WEAR –CONTACT ANALYSIS OF ACETABULAR CUP WITH FUNCTIONALLY GRADED MATERIAL

P.VINOD [1], J.VENUMURALI [2].

1 M.Tech Student ,Narasaraopeta Engineering College, Guntur dt, Andhra Pradesh, INDIA

email: danipallapu@gmail.com

2 Asst Professor of MECH, Narasaraopeta Engineering College, Guntur dt, Andhra Pradesh, INDIA

Abstract— **Metal-on-Metal hip implants are the most widely used implants in hip prosthesis surgery. Wear of the bearing surfaces in hip prosthesis is a key problem especially in the acetabular cup where the femoral head is in contact with it .The loads get transferred from femoral head to acetabular cup and cyclic loading leads to the failure of implant due to the wear of acetabular cup in hip prosthesis. In Metal-on-Metal hip implants, metal surfaces wear, giving off metal ions. Metal debris enters the space around the implant, as well as enters the bloodstream. This causes a reaction in some patients, such as pain or swelling around the hip, there by damaging the soft tissue around the implant and leads to loosening of the implant. In this project the wear of acetabular cup in Metal-on-Metal implant is estimated and a means of reducing the wear by using functionally graded materials is addressed. The contact pressure is obtained through finite element tool (Ansys) and the wear is obtained by Archard equation from the contact pressures obtained by Ansys. The contact pressures and wear is estimated for both Metal-on-Metal hip implant as well as implant coated with functionally graded material and the results are compared. The contact pressures are obtained for various loads and orientation of femoral head and acetabular cup according to a 3 dimensional gait cycle. The gait pattern associated with normal walking of human at 4 km/hr is considered for analysis. It was found that the maximum hip load in the gait cycle was about 230% of the body weight of the patient. This gait cycle is divided into 8 instances It is shown in this work that the linear wear for functionally graded implants are far lesser than Metal-on-Metal implants commercially used today.**

I. Introduction

Hip replacement surgery is considered as an effective solution for patients with osteoarthritis. This has been in practice from late 1960's and since then there has been a continuous search in finding the optimum material for the implants. Initially the implants were made of steel and chrome, which faced a number of drawbacks such as wear, failure and infection in some patients. Since then there has been various advances in the use of material. Modern day hip-implants use metals like (titanium alloys and chromium alloys) and ceramic materials .Metallic implants have a lower wear rate but these metallic implants releases metal ion in the blood stream and there by leads swelling of tissues around the implant and this in turn causes the implant to loosen and causes failure of hip prosthesis .Use of ceramic implants usually leads to failure as ceramic materials are very brittle materials and thereby leads to fracture upon impact loading .Though ceramic materials are very hard and lead to less wear and are biologically inert, these materials can lead to sudden fracture due to impact load . Thus these ceramic implants is not suitable for people who are very active and young .Metallic implants wear out faster than the ceramic implants but are not as brittle as the ceramic materials . Metal debris is very reactive to some humans. This arises the need for usage of material that are hard on the outer, that is wear resistant and are stronger in the inner core of the implant, that is, that can withstand impact loads. This need requires a material with different properties within the same geometry. One such material is functionally graded material. This variation of properties of a functionally graded material is used in application where different functions are required at different location of the same material.

II. LITERATURE SURVEY

M.s.Uddin studied ways of predicting wear in hard on hard joint prosthesis. They had mimicked the 3 dimensional gait cycle for normal walking and evaluated the wear in material for polycrystalline diamond. The wear for the bearing surface is found out[1].

M.M.Mak analyzed the contact pressure distribution for various clearances of acetabular cup and femoral head ranging from 0.02 mm to 0.08 mm. They had evaluated the contact pressures using a finite element technique for a 2 dimensional model and compared the results with hertzian technique, which saw a close similarity between them [2].

