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DESIGN AND STRUCTURAL ANALYSIS OF HIP-JOINT IMPLANT

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ABSTRACT:

An artificial joint (prosthesis) helps reduce pain and improve function. Also called total hip arthroplasty, hip replacement surgery might be an option if hip pain interferes with daily activities and nonsurgical treatments haven't helped or are no longer effective. We review the different materials, constructions, and surfaces used in the development of femoral stems, in order to solve and avoid various problems associated with their use. Femoral stem prostheses have undergone substantial changes and design optimizations since their introduction In this project a new design of hip joint implant is introduced by using Ti6Al4V(alpha-beta Ti alloy), Cobalt Chromium(Co Cr) alloy, 316L stainless steel alloy materials. All the parts are designed in CATIA V5.18 and static structural analysis was done in ANSYS WORKBENCH. The equivalent (Von Mises) stresses are analyzed and deformation of the Hip joint for all the three materials are compared. Also, Ti6AL4V has better properties that are similar to bone compared to the rest of the bio materials that are considered during the project work.

KEYWORDS: Implant, Femoral stem, Femoral head, Plastic liner, Acetabular component, Support plate, Structural analysis.

1. INTRODUCTION:

The substances which are engineered to meet the biological needs such as replacing a tissue, hip joint replacements, dental implants, heart valve replacements etc. are called as **biomaterials** and the study of biomaterials is called **biomaterials science** or **biomaterials engineering.**

Bone implant materials are often designed to promote bone growth while dissolving into surrounding body fluid. Thus, for many bio materials, good bio compatibility along with good strength and dissolution rates are desirable.

Ti6Al4V:

Ti6Al4V, Ti-6Al-4V or Ti 6-4, also called a grade 5 titanium alloy is so called because it is made of 6% aluminium (Al) and 4% vanadium (V), along with about 0.25% iron and 0.2% oxygen, with the remainder being titanium (Ti). It is also called an alpha-beta alloy (since it contains aluminium, which is an alpha stabiliser and vanadium, which is a beta stabiliser) and can undergo heat treatment.

Cobalt Chromium alloy:

The alloy composition used in orthopedic implants is described in an industry standard ASTM-F75: mainly cobalt, with 27 to 30% chromium, 5 to 7% molybdenum, and upper limits on other important elements, such as less than 1% each of manganese and silicon, less than 0.75% iron, less than 0.5% nickel, and very small amounts
of carbon, nitrogen, tungsten, phosphorus, sulfur, b oron etc.

316L STAINLESS STEEL:

316L has outstanding properties for manufacturing. Much of this has to do with the amount of nickel involved – between 10% and 15% – which is why it has excellent form ability, weld ability and ductility. The difference between 316 and 316L stainless steel is in the carbon content. To qualify as 316L surgical grade stainless steel, the carbon content can't exceed 0.03% – hence the "L" in the stainless-steel code, which stands for low carbon.

INTRODUCTION TO CATIA:

CATIA is an acronym for (Computer **A**ided **T**hree-dimensional **I**nteractive **A**pplication). It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products.

CATIA is a multi-platform 3D software suite developed by Dassault Systems, encompassing CAD, CAM as well as CAE. Dassault is a French engineering giant active in the field of aviation, 3D design, 3D digital mock-ups, and product lifecycle management (PLM) software. CATIA is a solid modelling tool that unites the 3D parametric features with 2D tools and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. It is also possible to generate model dimensions and create reference dimensions in the drawing views. The bi-directionally associative property of CATIA ensures that the modifications made in the model are reflected in the drawing views and vice-versa.

ANALYSIS:

First the domain is represented as finite elements. This is called descritization of domain. Mesh generation programs called processors, help in dividing the structure. Formulate the properties of each element in stress analysis. It means determining the nodal loads associated with all element deformation stress that is allowed. Assemble elements to obtain the finite element model of the structure. Apply the known loads, nodal forces in stress analysis. In stress analysis the support of the structure has to be specified. Solve simultaneous line algebraic equations to determine nodal displacements in the stress analysis. Postprocessors help the user to sort the output and display in the graphical output form. A typical finite element model is comprised of nodes, degrees of freedom, elements material properties, externally applied loads and analysis type. The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide range of engineering problems.

