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Design and Analysis of Total Elbow Replacement Joint

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ABSTRACT
The total elbow replacement joint is a surgical process of to replace the human arm joint into artificial joint. In this paper to present the investigation of various materials used like copper, stainless steel, titanium and cobalt chromium alloys in the total elbow replacement joint. Based on this paper the numerical simulation technique gives the comprehensive results for implantation of the device. The model was created in the Creo parametric by changing existing design and materials based on under design condition, then analysis was done. The various results were found like von mises stress, maximum principal stress during analysis and these results was compared to the good literature. After simulation, it was concluded that the cobalt chromium alloy based proposed design, which was gives the minimum stress and total mass of modal.
Keywords – Bio materials, FEA, Total elbow replacement joint, von mises stress, principal stress.

I. INTRODUCTION

Elbow joint replacement operation provided the chance for individuals to regain abundant of the lost comfort and performance in arthritic elbow. In other hands, this procedure will address the proscribing connective tissue that often accompanies inflammatory disease. It can also restore sleek, stabilizing joint surfaces once these surfaces are broken by inflammatory disease [1].

Joint replacement surgery will improve the mechanics of the elbow, however cannot create the joint pretty much as good because it was before the onset of inflammatory disease (arthritis). In several cases, the tendons and muscles round the elbow are weakened from prolonged neglect before the elbow replacement. The scar around them must be removed. when the surgery, it should take months of light exercises before the elbow has achieved peak improvement.

The effectiveness of the procedure depends on the health and motivation of the patient, the condition of the elbow, and the expertise of the surgeon. When performed by an experienced surgeon, total elbow joint replacement arthroplasty usually leads to improved elbow comfort and function. The greatest improvements are in the ability of the patient to sleep and to perform activities of daily living.

Fig. 1. A set of ankle implants [2].

II. MATERIALS

Up to now, the three most used metals for implants are stainless steel, CoCr alloys and Ti alloys. The first stainless steel used for implants contains ~18wt% Cr and ~8wt% Ni makes it stronger than the steel and more resistant to corrosion. Further addition of molybdenum (Mo) has improved its corrosion resistance, known as type 316 stainless steel. Afterwards, the carbon (C) content has been reduced from 0.08 to 0.03 wt% which improved its corrosion resistance to chloride solution, and named as 316L.

Now the day, most three metals are used for implants stainless steel, cobalt chromium alloys and Titanium alloys.

- The primary stainless steel used for implants contains approx. 18wt% chromium (Cr) and approx. 8wt% nickel (Ni) makes it stronger than the steel and additional immune to corrosion. For addition of molybdenum (Mo) has improved its corrosion resistance. Afterwards, the carbon (C) content has been reduced from 0.08 to 0.03% that improved its corrosion resistance to chloride (cl).
- The second Titanium alloys (Ti) is featured by its lightweight weight. Ti and its alloys, i.e. Ti6Al4V are good tensile strength a corrosion resistance.
- The third type of metal that is Cobalt chromium alloy (Co-Cr), which have been utilization of more decades in manufacturing artificial joints. It also having the excellence tensile strength and wear resistance. Due to its properties, the Co-Cr is used for heavy load joints like ankle joints implants as shown in Figure 1.

Table 1. Blood compatibility properties of implant metal

Properties	Stiffness	Strength	Corrosion resistance	Blood compatibility
Stainless steel	Best	Better	Good	Good
Co-Cr alloys	Better	Good	Better	Better
Ti-alloys	Good	Best	Best	Best

Table 2. Mechanical properties of implant metal [3]

Metal	ASTM	Mechanical Properties		
		Young's modulus (GPa)	Yield Strength (MPa)	Tensile Strength (MPa)
Stainless Steel	316L	193	190	490
Co-Cr Alloy	F75	210	448-517	655-889
	F562 Hot forged	232	965-1000	1206
Ti Alloy	F67	110	485	760
	F136	115	896	965

III. METHODOLOGY

The human arm is considered as lever class three types now using class three lever mechanics the problem can be solved.

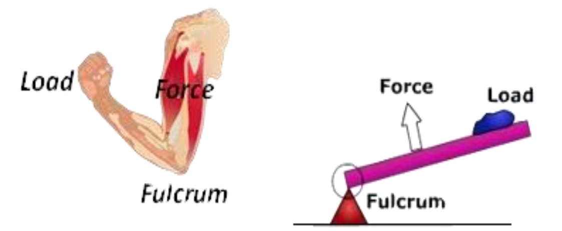


Fig 2. Elbow joint as Lever class three types

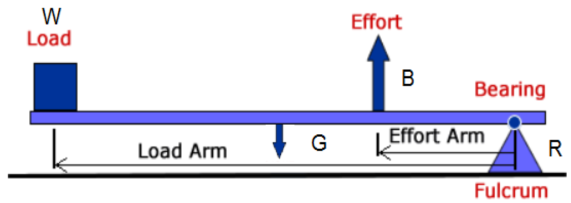


Fig 3. Free body diagram of elbow joint

Equations of Arm Mechanism

From the free body diagram in Figure 4, some equations were derived to determine the forces for boundary condition of the total replacement joint mechanism.

