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Computer Aided Design and Analysis of Artificial Human Wrist Joints

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Abstract: *The purpose of research was to design simple and reliable artificial wrist joint, because human body joint like wrist, ankle, knee, etc. suffering from rheumatoid arthritics. Rheumatoid arthritics occurs pain in joint, in this case they need to replace joint with artificial joint. In this study describes anatomy of wrist joint and design of artificial joint using of 3D software like solid works, and analysis of pulling and pushing motion of wrist joint using of ANSYS software to analyze the stress, total deformation and safety of factor.*
Keywords - *Artificial wrist joints, biomedical Engineering, Mechanical design & analysis, Mathematical model*

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I. Introduction

In human body the wrist joint is complex joint. Wrist joint is between forearm and five metacarpal bones. Now days in so many people suffering from pain in all body joint. Pain makes difficulty in daily life activities. Wrist joint damages by injures, infection, or arthritics disease, in those cases bones themselves will rub against each other, wearing out the ends of bones, it occurs painful arthritics condition. In rheumatoid arthritics disease in joint that result in pain, stiffness swelling in wrist joint. It creates a damage in the joint. After while patients suffering from pain, swelling and loosing motion of wrist joint, daily activities became hard for them. These primary reasons of wrist joint need to replace with artificial wrist joint to give relieve pain and maintain function of wrist joint.

First wrist joint implant was performed in berlin as early in 1890. Implant artificial wrist joint help in reduce joint pain, maintain motion of wrist joint and improve overall hand function. There are common complain after implanting artificial wrist joint likes infection, loosening, damage to vessels, implants fail or joint stiffness. All complainants show up sometimes early stage or may not show up months or year after implant of artificial wrist joint.

Artificial joint will usually last 10 to 12 years after replacement. This study describes the basic structure of human wrist joint and design and mathematical model and analysis of artificial wrist joint.

II. BASIC STRUCTURE OF WRIST JOINT

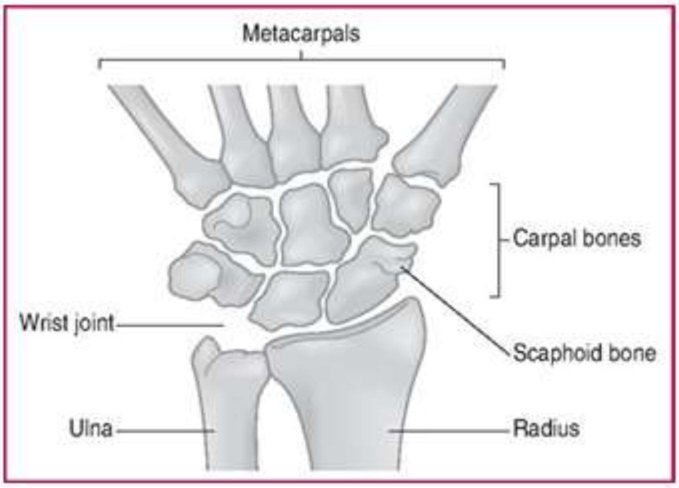

Fig 1 basic structure of human wrist joint

Anatomy of wrist joint is very complex structure in human body. The wrist joint variably define carpal bones and complex of eight bones forming the proximal skeletal segments of the hand. Wrist made of eight separate small bones called carpal bones. Carpal bones connect with two bones forearm and radius and ulna to the bones of hand. Ligaments connect all the small bones to each other. The wrist joint also known as the radiocarpal joint or synovial joint. This joint in the upper limb, making the area of transition between the forearm and the hand. Wrist joint formed by synovial joint the capsule is dual layered. The outer layered attached to radius, ulna and proximal raw of the carpal bones and the inner layered is comprised of synovial membranes, secreting synovial fluid which lubricant in the joint.