A.Buford presented the review of wear mechanisms in various hip implant materials like the Metal-on-Metal, polyethylene on metal and ceramic on metal .The average linear wear for all materials are studied and their relation with hardness estimated [3]

Jorge C. studied the wear and heat generated in hip implant acetabular cup for Ceramic –plastic, Cobalt chromium plastic, Cobalt chromium- cobalt chromium and ceramic-ceramic implants[4]

III. MODELLING A HIP IMPLANT

Hip Implant Geometry

Hip prosthesis mainly consists of 2 main parts the femoral bone and the acetabular cup. The femoral bone consists of a spherical head which is in contact with the acetabular cup that forms the ball and socket joint. The acetabular cup is positioned in a hollow acetabulum in the pelvic bone .Loads are transferred from the femoral head to the acetabular cup. Thus during daily activities the femoral head moves inside the cup and there is a varying contact stress in the bearing surface. This varying stresses causes wear in the acetabular cup .The main reason for failure of hip implant is the wear caused in acetabular cup.

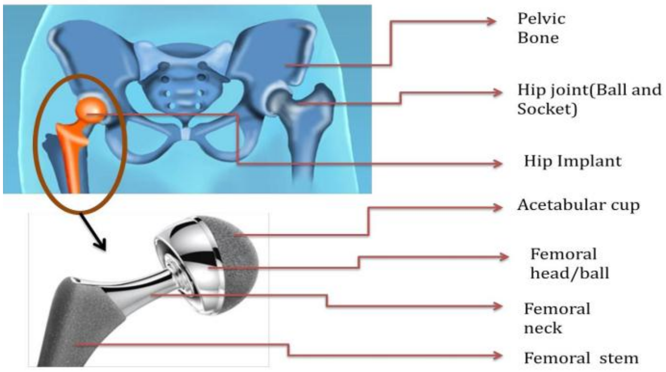


Fig.1 Hip implant and the anatomical parts of human hip joint [2]

Since in this study we are more concerned in the wear caused in the cup due to the femoral head, the portion of the femoral bone below head is not of much importance in this study. Thus while modeling the femoral bone only the head portion of the femoral bone is taken in to consideration.

IV. RESULT AND DISCUSSION

A. HIP PROSTHESIS

A simple axisymmetric model is used to model the hip implant considering the ideal condition of the implant. The assumption used in this study is that the femoral head always remain within the acetabular cup and the contact occurs well within the cup. In case of adverse condition there is edge contact between the acetabular cup and the femoral head.Thus for modeling this adverse condition a 3d model of the implant needs to be considered. Thus in this 2d model we assume that there is no edge contact between the acetabular cup and the femoral head.

B. Geometry

The 2d model is created and then validated for contact stresses using literature[6] The geometry used in validating is Femoral head diameter = 14mm Clearance = 0.04mm

Thickness of acetabular cup insert = 5mm
Thickness of inlay = 5mm

C. Meshing

The meshing was done using 4 noded PLANE42 elements. The mesh convergence was checked and a mesh density of 1 per mm was found to be optimum for an error % less than 1 in the maximum contact pressure values.

D. Material

TABLE .1

Component	Material	Young's modulus(GPa)	Poisson ratio
Femoral head	Ceramic	380	0.26
Cup Insert	Ceramic	380	0.26
Inlay	UHMWPE	1	0.4
Stem	Metallic	210	0.3

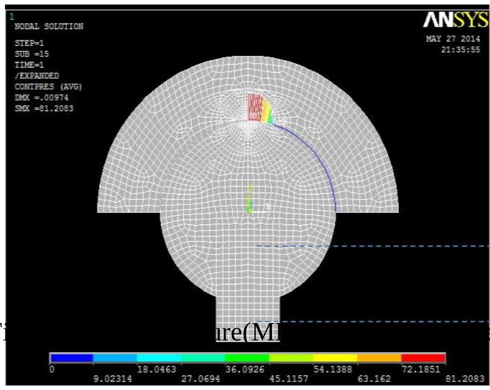
The material properties used in the contact study2d hip prosthesis for validation with the journal

E. Boundary condition

The acetabular cup is fixed in position .Half the geometry is modeled as the problem is considered as an axisymmetric problem as the load is vertical about the stem and the edge loading is neglected .Load is applied on the stem of the implant.