1. **Part design:**

1.1 Femoral stem

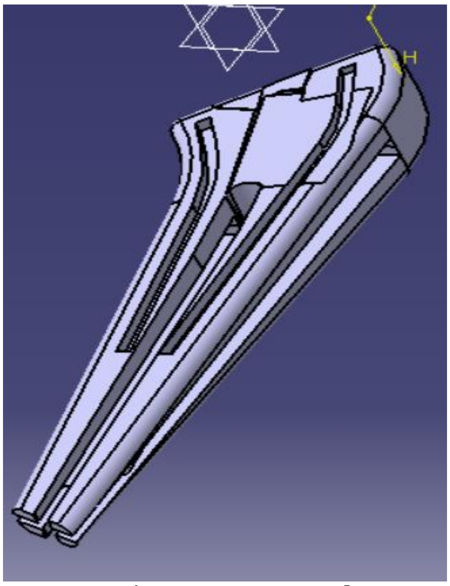

Fig.1.1.1. Femoral stem

1.2 Femoral head

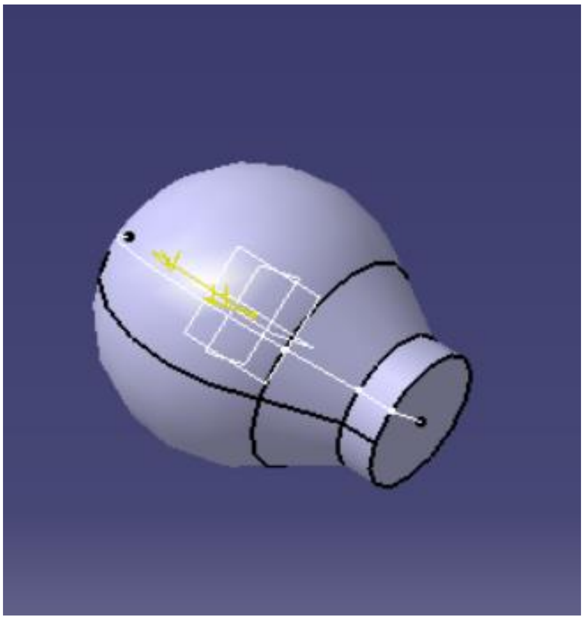

Fig.1.1.2. Femoral Head

1.3 Support plate

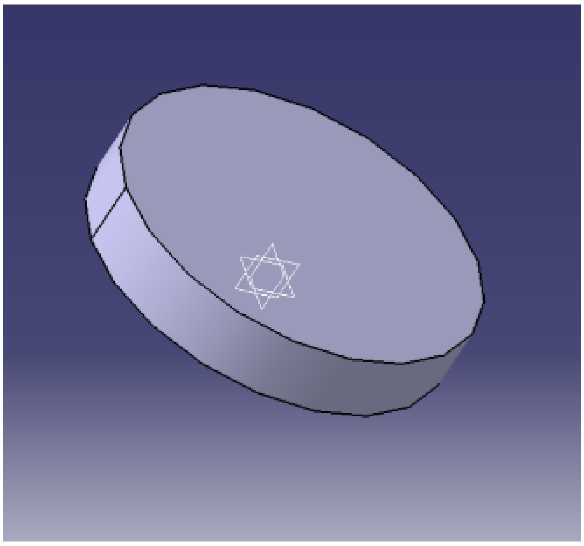

Fig.1.1.3. Support plate

1.4 Plastic liner

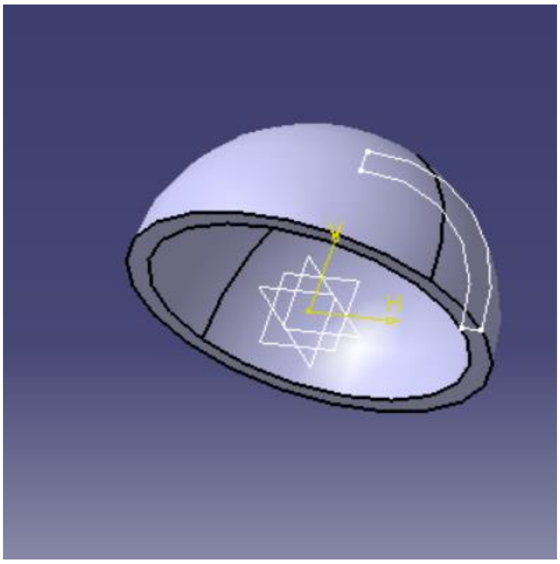

Fig.1.1.4 Plastic liner

1.5 Acetabular Component