There are four ligaments of note in the human wrist joint. Palmar radiocarpal ligamentsare found on the palmar side of the hand. Dorsal radiocarpal ligaments are found on the dorsum side of the hand. It passes from the radius to both rows of carpal bones. Ulnar collateralligaments are runs from the ulnar styloid process to the triquetrum and pisiform. Radial collateral ligaments are run from the radial styloid process to the scaphoid and trapezium.

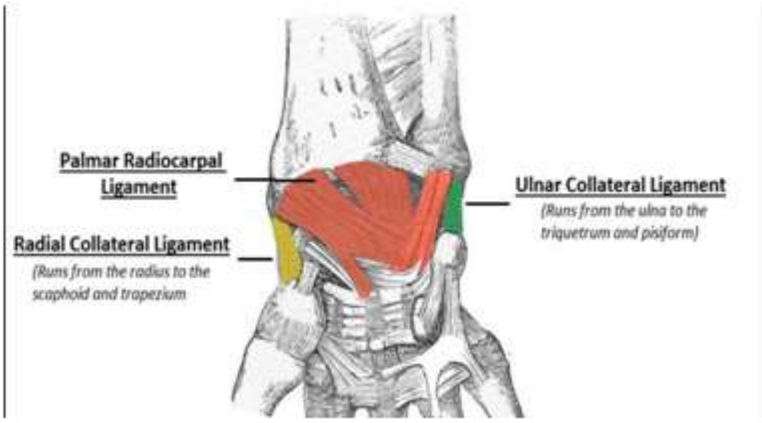

Fig 2 ligaments of human wrist joint

The wrist joint receives blood from branches of dorsal and palmer carpal arches which derived from ulnar and radial arteries. The wrist joint is a condyloid type synovial joint allowing movements along two axes.This means that wrist has movement in flexion and extension and radial divination & ulnar divination.

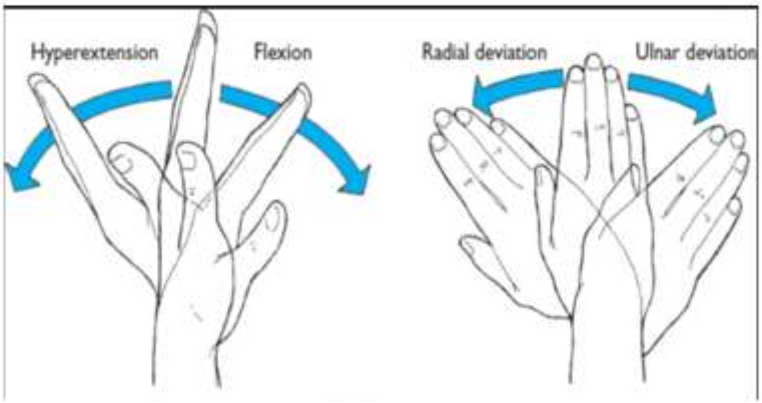

Fig 3 motion of human wrist joint

III. DESIGN OF ARTIFICIAL WRIST JOINT

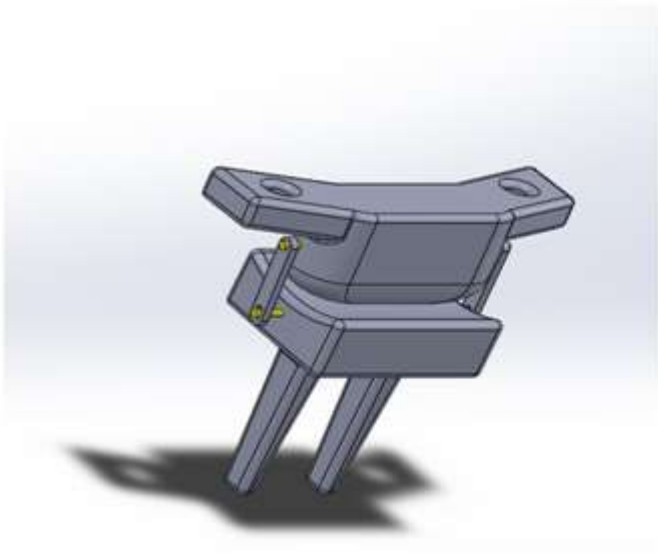

Fig 4 design of artificial wrist joint

The artificial wrist joint was design in 3-D Software like solid works. The model of artificial wrist joint mainly include two pieces radial components and distal components. In radial components end of radius bone of the forearm called radial components. There is flat metal piece placed on from part of radius bone and stream that attached down into canal of the bone. In distal components small wrist joint called distal components. The distal components consist two screws and semi ellipse shape.

