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STRUCTURAL ANALYSIS & FABRICATION OF FEMORAL STEM COMPONENT OF A NEWLY DESIGNED CEMENTED HIP IMPLANT THROUGH FUSED DEPOSITION MODELING

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ABSTRACT
Hip implant also termed as Hip prosthesis is a artificial bio mechanical structure especially designed for implantation in the surgeries like Total Hip arthoplasty (THA)as a replacement to the natural hip joint. A typical hip joint consists of a longitudinal bone called as Femur bone with a ball like structure at the end fitted in a cup or socket type component in the human pelvis thus forming a ball and socket type of joint which is also called as acetabulofemoral joint. Due to certain factors like age, orthopedic diseases and accidents damage will occur at hip joint resulting surgery. To restore the functionality of hip joint artificially designed structure called as hip prosthesis is implanted at hip joint. During the past few decades thousands of hip revision surgeries were done due to implantation of improperly designed or unsuitable implants to the patients. Other than this the improper design may leads to certain problems like aseptic loosening blood clots and infection across the implant etc. To avoid this there is a strong necessity of properly simulated new designs of hip implant. The current work illustrates the design and analysis of femoral stem component of a newly designed hip prosthesis along with parallel comparison with pre established design followed with fabrication done through one of the rapid prototyping technique called fused deposition modeling.

KEYWORDS: Hip prosthesis, CAD Model, Analysis, Fused deposition Modeling (FDM).

INTRODUCTION
Hip joint is a very integral joint in total human body due to its bio mechanical functionality. Nearly~ 2/3rd of the total body weight is supported by the hip joint and it also facilitates the free articulation of the lower limbs. Hip joint is also termed as Acetabulo femoral joint a hip joint generally consists of ball and socket type of joint quite spherical bone structure called as Femur is naturally attached to a cup like structure in the human pelvis. Continuous transfer of forces occurs from acetabulum to femur and vice versa because of the routine human activities if these forces exceed the natural limit then this condition will leads to fracture of the bone. the damage to the bone is not only occurs due to the fracture but also due to certain diseases like osteoarthritis and osteoporosis in this condition the bone damage will occur due to the infection and depletion of bone material at the joint area. . To repair the bone surgeries like total hip arthoplasty (THA) and total hip replacement (THR) are carried out. THA and THR surgical procedures involve the surgical removal of the head and neck of the proximal femur and the cartilage and subchondral bone in the acetabulum. A new joint is then created by inserting a metallic femoral stem and cup into the medullar of the femur and the acetabulum the artificially arranged metallic component is called as “implant or prosthesis”.

Fig. 1 Hip Prosthesis

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The artificial implant will relieves pain and restore the functionality of the hip joint. Since the first THA carried out in 1938 by Philip wiles a lot many implants were designed and implanted the failure rate is still at considerable mark due to improper design. The improper design of hip prosthesis may leads to a stiffness mismatch and tends to aseptic loosening over 76% of the hip revision surgeries occurs due to this condition . The improper geometry of the implants may causes swelling of the tissues around the bone region and may causes infection at affected area .The use of un suited materials for manufacturing of implants leads to mechanical failure. so proper simulation study of properties and conditions is very much important for manufacturing of implants to serve the purpose conventional design and analysis methods are nonfunctional because conventional design and analysis of bone–implant hip prosthesis highly rely on expert's knowledge and experience. The hip implant should be designed and studied in computer environment before implanting to a person on a patient. Finite element method (FEM) as one of the mostly used simulation technique has been used in orthopedic biomechanics for many decades. In the present work the design of implants is carried out in CATIA and analysis is performed in ANSYS. Static structural analysis is performed to predict the effects of relative stresses and strains on implant. Certain parameters like effect of stresses and strain , deformation criteria and safety factor for different implants is predicted in ANSYS work bench and the best implant is chosen for rapid prototyping by careful analysis and comparison of results.

DESIGN OF IMPLANTS

The design of implant is carried out in computer environment and it is often termed as CAD (Computer aided design) modeling. The modeling is carried out by selecting certain geometrical parameters. Several software packages like AutoCAD, PRO E, and solid works are in existence but CATIA is the most preferred software package used to design bio mechanical parts. The designed model is further utilized for analysis.