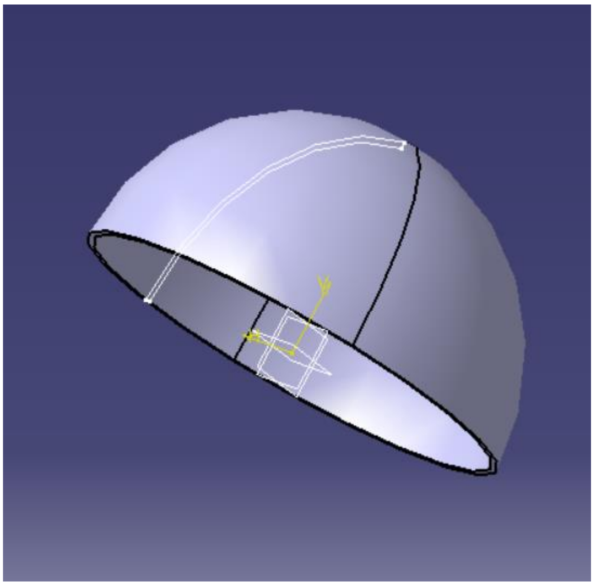

Fig.1.1.5. Acetabular component

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2. ASSEMBLY OF THE HIP JOINT IMPLANT:

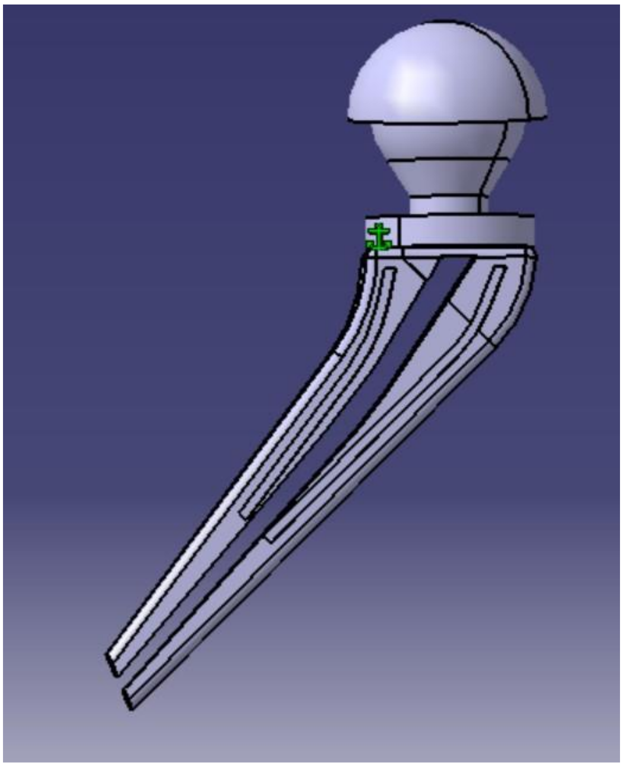

Fig.2.1. Assembly of Hip joint implant

3. STRUCTURAL ANALYSIS OF THE HIP JOINT:

3.1 Ti6Al4V:

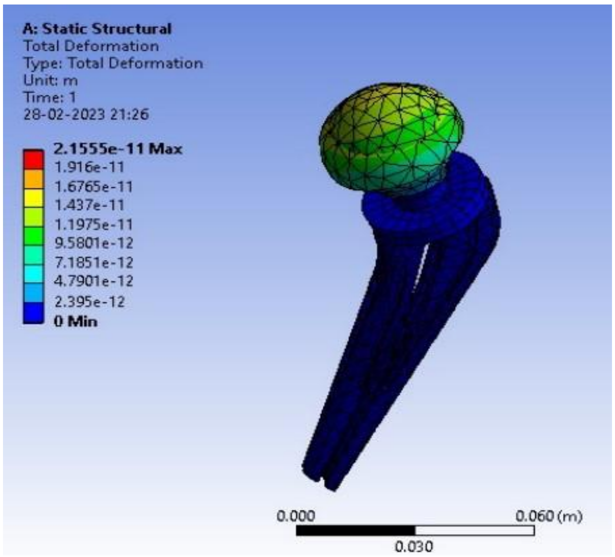

Fig.3.1.1 Total deformation of hip joint implant (Ti6Al4V)