In implant remove whole damage wrist joint form hand replace with artificial wrist joint. Distal components fit into center of upper part by screws. And radial compensates fit in to forearm. The movement of this artificial joint act like condyloid type synovial joint. In this design radial and distal components joined by elastic strings to keep together when polling and pushing activities done by an implant patient.

IV. MATHEMATICAL MODEL AND CALCULATION

In daily life activities people needs to be pulling or pushing weight in this situation a torque will be generates on their hand because stress point is not exactly same rotation center which generated on wrist joint. For situation of pulling weight load acting on the upper part of joint same in pushing weight same load acting as same as pulling but direction of load is opposites.

□ □ $= FN$ □ □
$FN = -FBcos$ □ □
Thus, □ □ $= FB$ cos □ □
$= (100N)\ (cos30°)\ (15cm)\ (1/100\ m)$
$=12.99N/\text{m}$.

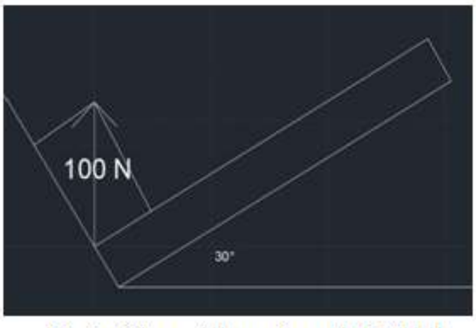

Fig 5 pulling weight mathematical Model

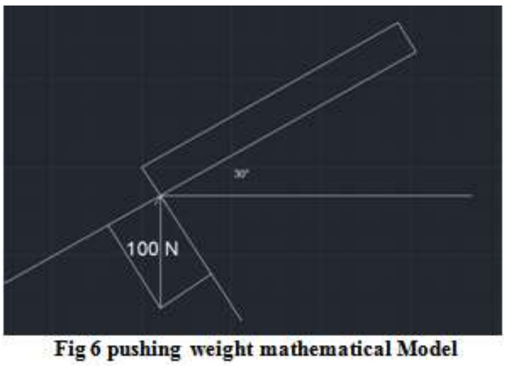

Fig 6 pushing weight mathematical Model

V. MECHANICAL FORCE ANALYSIS

In the design of the artificial wrist joint modeled in soil works 3-D software and analysis done in ANSYS static structure analysis. Regarding the design of artificial wrist joint before implant in patients we need to make sure design modal is fulfill the all situation which people facing in daily life activities such as like lifting, pushing and pulling weight. So, for the analysis modal assuming the 50 pounds weight needs to be pulling or pushing that situation force converted into 200N to fulfill real life activities. Usually titanium alloy is most common materials use to make artificial joint. So, titanium alloy used in ANSYS workbench.

