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STUDY & PERFORMANCE OF METAL ON METAL HIP IMPLANTS: A REVIEW

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***Abstract*— Recent joint surgery studies reveal increased revisions and resurfacing of the metal on metal hip joints. Metal on metal hip implants were developed more than thirty years ago and their application has been refined because of availability of advanced manufacturing techniques and partly by advancements in material science and engineering. Development of composite materials may provide greater durability to metal-on-metal hip implants .This review article is a study of the latest literature of metal-on-metal hip implants and its various modeling techniques. Numbers of methods are used for convergence and numerical solution to investigate the performance of metal-on-metal hip implant for accurate stable solution. This paper presents analysis done by various researchers on metal-on-metal hip implants for wear, lubrication, fatigue, bio-tribo-corrosion, design, toxicity and resurfacing. After in vivo and in vitro studies, it is found that all these methods have limitations. There is a need of more insight for lubrication analysis, geometry of bearings, materials and input parameters. The information provided in this work is intended as an aid in the assessment of metal-on-metal hip joints.**

***Index Terms*— Finite element method, Hip joint, MOM hip implants, Numerical Methods.**

I. Introduction

There are several joints in human body, each have specific function and motion. Major joints are knee joint, shoulderjoint & most important hip joint. Hip joint plays an important role to balance the whole body weight in respect of the requirement of motion and work. In tribological study, continuous contribution of researchers improves the performance of MOM hip joint over a variety of hip implants. After having hip implant,physically patients may or may not be comfortable because of various complications that arises due to wear.

This joint is ball-in-socket joint Literature review shows number of research works on hip joint replacement withvarious methods. Brown C et al. [1] concluded that in current, there is no ideal method for hip replacement in view of toxicity, adverse biological effects andtribological properties depends upon wear rate. American Academy of Orthopedic Surgeons advised for Total Hip Replacement (THR) when this joint damaged due to a fracture ,arthritis like Osteoarthritis , Rheumatoid arthritis, Post Traumatic arthritis and avascular necrosis or any childhood problem. A typical metal-on-metal hip joint is shown inFigure1. [2]

Figure 1.Typical metal-on-metal hip joint [2]

There are various types of hip implant joint according to their material and use i.e., ceramic-on-metal, metal-on-metal, metal-on-polyethylene, ceramic-on-ceramic, ceramic-on-polyethylene etc. In 2006 D Dowson and Z-M Jin [3] explained the four type of lubrication pattern in Metal-on-Metal hip joint tribology like hydrodynamic fluid film lubrication, mixed lubrication, boundary lubrication,and dry lubrication. They concluded that the ceramic on polyethylene joint, metal on metal joints (mild mixed lubrication regime, Co-Cr-Mo alloy high carbon>0.20%C)are significantly recommended as compare to metal and ceramic for current hip replacement due to high strength and low wear rates.

In old practiceship implant, the cobalt (Co), Chromium (Cr), Molybdenum (Mo) was adopted by DobbsH. S. and M.J. Minski[4]. They observed that the metal ions are fifty times stronger than their standard value in urine and conclude that the metal-on-plastic joint are more relevant. In recent again focus on the use of metal-on-metal hip implant instead of others because of its strong capacity for wear and indicated that second generation of metal-on-metal hip implant are more efficient for strength to young patients [5][6].

Feng Liu et al. [8] reported numerically work on bearing geometry and structure support of metal-on-metal hip implantsin terms of a little clearance for 28 mm head diameter and analyzed fluid film lubrication in-vivo and in-vitro conditions. In their study, they adopted spherical mesh through finite element and calculate the minimum film thickness by integrating the pressure with the help of fast Fourier transform.Bharma M. S. and C. P. Case[9]mentioned in their study that the metal-on-metal hip arthroplasty gives more better result as compared to metal-on-polyethylene articulation.JagatiaM. and JinZ. M. introduced Reynolds equation in spherical coordinate and it was solved by Newton-Raphson Finite Difference Method.This numerical method applied for a relatively thick actabular cup shows little effect on contact pressure [10].Leiming G et al. [11] investigated the effect of loading and motion on lubrication of metal-on-metal hip replacements. In their analysis, they adopted multigrid method for three level grid methods for 257 X 257 maximum nodes.