3.2 316L STAINLESS STEEL:

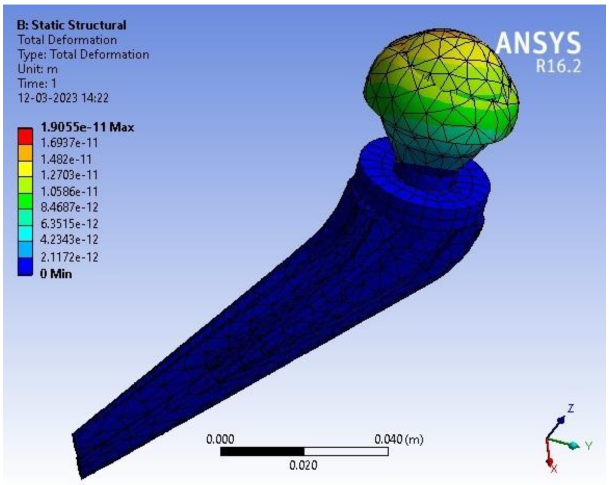

Fig.3.1.2. Total deformation of hip joint implant (316L Stainless steel)

3.3 Cobalt Chromium alloy

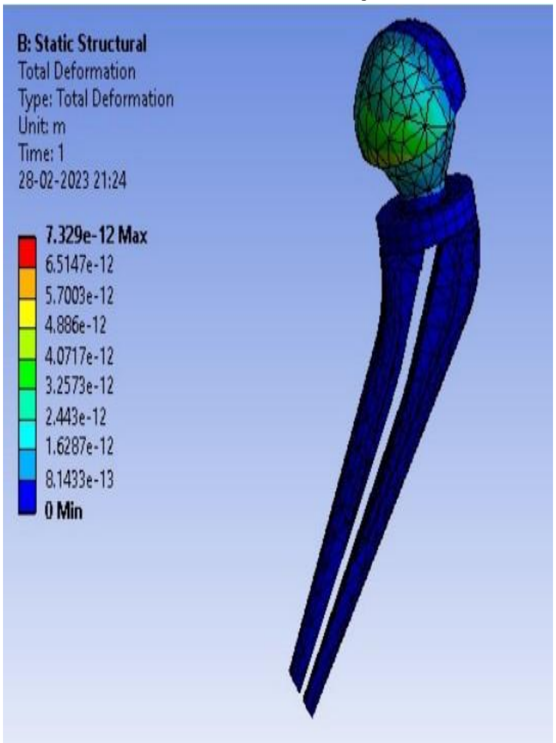

Fig.3.1.3. Total deformation of hip joint implant (Cobalt Chromium alloy)

4. RESULTS OF THE HIP IMPLANT WITH 4 STEMS AFTER APPLYING LOADS

S.No.	Material	Total Deformation in m (Minimum and Maximum
1	316L Stainless Steel	0 **(**Minimum**)** 125.12 (Maximum)
2	Cobalt Chromium alloy	0 **(**Minimum**)** 62.374 (Maximum)
3	Ti6Al4V	0 **(**Minimum**)** 2.1555 (Maximum)

5. CONCLUSION:

After all the analysis is made it is found that the hip joint with 4 stems showing satisfying properties by showing the least deflection and maximum stability compared to the hip joint with 2 stems. Also, Ti6AL4V has better properties that are similar to bone compared to the rest of the bio materials that are considered during the project work. The surgical procedure for the four-stem hip joint implant will be differ from conventional procedures. Four-stem hip joint can be placed for a middle-aged man/woman whose bone density is high also doesn't have osteoporosis.

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