5.1 Mesh modal

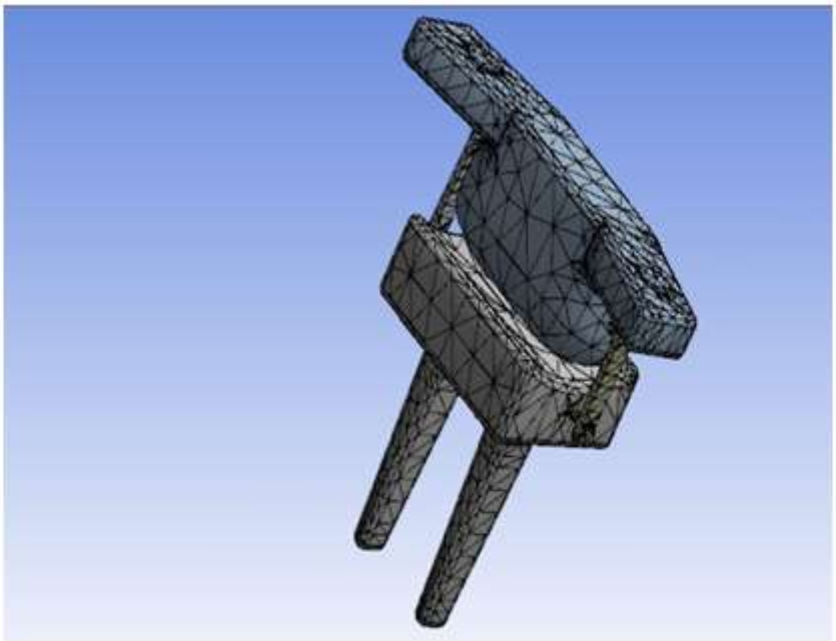

Fig 7 mesh model of artificial wrist joint

The mesh model is generated by ANSYS software in static simulation. In this mesh model radial components consider fixed support and applied load on distal components. So, in pulling load situation load applied in upward direction on distal components and pushing load situation load applied in downward direction.

In this paper model analysis did in two types of condition. In pulling load situation and pushing load situation.

5.2 Pulling situation

In pulling situation load applied on distal components 200 N which means 50 pounds load pulling situation.

5.2.1 Equivalent (von-Mises) Stress

For the stress analysis 200 newtons of force applied in upward direction on distal components. Regarding to situation of 50 pounds pulling load is good enough weight for pulling in daily life activist. The results in ANSYS showed that model is strong enough to hold that situation.

Table I RESULTS OF STRESS

Equivalent (von-misses) stress	**Results**
Minimum	2.0227 pa
Maximum	3.12e8 pa

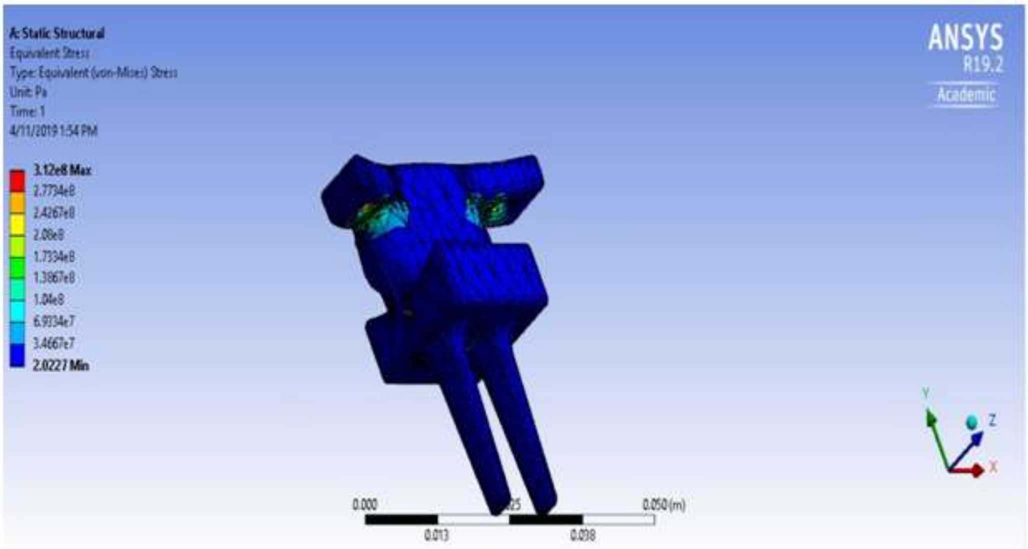

Fig 8 Equivalent stress analysis

The figure shows that the maximum von-Mises stress that the model take is 3.12e8 Pa and the minimum von-Mises stress is 2.0227 Pa. results shows that the model can hold this situation, so the model is reasonable and safe.