II. Lubrication Model & Materials Used

Boundary lubrication is adopted for the study of various tribological surfaces to enhance the performance, and life of hip implant and protect their surfaces from wear & friction, which are in mutual contact. Elastohydrodynamic films are then adopted for better performance of joint for metal-on-metal hip implant for this purpose there are two types of models were generally adopted ball- in-socket andball- on- plane. Hip implants made up by 316Lstainless steel, cobalt-chromium-molybdenum and ceramic like alumina and zirconium, titanium based alloy.D Dowson and Z-M Jin[3] reported that the ceramic-on-polyethylene or metal-on-polyethylene have some limitation for strengthand MOM (metal-on-metal) are much durable when their design is subjected to proper surface finishFor lubrication analysis, it is assumed that flow of lubricant is in between two bearing surfaces and in this Reynolds equation for spherical co-ordinate is solved by various researchers to find out optimum result.

MengQ. E [12] adoptedtransient elastohydrodynamic lubrication analysis for novel metal-on-metal of hip prosthesis with non-spherical femoral bearing surface. Synovial fluidis used as lubricant in artificial hip joint which a Non-Newtonian fluid and have a low shear stress and solved Reynolds Equation by numerical method.

Equation 1

$$\frac{\partial}{\partial\phi}\left(h^3\frac{\partial p}{\partial\phi}\right)+\sin(\theta)\frac{\partial}{\partial\theta}\left(h^3\sin(\theta)\frac{\partial p}{\partial\theta}\right)=6\eta R_1^2\sin(\theta)\times\begin{bmatrix}-\omega_x\left(\sin(\varphi)\sin(\theta)\frac{\partial h}{\partial\theta}+\cos(\varphi)\cos(\theta)\frac{\partial h}{\partial\theta}\right)\\+\omega_y\left(\sin(\phi)\sin(\theta)\frac{\partial h}{\partial\theta}-\sin(\phi)\cos(\theta)\frac{\partial h}{\partial\phi}\right)\\+\omega_z\left(\sin(\theta)\frac{\partial h}{\partial\varphi}\right)\end{bmatrix}$$

$$+12\eta R_1^2\sin^2(\theta)\frac{\partial h}{\partial t}$$

Performance & lubrication analysis of metal-on-metal hip implant investigated by using above Reynolds's equation. [11-13] Where, and are spherical coordinates andWx ,Wy and Wz are the angular velocities presented in figure 2 forflexation-extension (FE), internal external rotation (IER) and abduction-adduction(AA) motions [11].These are the types of relative motion in between femoral head and actabularcup, under load for demonstration.Most of time this partial differential equation is widely used for lubrication analysis, texturing of hip implant for spherical coordinates.

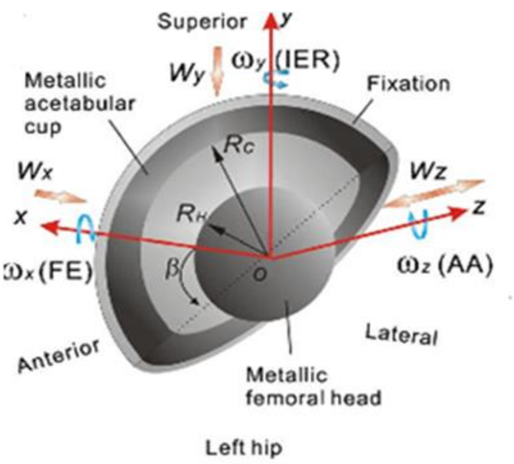

Figure 2.Metal-on-metal hip implant under loading [11]

Researchers in this field are applying this equation in numerical methods. The governing Reynolds equation (2) was written for all three dimensional motion. [14] [15].

