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FEM ANALYSIS ON ARTIFICIAL FEMUR HEAD OF HIP JOINT PROSTHESIS – A STUDY

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ABSTRACT: ***Cobalt-chromium-molybdenum ball heads for total hip replacement are highly loaded in finite element load step on the basis of ISO 5832-12 rupture test to meet the stress requirements concerning strength and safety. High stresses inside the ball head originate from the press fit between the conical stem neck (made of titanium alloy) and the borehole of the ball. The aim of this study was the development of an optimized contour at the fillet inside the ball head and the borehole contact length depth by means of numerical methods, in order to reduce local stress concentrations. The finite element optimization method was applied on the customary engineering fillet radius to reduce local stress peaks. Since the static load from experimental realistic hip implant test is governed by the maximum von-mises, shear, normal and principal stresses in the contact area of the taper. The optimal reduced local stress of the examined ball head design was obtained in the medium neck contact length at o.8mm fillet for the relevant realistic load case of stumbling.***

Keywords:* *Femoral head, Stem neck, Optimum geometry, Stress concentration, FEA

1. INTRODUCTION

The increase of knowledge in all areas of research forms the premises for an increase in the life expectancy of the population as well as the quality of life, this increase of life expectancy are achieved through efficient medical care to meet the main objectives of improving and ensuring an adequate mobility for performing daily tasks [1]. For this maximum mobility the hip joint is a major structure within the human body, it supports most of the upper body weight. The hip joints are connecting the torso to the legs and, the weight of the upper body and decrease theimpulsion loading from lower body to the upper body. Experimental studies have found that the resultant force acting through the hip joint during normal walking is around 300% body weight. Having

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known the load, the hip joint could be destroyed under complex working conditions and needs to be replaced.[2] The replacement of the natural hip with artificial replacement is the most effective way of restoring mobility for patients that suffer from chronic diseases such as osteoarthritis, chronic arthritis and severe trauma. Attempts at replacing the diseased hip joint can be traced back as far as 1890 when Gluck described the use of ivory to replace the femoral head. Early attempts were largely unsuccessful and more recent developments in hip prostheses owe much to the work of Charnley in the 1960s and 1970s. [3] Since the 1950's, a very common solution to the debilitating pain associated with this condition has been a procedure termed Total Hip Arthroplasty, or Total Hip Replacement (THR).

2. METHOD AND MATERIAL

During this research fifteen 3-D models were required for the stress analysis in order to determine the safe zone from the introduced geometries. The head engages with one extremity of the stem neck via a conical press-fit connection this press-fit connection provides self-locking mechanism, thus requiring no additional fasteners. The spherical pair thus obtained behaves kinematic ally as the replaced natural joint. While the geometry of the stem's conical end is fixed, the head cavity is available, according to a modular concept, in two geometries, which essentially not differ in the diameter of the cavity mouth hence the press-fit comes from the taper angle of 12/14 which is globally recommended by manufactures hip implant. Basically in this paper 15 different femur models was created according to the selected design parameters of interest. The design parameters in this study were the conical borehole depth and the fillet radius at the bottom of borehole ball head. Consistently, three distinct stem penetrations into the head bore and, consequently, three stem projections are obtained, with a borehole depth of 23mm called 36/M, where M refers to a medium neck length with 36 mm diameter of ball head (Fig.1).

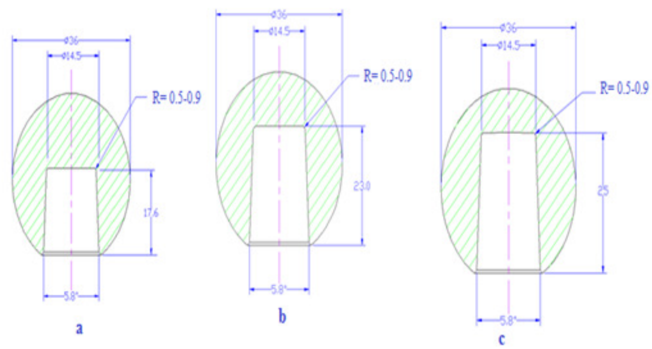

Fig 1 Femur Head shapes

3. RESULT

Results obtained from static force analysis during the present study. After completion of the static analysis in ANSYS, results were reviewed by result report. Four significant types of results were recorded from static analysis of all 15 models. In this chapter, results are presented for each of the four categoriesnamely: von Mises, Shear, Principal and Normal stresses. The results illustrate the rapid structural responses in the femur and the femoral neck and, the contact mechanics of the bearing couples during the sudden femoral head loaded event as analyzed computationally. The most important step of finite element analysis procedure is the

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physiologically realistic interpretation of the results by the analysis. Since finite element analysis procedures are invariably accompanied by an extensive output of data, it is extremely important that we interpret the results correctly.