5.2.2 Total Deformation

The total deformation shows whole deformation of artificial wrist joint model. In ANSYS Workbench, the deformation of the model is generally showed as the output of the analysis process.

TABLE 2 RESULTS OF TOTAL DEFORMATION

Total deformation	Results
minimum	0 m
maximum	4.3905e-5 m

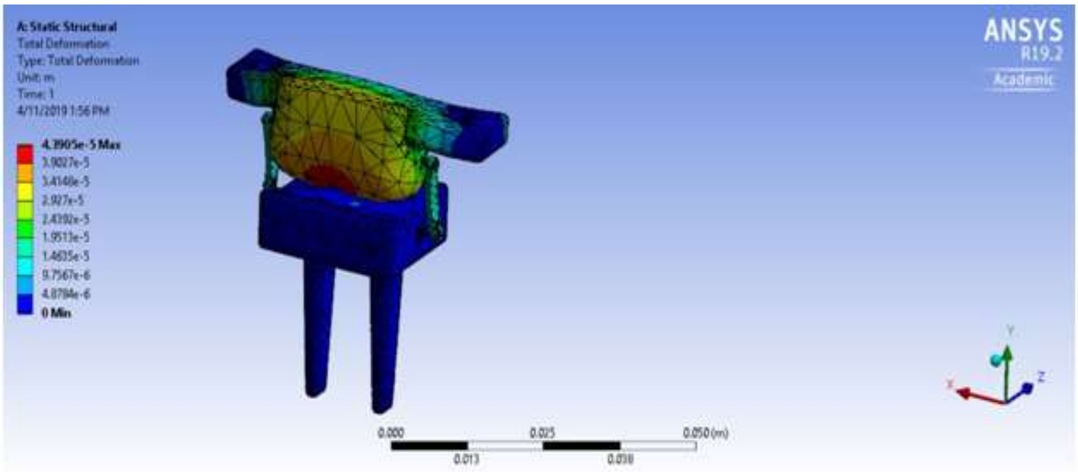

Fig 9 total deformation

Fig 9 total deformation

As figure shows, the maximum total deformation of the model is 4.3905e-5 meters and the minimum deformation is 0 meter. There are two areas that are presented in red which means that the model in these two areas are probably not well designed. To make sure that the model is reasonable, the dimensions should be recalculated in the future.

5.2.3 Safety factor

Factor of Safety presents the modal of to carry load and it is a commonly used factor for designers to analyze that whether their products are safe or not. Factor of Safety is a ratio of absolute strength to actual applied load. Results shows FOS of 2.98 which means that the model can pull load up to 50 pounds. In other words, the design is safe enough to hold pulling 50 pounds in daily life activities of the patients who will use it.