For designing a hip implant we require certain geometrical parameters like Femoral head diameter, femoral neck angle and diameter and femoral stem length again the acetabulum component design is dependent o the geometrical considerations chosen for Femoral component design. The design factors varies in the case of cemented and un cemented Prosthetic designs. The geometrical data required for implant design is taken from patient through data acquisition techniques like Computed tomography (CT) and Magnetic resonance imaging (MRI) data. To design the current new implant model standard manufacturers data is taken in to account and the second implant data is obtained from literature [3].

Table 1 :Standard dimensions of hip implant

Parameters	**Values**
Neck Shaft angle	128 degrees
Femoral length	162mm
Head diameter	28mm
Liner diameter	32mm
Cup diameter	44mm
Neck diameter	14mm

The newly designed implant model is provided with grooves in the top mid center with an aim to reduce the total weight of the implant. At the bottom portion of the femoral stem were created with notchy structures which can facilitates better fixation during implantation when fixed inside the femur bone along with PMMA or bone cement.

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Fig: 1: Redesigned implant model from the parameters taken from the Paper probabilistic design of newly designed cemented hip prosthesis.

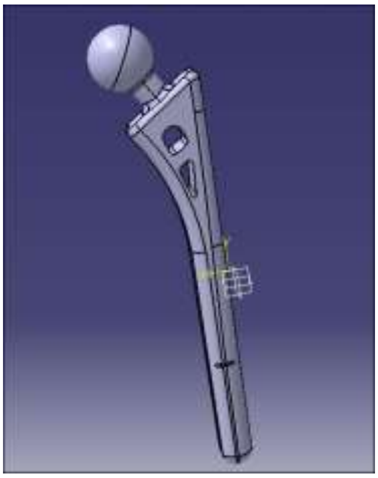

Fig. 2 Newly designed Implant(Implant-2)

ANALYSIS OF IMPLANTS

Finite element analysis is one of the computational technique used to solve technological problems for example we can predict strain rate for a particular object for a specific amount of forces or stresses applied, deformation rate for a specific period of time can be estimated through FEA analysis . to carry out such computations data such as material properties ,loading conditions should be specified before solving the problem.FEA is a great tool to study the stress response of the hip joint. For present analysis ANSYS 14.5 software is used. ANSYS is a flexible, user friendly plat form to perform implant analysis [3].

In the present work a Static structural Analysis is performed on all the four implants by keeping the femoral stem portion in fixed conditions as like the implant is fixed in Femur bone. After meshing a force of 2000N is applied on femoral head positioning the down ward direction [4].

To carry out the analysis proper material should be specified before Analysis. To solve current problem Titanium alloy is selected for Analysis as this material exhibits high mechanical characteristics with bio compatibility factor. After giving proper inputs the problem is solved and certain results of Equivalent (von-mises) Stress, Equivalent elastic Strain, shear stress, deformation and safety factor are evaluated.

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Table 2: Material properties of titanium alloy

S.no	Properties	Value
1	Density	4620kg/m^3
2	Young's modulus	9.6e+10 pa
3	Poisson ratio	0.36
4	Thermal conductivity	21.9w/mk

Analysis Results For Implant 2

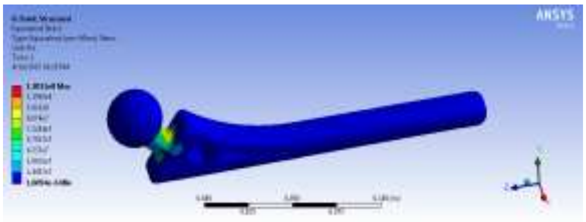

Fig 3. Equivalent stress

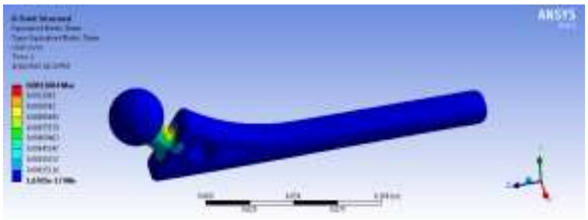

Fig 4. Equivalent elastic strain

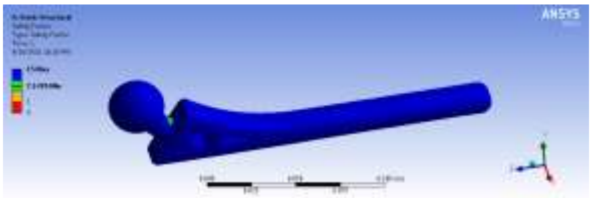

Fig 5. Safety factor

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Impact Factor: 4.116
CODEN: IJESS7