Load of 2500 N is applied, which is approximately the peak load in the human gait cycle for normal walking. Thus the maximum contact pressure stresses obtained in the acetabular cup is 81.2083 MPa for ceramic on ceramic which is in close conformance with the result obtained in the literature [6]

Tungsten carbide also called cemented carbide, hard metal. There are 2 compounds of tungsten and carbon, WC and tungsten semi carbide.



Fi re(M esis

A. Variation of maximum contact stresses

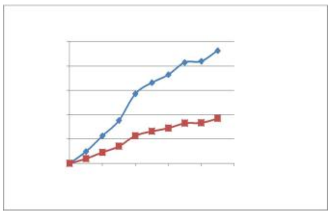
The variation of contact stresses with various parameters like the young's modulus, radial clearance, insert thickness is studied in functionally graded material (Ceramic-Metal FGM).The stem and the inlay are considered to be metallic (Ti alloy

B. Variation of maximum contact stresses for metallic and FGM coated implant

The maximum contact stresses vary with the material property (young's modulus). The maximum contact pressure increases with the young's modulus of the material .In this the insert thickness is kept constant at 5 mm and the radial clearance is kept constant at 0.04 mm between the cup and the head component.

C. 3D Hip Prosthesis

The modelling, boundary condition and loading of 3d hip prosthesis has been discussed previously in chapter-2. The contact pressures are obtained at each instance. Thus a total of 9 instances are chosen and the variation of contact pressure at each instance found. The maximum contact pressure is obtained in the third instance and the maximum hip load is about 238% of the body weight at that instance. The contact pressure variation is obtained for both Metal-on-Metal and functionally graded material for all 9 instances of normal walking gait cycle. In this study only the cup and the head portion are considered thereby neglecting the effects of femur stem. Load is applied at the center of the femoral head the cup.



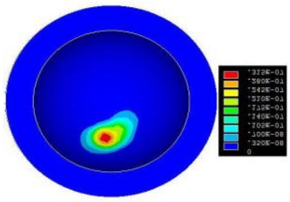


Fig:2 Total wear Vs Gait cycle

V. SUMMARY AND NCLUSION

The wear-contact in the hip prosthesis using functionally graded material was studied. The wear was estimated by contact stresses which were obtained using finite element software ansys. The methodology followed and the results obtained were discussed in the previous chapters. The summary of the work is presented below:

1. A 3D model of the acetabular cup and the femoral head was modeled and the loads were applied using gait pattern. The peak contact stress for an instance is verified for PCD on PCD implant and a good agreement was obtained.

2. The 3D model was then modeled with Metal-Ceramic FGM and the contact stresses were obtained for all gait instances. The variation of peak contact stresses with gait cycle for metallic and FGM coated implant was then studied.

3. The cumulative linear wear was estimated for both metallic and FGM coated implants using Archard equation discretized within nodal points. The wear plot is generated using cumulative linear wear at each node and at each instant of the gait cycle and the wear progression is visualized for both metallic and FGM coated implants.

4. The total wear which is the sum of all nodal cumulative linear wear is obtained at each instance and studied for both metallic and FGM coated implant.

5. The total wear is obtained after 1 year or 10^6cycles for both the implants and was found that FGM implants wear 61% less than the metallic implant

VI. REFERENCES

1. **M.S. UDDIN** Predicting the wear of hard-on-hard hip joint prostheses. wear journal 301 (2013) 192–200.

2. **M.M.MAK** Analysis of contact mechanics in ceramic-on-ceramic hip joint replacements. Journal of Engineering in Medicine 2002 216: 231DOI: 10.1243/09544110260138718.

3. **A Buford** Human hip joint and hip prosthesis. http://www.hss.edu/conditions_hip-replacement-for-arthritis-of- hip.asp#.U42nTnI72Sg

4. **Jorge C.** A functionally graded particulate composite: preparation, measurements and failure analysis. DOI: 10.1016/S1359-6454(98)00305-X