Equation 2

$$\frac{\partial}{\partial\phi}\left(\bar{h}^{3}\frac{\partial\bar{p}}{\partial\phi}\right)+\sin(\theta)\frac{\partial}{\partial\theta}\left(\bar{h}^{3}\sin(\theta)\frac{\partial\bar{p}}{\partial\theta}\right)=6\eta R_1^2\sin(\theta)\times\begin{bmatrix}-\bar{\varpi}_x\left(\sin(\varphi)\sin(\theta)\frac{\partial\bar{h}}{\partial\theta}+\cos(\varphi)\cos(\theta)\frac{\partial\bar{h}}{\partial\theta}\right)\\+\bar{\varpi}_y\left(\sin(\phi)\sin(\theta)\frac{\partial\bar{h}}{\partial\theta}-\sin(\phi)\cos(\theta)\frac{\partial\bar{h}}{\partial\phi}\right)\\+\bar{\varpi}_z\left(\sin(\theta)\frac{\partial\bar{h}}{\partial\varphi}\right)\end{bmatrix}$$

$$+12\eta R_1^2\sin^2(\theta)\frac{\partial\bar{h}}{\partial t}$$

III. Discussion

In general there are various numerical methods Multigrid, fast- Fouriertransform, FDM (Finite difference Method), Newton-Raphson method were adopted for calculating convergence and optimum solution for accuracy. According toGao L. M.and MengQ. E.[13] the four level grids multi integration method has more effective as compared to fast Fourier technique.Multigrid method was also adopted by various researcherswhich is much more fast and effective.Where FDM method is limited for two elements like square and rectangle but, there is alsoananother method for analysis which is now in trend called FEM (Finite Element Method). FFT (Fast Fourier transform technique with FEM measures elastic deformation for complicated structure in artificial hip joint [18].As compared to above methods, the finite element method will be suggested for lubrication analysis of metal-on-metal hip implant for finding more realistic results with fast convergence and calculation. In hip implant expected time period of stay is in between 10-15 years [16][17].There are various vivo –vitro studies performed outside and inside living being .Wear effect on MOM hip implant under vivo condition and tested in hip simulator , linear wear depthwas found for geometry of bearing surface which was investigated for running case[19]. By Clinically metallic wear particles generated but their volume is less as compared to polyethylene [20-23] [29].Hip resurfacing and surface texturing improve the quality of MOM hip implant offer low wear also improve the quality [19-23.]For analysis following input parameters are put in under consideration given in table1 [10].

Table 1. Input parameters

S.No.	Parameters	Value
1.	Radial clearance	24-30 µm
2.	Cup wall thickness	9.5mm
3.	Equivalent support thickness	2mm
4.	Cup inside radius	12-14mm
5.	Elastic modulus of metal	210 GPa

The research on two generation of metal-on-metal hip resurfacing with different cup wall thicknesses and clearances were investigated and confirmed the importance of the geometry and input parameters on the performance of MOM hip implant [24]. Surface texturing found to be more effective in fluid film lubrication by micro geometrical design on hip bearing surface [30] [31]

IV. Conclusion

Based on the above literaturereview, it is found that there is a need to develop a new way to compute more realistic results with appropriate method for analysis of MOM hip implants. Hip implants depends not only on geometry but also on proper methods and materials that are adopted for lubrication analysis , that depends on the film thickness, head and the pressure distribution around the surface of contact. An advance material combination with advance simulation methods in MOM hip implant again increases the interest to adopt this MOM hip implant in hip replacement joint. So in the field of tribological study of MOM hip implants more and more realistic studies are required, to get minimum revised cases because hip replacement procedure is more severe than previous hip prosthesis.

V. Notations

ø	Spherical co-ordinate	p	Fluid pressure
µ	Fluid viscosity	ρ	Density of fluid
h	Fluid film thickness	ω	Angular velocity
R1	clearance	θ	Angle of contact

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