Moments about Elbow joint = 0,

$(B \times D\_1) – (G \times D\_2) – (W \times D\_3) = 0$ ----------(1)

D_1, D_2, & D_3 are distances from perpendicular the elbow joint.
After the force applied in the biceps was determined, the total of the moment in the horizontal direction taken zero.
Total of moments on horizontal direction = 0,

$-R + B - G - W = 0$ -----------(2)

Where, G= Gravitational force of weight in forearm,
B= Force applied into the biceps or effort.
W= Weight of the object and
R= Reaction force of the joint or fulcrum.

Modeling and Analysis

In this paper, the model has been created using Creo parametric as shown in Figure 4 (existing model) and Figure 5 (proposed model) and analysis are done in ANSYS. The finite element analysis is used for finding the solution for different materials. For dimension of the model taken from literature [4] and after existing the design was changed by using some modification. The boundary condition has been taken from literature [4], the conditions are taken for adult arm and for load of 2.5kg with 90^o arm conditions.

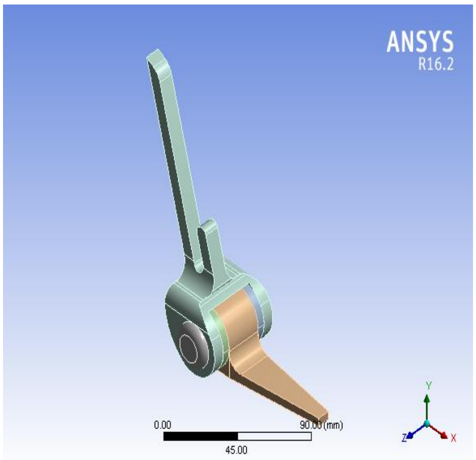


Fig 4. Existing model of elbow joint [4]

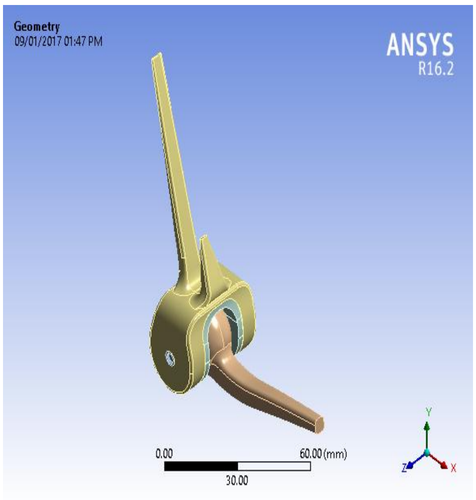
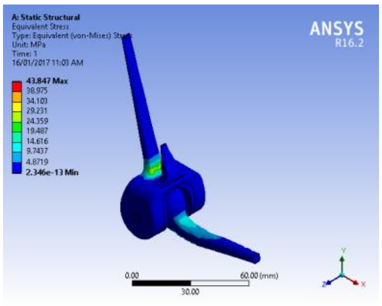
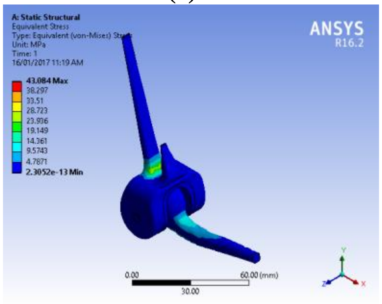


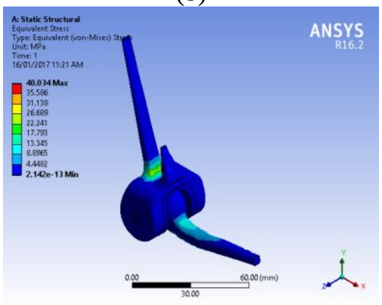
Fig 5. Proposed model of elbow replacement joint



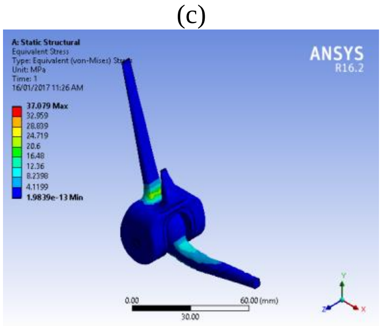
(a)



