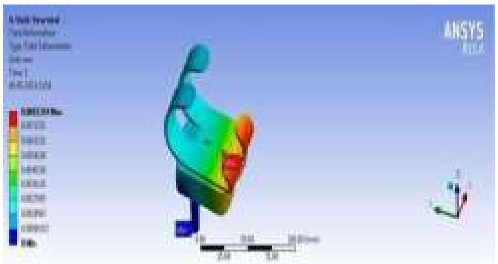

Figure 16: Total deformation of ABS Material

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Vol.16 Issue 4, 2024

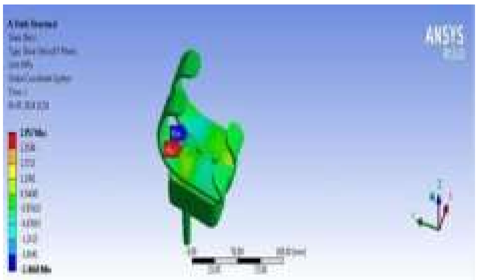

Figure 17: Shear stress of ABS Material

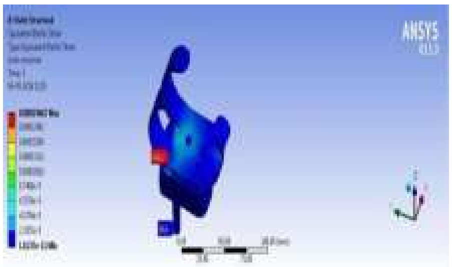

Figure 18: Strain stress of ABS Material

Von-Misses Stress:

we can observe that in case of Von-misses stress of knee Prosthesis implant made of various materials ABS, SS L316, TI-6AL-4V, TI-6AL- 7NB, found to have least Von-misses stress is TI-6AL-7NB Material 21.801Mpa when applied 3000N comparison with remaining materials including the present material.

Figure 19: von-misses stress

Total Deformation:

we can observe that in case of Total deformation of knee Prosthesis implant made of various materials ABS, SS, TI-6AL-4V, TI-6AL-7NB, found to have least Total deformation value is TI-6AL-7NB Material 0.0065mm when applied 3000N comparison with remaining materials including the present material.

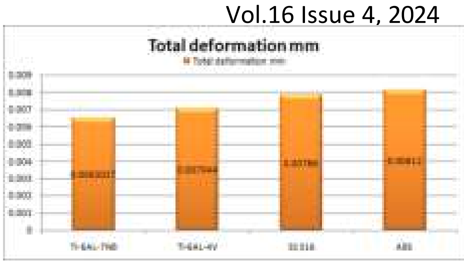

Figure 20: Total deformation

Shear Stress

we can observe that in case of Shear stress of knee Prosthesis implant made of various materials ABS, SS, TI-6AL-4V, TI-6AL-7NB, found to have least shear stress value is is TI-6AL-7NB Material 2.365Mpa when applied 2500N comparison with remaining materials including the present material.

Figure 21: Shear stress

Strain Graph:

we can observe that in case of Strain of knee Prosthesis implant made of various materials ABS, SS, TI-6AL-4V, TI-6AL-7NB, found to have least Strain value is TI-6AL-7NB Material 0.000157. when applied 3000N comparison with remaining materials including the present material.

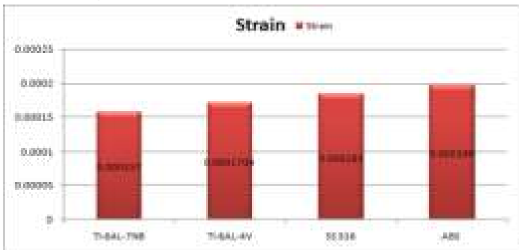

Figure 22: Strain

V. CONCLUSION:

A new generation of implants has been developed as a result of careful examination of the normal biomechanics of the knee joint and an analysis of prior implant failures. Improved cementless attachment in conjunction with this advancement has

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http://www.ijmert.com
Vol.16 Issue 4, 2024

produced prosthetic designs with lower failure rates. Nonetheless, a successful knee replacement still depends on carefully choosing the patients.

- Using CATIA software, a design strategy for tibial and femur component implants was created in this work.
- ANSYS software has been used to do non-linear static analysis of a knee joint by inserting the contact pair between the components.
- Typically, the knee joint is under strain.
- A running condition load of 3000 Newton's is applied to the knee implant to conduct the analysis.
- We examine four distinct materials.
- Both modal and static analyses were completed. In the end, it was determined that titanium alloy material is appropriate for replacing knee joints.
- In the end, titanium alloy implants provide longer lifespans.

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