Analysis of Robotic End Effector

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ABSTRACT

In this study analysis of end effector of a pick and place robot is carried out to analyze its strength and develop a reconfigurable robotic end-effector for machining and part handling. Industrial robotic manipulators require an end-effecter to perform tasks. The device eliminates the need for separate robots to perform part handling and machining operations. A reconfigurable, dual-purpose design eliminates lengthy end- effector changes. Robots are very important in the field of automation of machinery. Performance of the robotic manipulator is dependent on the work done by the end effectors. The selection of end effector is based on the type of task that has to be performed. For picking, holding, and placing tasks to the specified end effector is selected and various different types of workshop operations tools are fixed on the manipulator for different applications e.g., welding electrode holder, painting spray gun etc. In the present scope of work, design and development of robot end effector by using Solid Works software. End effector model is imported to ANSYS Workbench to analyze the strength. Analysis for different materials with same load are carried out and compared with the results. Selecting the best material for an application in material handling. Further for the best material, design of end effector will be optimized for the industrial robot application.

Keywords—end effector, robotic manipulator, Solid Works, ANSYS Workbench, Structural Steel, Titanium Alloy, Connections, Joint displacement.

I. INTRODUCTION

An end effector is an accessory that fastens to a robot's manipulator or wrist and enables it to carry out its objective. End effectors often act as grippers, process tools, or sensors and are powered by mechanical or electromechanical sources. They are available in a broad range of forms, from straightforward two-finger grippers for pick-and-place work to intricate sensor networks for robotic inspection. Robotic work is challenging or just impossible without an end effector. A robot may be made to travel to a certain point, but without an end effector, it cannot carry out any operations.

Robot manipulators work from a sequence of links, joints and contact combinations. These links are rigid members that are connected to the joints, or axes. The relative motion between adjoining links can be obtained by the axes of the movable components of the robotic manipulator. The robotic arm manipulator is made up of two linear joints and three rotational joints, out of the five main types of mechanical joints employed in its construction. The linear joints have non-rotational relative motion between adjacent links whereas the rotary types have rotational relative motion between links. There are six robotic configurations namely Cartesian, spherical, Selective Compliance Articulated Robot Arm (SCARA), Cylindrical, Delta (Parallel) and articulate. The arm-body section of robotic manipulators is based on one of these configurations. Depending upon different applications each and every configuration of these anatomies gives a different work envelope [1, 4, 7]. Articulate type of robotic manipulator configuration boundary conditions are used to analyze the end effector with a displacement of 5mm [1].

II. LITERATURE REVIEW

Anurag Sharma [1] studied the end effectors' where he is selecting various grippers, like 3 finger gripper, 2 finger gripper, vacuum gripper, etc. also he did study on robotic tools like drilling spot welding after all he concluded that, the selection of correct end effector is very important and necessary considering the robot manipulator work space limit and type of operations to be performed on the type of works piece. In this study a co-relation and co- ordination of different types of end effectors is shown for completing the desired task completely and satisfactorily. **P.Ferdinandlivi joseph et al, [2]** modeled the robotic arm where everyone using same material, he focused on reducing the weight of the robotic arm using different alloys and composite materials. For example, structural steel, aluminum alloy365 and ARAMID Epoxy. After modeling the model using Solid works, they analyzed all three-material using ANSYS Workbench and concluded that structural steel and ARMID Epoxy Broke while analysis, whereas the Aluminum 365 withstand. **Treveljian et al.[3]** has studied about how the Robot wrists are designed to provide orientation to the end effector. Which has a "spherical joint", because the resulting configuration is more dexterous and less cumbersome than the other configurations. Robot wrists should have a low degeneracy level that represents the region where some rotations around certain fixed axes in the Cartesian space are require high speed actuators. Based on the viability test outcomes of a flexible gripper design, **Ho Choi & Koc, 2006 [4]** it was developed, analysed, built, and tested using compliant materials (i.e., rubber) with pneumatic inflation. To explore the impacts of process and design characteristics such rubber material, pressure, starting jaw displacement, and friction, FEA parametric calculations were carried out. An easy to understand, single rubber enclosed flexible gripper was designed and fabricated based on the outcomes of the FEA calculations. Compared to the traditional cam and follower gripper, **Biswal, 1997 [5]** designed and constructed a two-jaw actuated gripper with the aid of pneumatic cylinders using air pressure, force, and torque that have been calculated for various sets of conditions.