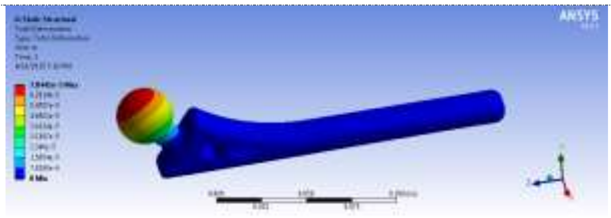

Fig 6.Total Deformation

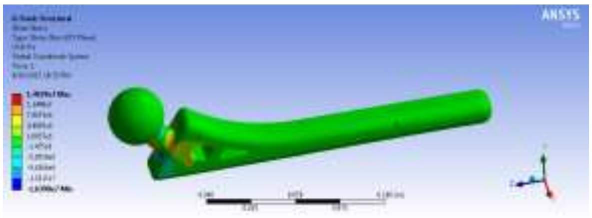

Fig 7. Shear stress

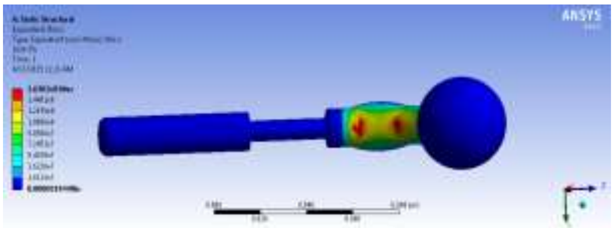

Fig 8. Equivalent stress

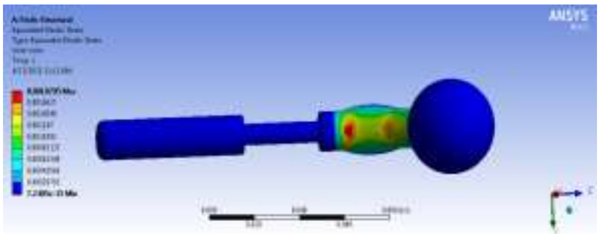

Fig 9. Equivalent elastic strain

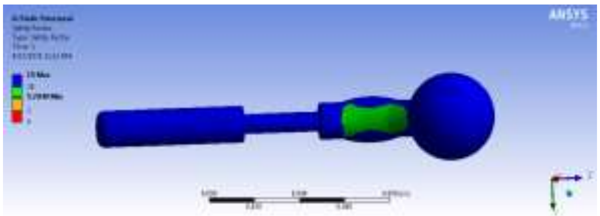

Fig 10. Safety factor

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Impact Factor: 4.116
CODEN: IJESS7