In this section all the modeling results of stresses Von misses, Principal, Shear and Normal stresses were presented from finite element analysis results with the condition of Short Neck (SN), Medium Neck (MN) and Long Neck (LN). The three contact length parameters will be conjugated with fillet radius.

4. DISCUSSION AND CONCLUSION

The design parameters for all the fifteen solid femur head models were determined based on the review of literature. Design parameters were studied in this research to develop a hip implant model with an ideal combination of head diameter, neck diameter and neck length in order to achieve a stable artificial hip joint to prevent from post- surgery failure. Analytical results were used to develop stress prediction of models. All models were developed to predict contact stress penetration. This study provides new models to minimize the concentration of stress on contact areas. The results are discussed below for various categories.

- Effect of Stem Neck and Taper-Borehole Contact Length with Fillet Radius

The taper-bore contact length, as defined in the chart 5.2, is important, which affects the stress distribution and mechanical reliability of femoral head. In the current analysis, three taper-bore contact lengths are considered for the case of the femoral heads with the : (1) 23.5mm contact length (LN), (2) 21.5mm contact length (MN) and (3) 16.5mm contact length from the top of the taper-bore, appendices show all stress profiles along the inner wall of the taper-borehole and table 4.1,4.2 and 4.3 indicated with the decrease of the contact length from LN to MN, the stress decreases. This is due the increment thickness of ball head from the hole to outer surface to withstand the applied load. On the other hand the stress increases from MN to SN. This is due to the less contact area at the interface to withstand the applied load. A reduction of contact length from LN to MN causes a decrease in the maximum von-mises, principal, shear and normal stresses by about 90%, 89.5%, 69.5% and 85.5% respectively. And a reduction of contact length from MN to SN causes an increment in the maximum von-mises, principal, shear and normal stresses by about 89%, 69%, 90.5%, and 89% respectively. This comparison indicating that, the contact length should be as medium as possible in the design of a borehole to minimize the stresses and hence to maximize the mechanical reliability of the artificial femoral head.

Finally, numerical optimization by means of the FEM was performed on a type LN, MN, and SN Co-Cr-Mo femoral head with a cone taper size 12/14. Although the maximum stresses occurs in the contact zone to the stem neck, the local maximum inside the borehole has to be considered, as local material flaws could reduce the strength of a ball head. The resulting design was applied on all three ball types SN, MN, and LN, whose geometry mainly differs with respect to the borehole depth. Validation was performed for all ball head. The results of the finite element

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calculations showed considerable improvements, i.e. a reduction in the maximum Von-mise, Shear, Normal and principal stress in the fillet by 90, 69.5, 85.4 and 89.5 percent respectively on medium neck contact length at 0.8mm fillet radius. The stress distribution and therefore the failure mechanism in the examined system of the Cobalt-Chromium alloy ball head, the titanium alloy replacement stem neck, and loading device strongly depend on the amount of the external load and on the bearing geometry type. In addition, the load level strongly influences the effectiveness of the shape optimization. The optimized shape is still ideal for a load level of 11 kN considering stumbling case; higher loads of more than this, however, lead to a stress relocation where, on the one hand, the shape is not optimal any longer and, on the other hand, the global maximum of principal stress moves from the fillet to the contact zone with the stem. Best results were obtained in a configuration according to ANSYS result, as this load case also had been considered for optimization with taking into account the contact between the stem neck and the ball head. The load case with point loading did not show any improvement, as the high stress concentration around the filleted zone always induced the Co-Cr-Mo ball to burst. But in this paper would not happen because optimally minimized all failure stress from the vicinity area of filleted part. On the other hand due to higher load the stress was forced to relocate and the maximum stresses moved back to the conical surface of the borehole till dead bottom of opposite end from filleted part. The stress relocation might not lead to failure since material applied has good properties in the ease of stiffness to resist deformation and wear having around fifteen safety factors allowance.

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