III. OBJECTIVE AND METHODOLOGY

A. Objective

- Analysis carried out to predict the strength and dynamic behaviour of end effector for different materials with a same load in terms of joint displacement of puller rod.
- The dynamic behaviour of the end effector and as well as the test piece will be observed to identify how both will act to a certain condition.
- The results of the two different materials are compared and concluding the factors of using it within certain parameters.

B. Methodology

1. Modeling of robot end effector using solid works software.
2. Analysis by using ANSYS workbench.
3. Analysis carried out for different materials with a same joint displacement and compared with the results.
4. Analyzing the behaviour of the component with different material application.
5. Selection of best material for industrial applications.

1. Modeling of robot end effector using solid works software.

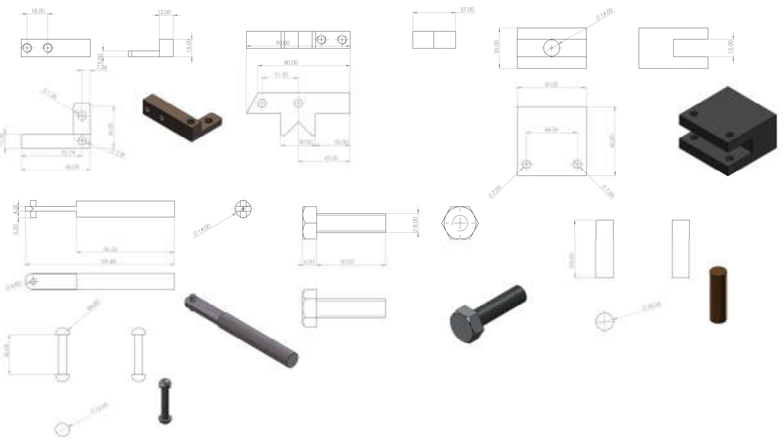
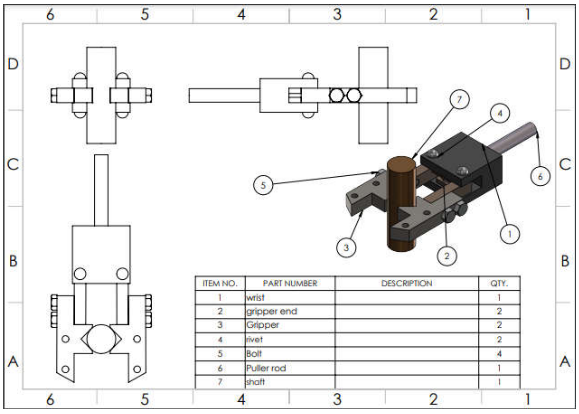


Fig 1 Dimensions of all the components

The model of end effector is created in Solid Works software with all dimensions including 2D and 3D dimensions, to minimize the errors model has created from 2D to 3D as shown in fig 1. Fig 2 and fig 3 shows that the assembly of components and 3D view of end effector respectively.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	wrist		1
2	gripper end		2
3	Gripper		2
4	rivet		2
5	Bolt		4
6	Puller rod		1
7	shaft		1