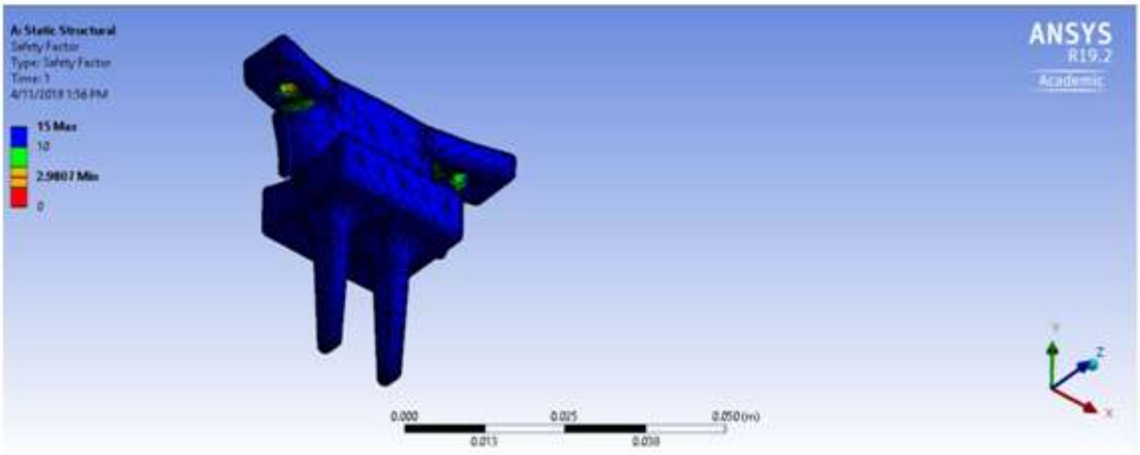

Fig 10 safety of factor in pulling situation

5.3 Pushing situation

In pushing situation load applied on distal components 200 N which means 50 pounds load pushing situation.

5.3.1 Equivalent (von-misses) Stress

For the stress analysis 200 newton of force applied in downward direction on distal components. Regarding to situation of 50 pounds pushing load is good enough weight for pushing in daily life activity. The results in ANSYS showed that model is strong enough to hold that situation.

TABLE RESULTS OF STRESS

Equivalent (von-misses) stress	Results
Minimum	2.0416 pa
Maximum	3.0612e8pa

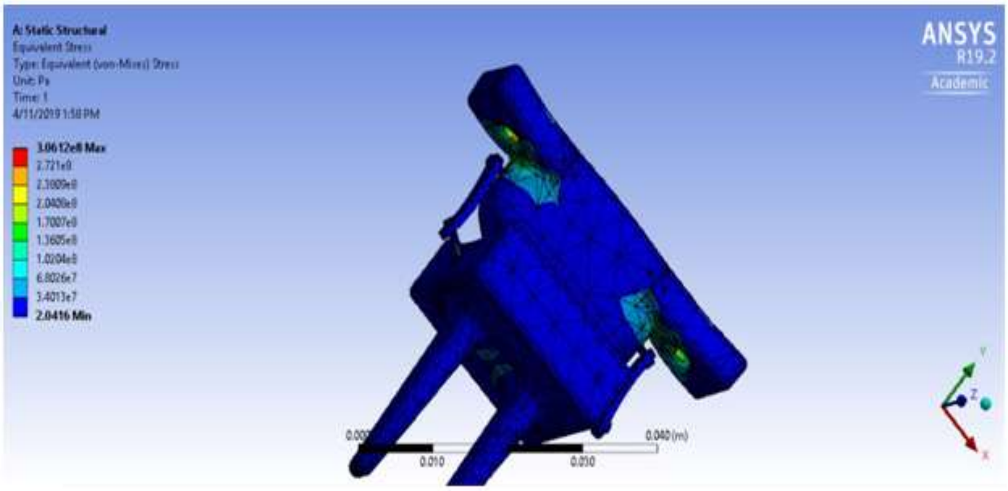

Fig 11 equivalent stress

The figure shows that the maximum von-Mises stress that the model take is 3.0612e8 Pa and the minimum von-Mises stress is 2.0416 Pa. results shows that the model can hold this situation, so the model is reasonable and safe.

5.3.2 Total Deformation

The total deformation shows whole deformation of artificial wrist joint model. In ANSYS Workbench, the deformation of the model is generally showed as the output of the analysis process.