(b)

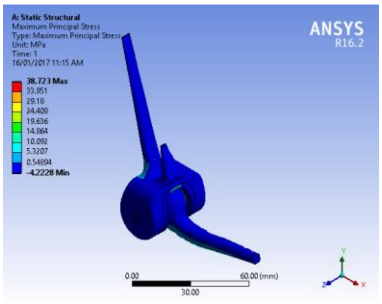


(c)

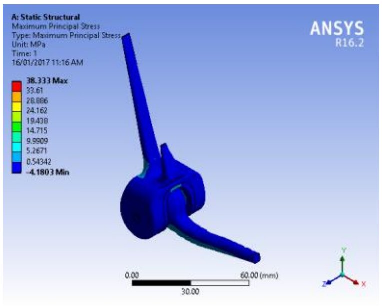


(d)

Fig 6. Contour plot for von mises stress in proposed elbow joint for materials (a) Cu (B) Stainless Steel (c) Ti alloy and (d) Co-Cr alloy



(a)



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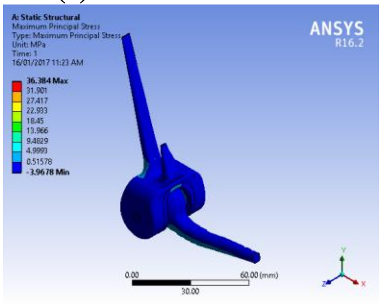
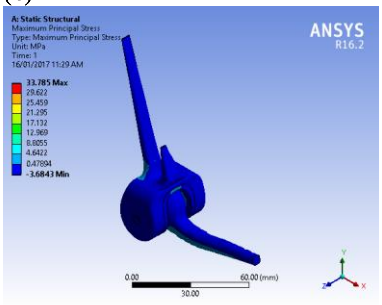


(c)



(d)

Fig 7. Contour plot for maximum principal stress in proposed elbow joint for materials (a) Cu (B) Stainless Steel (c) Ti alloy and (d) Co-Cr alloy

Figure 6 and Figure 7, indicates the contour plot of von mises stress and maximum principal stress for proposed model.

IV. CONCLUSIONS

In this paper, existing model [4] and proposed model are compared. The Figure 7 and Figure 8 shows that the comparison of results.

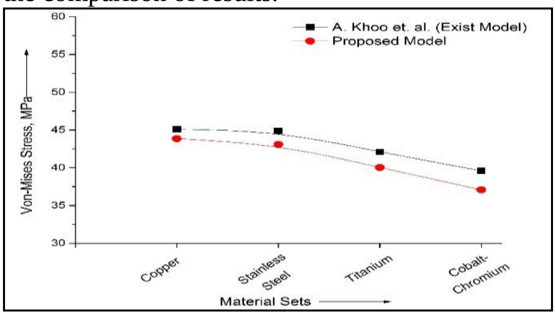


Fig 7. Comparison of von mises stress between existing model [4] and proposed model

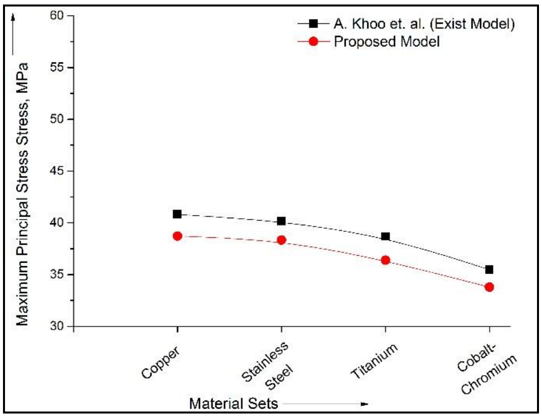


Fig 8. Comparison of maximum principal stress between existing model [4] and proposed model

The following conclusion has been discussed:

- In this paper, the application of bio materials has been proposed.
- In this investigation, the different materials were used in literature [4] and present work.
- The proposed model was reduced weight of model by using dimension modification like fork and eye end stem mass reduction and using polymer busing (liner).
- In this paper, it has been concluded that the copper, steel, titanium and cobalt chromium alloys are used. After analysis, it has been concluded that the cobalt chromium alloys are given the less stress.
- It is concluded that the von mises stress developed in the proposed model was given 12.477% less as compared to literature [4].
- Also, proposed model given maximum principal stress was reduced 14.03% as compared to literature [4].
- From many literatures, it has been concluded that the cobalt chromium alloy is the excellent ultimate tensile strength, antic corrosion and excellent blood compatibility.
- After all discussion, it has been concluded that the cobalt chromium alloy with proposed design is safe and suitable for further application.

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