Fig 2 Assembly of components

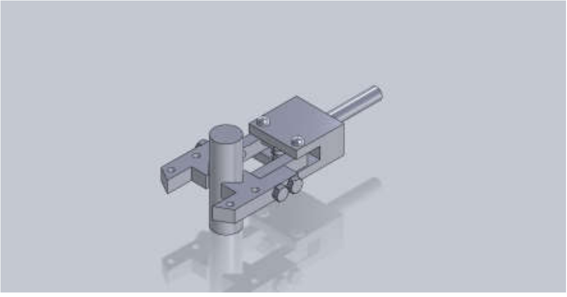


Fig 3 3D view of end effector

2. Analysis by using ANSYS workbench

a. Engineering geometry

As shown in Fig 3 the assembled components of end effector is designed and created using the Solid Works software and saved in IGES format. Further the 3D model is imported to the analysis software ANSYS Workbench in IGES format.

b. Materials Used

Material selection is an essential aspect of product design and development. The material selection should be done not only to meet the application requirements of the product, but it must be cost-effective also. Selection of suitable materials is very much significant in designing as it contributes to the enhancement of time and cost efficiency.

Table 1 Properties of materials

Properties	Structural Steel	Titanium Alloy
Density ton/mm^3	7.85×10^{-9}	4.43×10^{-9}
Coefficient of Thermal Expansion /°C	1.2×10^{-5}	8.5×10^{-6}
Specific Heat MJ /ton °C	4.34×10^{8}	5.44×10^{8}
Thermal Conductivity W/ mm °C	6.05×10^{-2}	7.2×10^{-2}
Compressive Yield Strength MPa	250	1080
Tensile Yield Strength MPa	250	862
Tensile Ultimate Strength MPa	460	1200
Young's Modulus MPa	2.0×10^{5}	1.2×10^{5}
Poisson's Ratio MPa	0.3	0.35
Bulk Modulus MPa	1.6667×10^{5}	0.96×10^{5}
Shear Modulus MPa	76923	45000

c. Connections and joints

The links in between the end effector components are Cylindrical, Revolute, Fixed to the part and Ground to body, Body to body. These are defined because during the joint displacement along Z-axis dynamic behaviour are observed in order to analyze the model. The main body, jaws, bolts are fixed (fig 4), the rivets make revolute connections with the main body (fig 5), whereas cylindrical connections with the movable jaws (fig 7), the puller rod makes transitional connections (fig 6), and the shaft makes rough contacts with the fixed jaws (fig 8).