TABLE RESULTS OF TOTAL DEFORMATION

Total deformation	Results
minimum	0 m
maximum	4.3296e-5 m

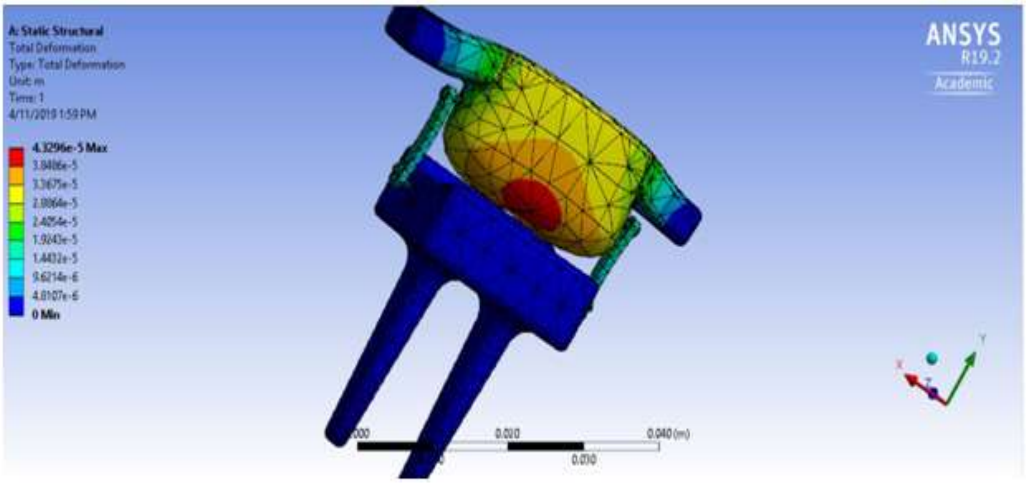

Fig 12 total deformation

As figure shows, the maximum total deformation of the model is 4.3296e-5 meters and the minimum deformation is 0 meter. There are two areas that are presented in red which means that the model in these two areas are probably not well designed. To make sure that the model is reasonable, the dimensions should be recalculated in the future.

5.3.3 Safety factor

Factor of Safety presents the modal of to carry load and it is a commonly used factor for designers to analyze that whether their products are safe or not. Factor of Safety is a ratio of absolute strength to actual applied load. Results shows FOS of 3.03 which means that the model can push load up to 50 pounds. In other words, the design is safe enough to hold pushing 50 pounds in daily life activities of the patients who will use it.

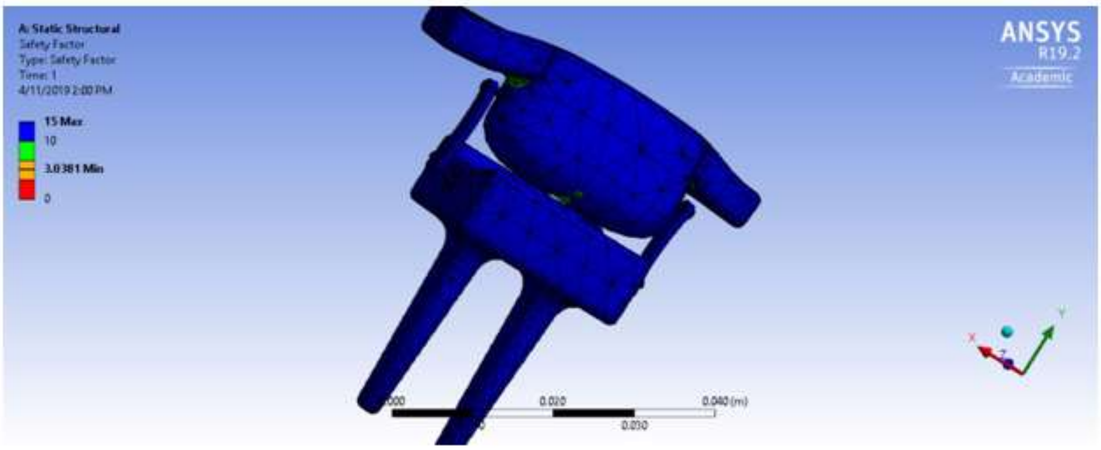

Fig 13 safety factor for pushing situation

VI. Conclusion

In this paper presents design of artificial human wrist joint based on using of 3D software solid works and mechanical analysis in ANSYS software. This design model of artificial wrist joint gives movements of wrist joint. The study of analysis artificial human wrist joint indicates safe and suitable results. Its reliable and safe use in who needs to replacement of wrist joint.

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