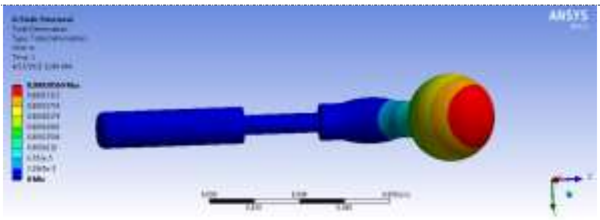


Fig 11. Total Deformation

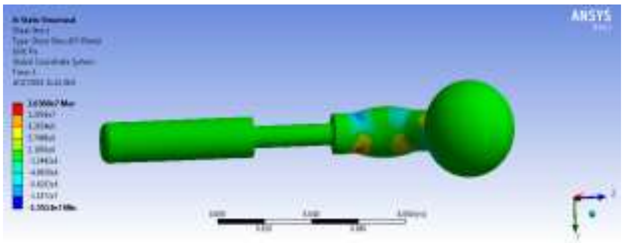
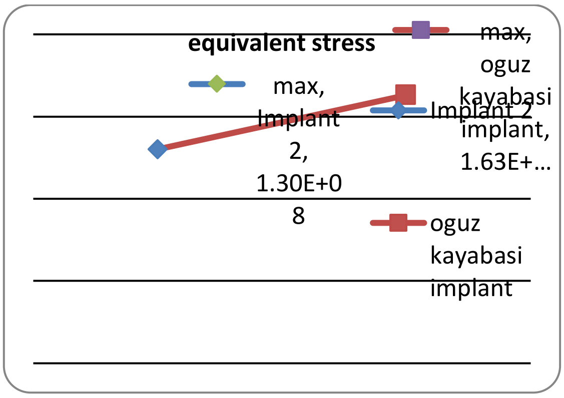
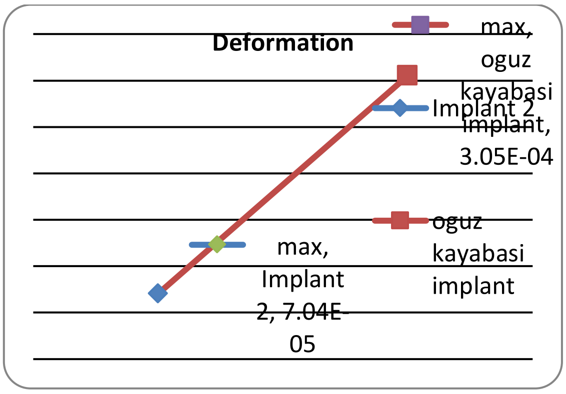


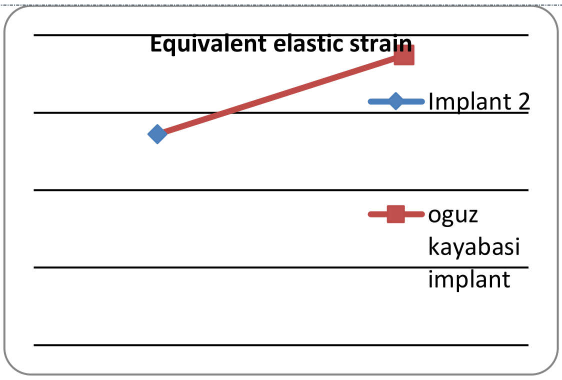
Fig 12. Shear stress

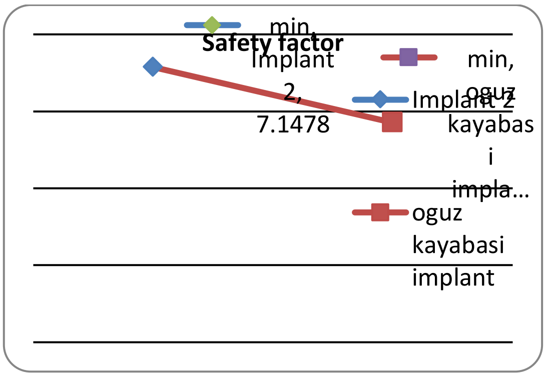
Comparision Of New Implant With Oguz Kayabasi's Model

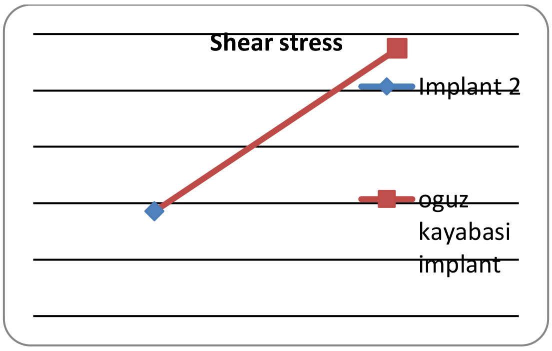




ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7







The analysis results comparision of Newly designed model with oguz kayabasi's redesigned model depicts that implant 2 is exhibiting better results with least values of von mises stress and von mises strain,minimum rate of deformation, less shear stress and high safety factor interms of kayabasi's redesigned implant model results.further implant 2 is chosen for rapid prototyping.

NEED FOR RAPID PROTOTYPING OF FEMORAL STEM

The designed and analyzed model may actually starts with hand sketches and designed in a CAD software by a design engineer it is very easy to understand the design for an engineer to understand in a 2D view but for a medical person who actually carry out the implantation it is very impossible to experience the tolerances and sizes in orthographic view so 3Dmodel is required to serve this purpose rapid prototyping femoral stem is carried out to build this gap. Rapid Prototyped models facilitate Diagnosis pre operative planning and communication between the colleagues. Through rapid prototyping not only models but also very complex and intricate parts of human body can be printed by utilizing various other RP systems. The full scale model of designed femoral stem is printed by utilizing Fused Deposition modeling (FDM) technology in Flash forge 3D printer.

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Fused deposition modeling (fdm) of femoral stem:

Fused deposition modeling is one of the most widely used rapid prototyping process in which, filaments of heated thermoplastic are extruded from a tip that moves in the x-y plane. FDM builds plastic models by extruding a semi-molten filament through a heated nozzle in a prescribed pattern onto a platform. The nozzle is moved over the platform in the required geometry of the part which is driven by the CAD data [5]. The platform is maintained at a lower temperature, so that the thermoplastic quickly hardens. After the platform is lowered, the extrusion head deposits a second layer upon the first layer. The process is repeated until the required object is built. After building the part the part is finally removed from the platform just by snipping or dissolving the support structure in water based resin.

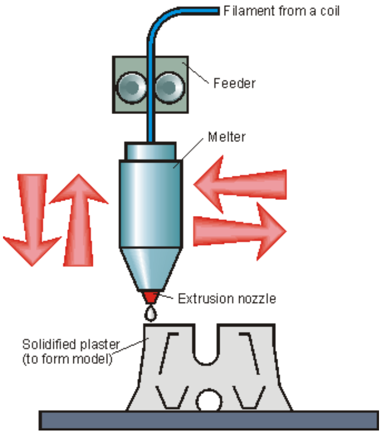

Fig 13. Fused deposition modeling diagram

After performing analysis the chosen implant model is converted in to STL file format. STL stands for standard triangulation language. it is the file format which is generally accepted by most of the 3D printers. The STL file is fed to slicing software. In a slicing software the required parameters like layer thickness, deposition rate and tool path are fixed after specifying all the values the implant model is virtually sliced into thin horizontal cross sections by the software . After slicing operation a G-code is generated this can be fed to the 3d printer for final printing.

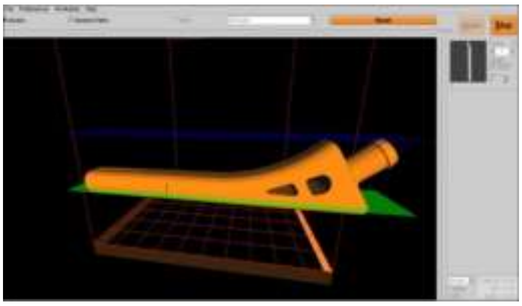

Fig 14. Implant while slicing

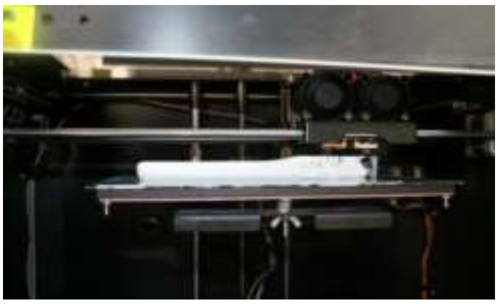

Fig 15. Implant while printing in 3d printer

The slicing of implant model is carried out in KIS slicing software with slice thickness of 0.5mm and the printing is done in flash forge 3d printer with ABS as material for printing.

Fig 16. 3D printed implant model

Once the model is completely printed the model is taken out from the 3d printer just by snipping out with hand. The support structure is removed by dissolving in a solvent or just snipped of with hand. The model is rubbed with a sand paper to obtain surface finish.

CONCLUSION

In the Present work new implant was designed in CATIA by considering several factors in the previous literature and static structural Analysis is performed on newly designed implants in ANSYS workbench .The Analysis results were carefully compared and new implant model stands best. Implant-2 is again in turn compared with Oguz Kayabasi's redesigned model and implant-2 exhibited superior characteristics with least effect of stresses, minimal strain rate and high safety factor. The best evaluated implant model is successfully created for design verification purpose by utilizing fused deposition modeling (FDM) which is one of the rapid prototyping or Additive manufacturing technique.

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