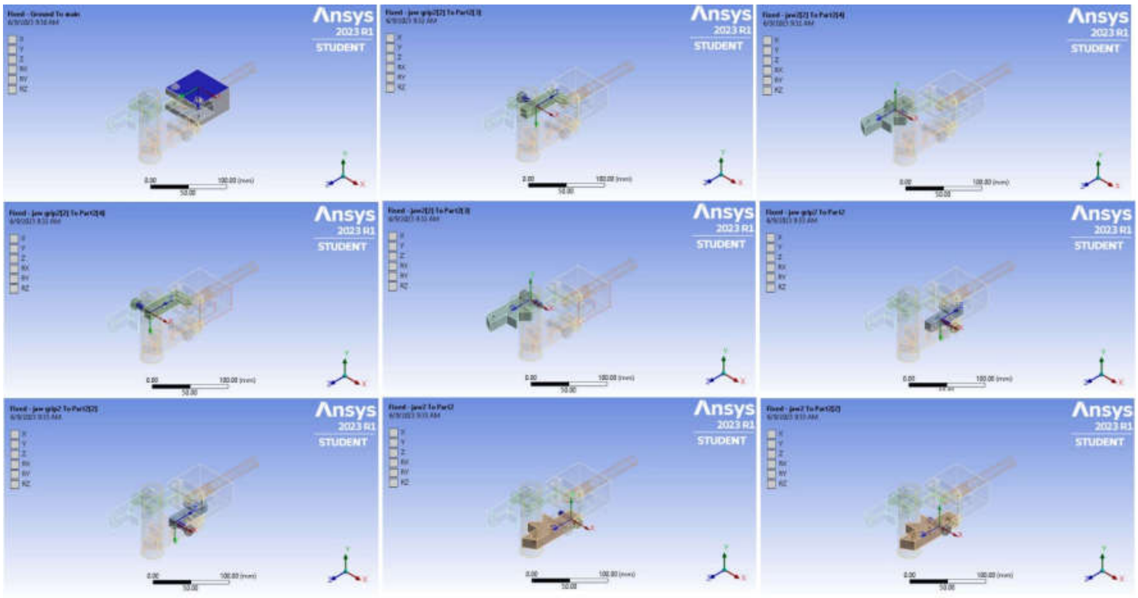


Fig 4 Fixed joints

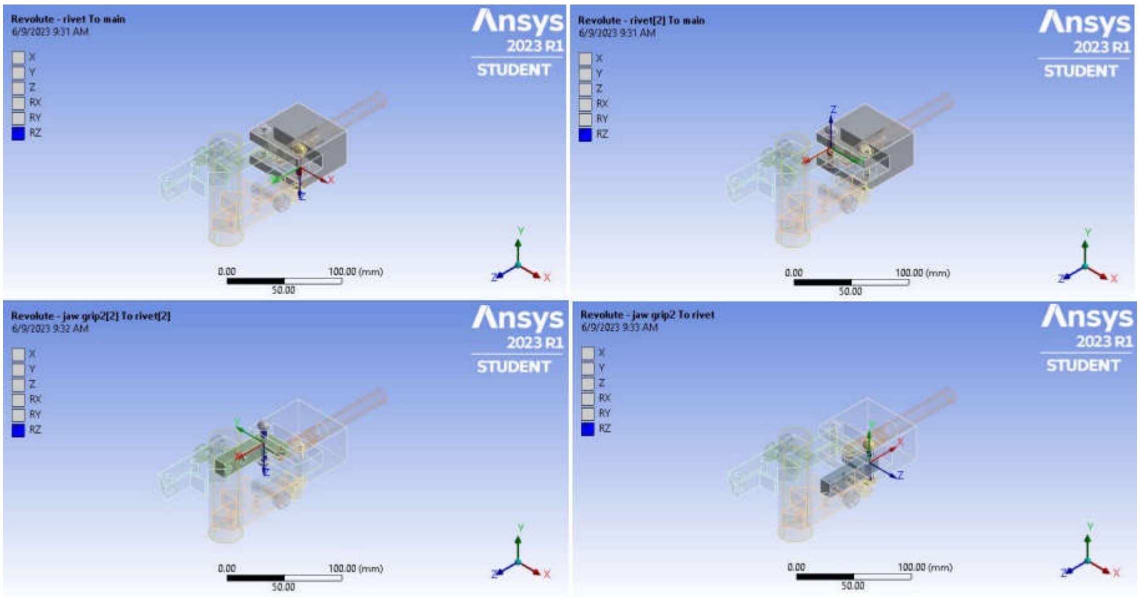


Fig 5 Revolute Connections

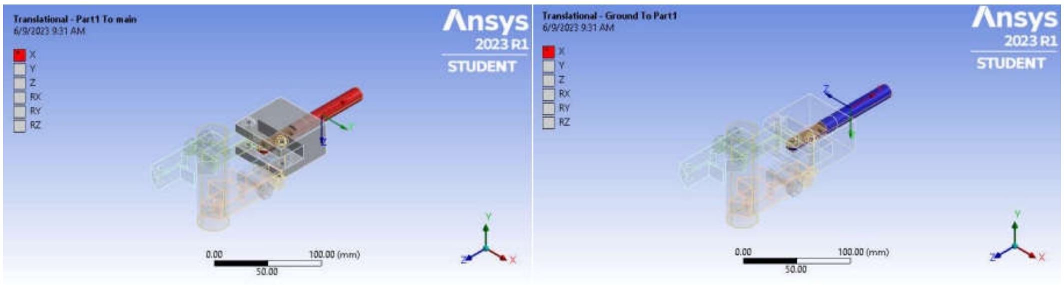


Fig 6 Translational connections

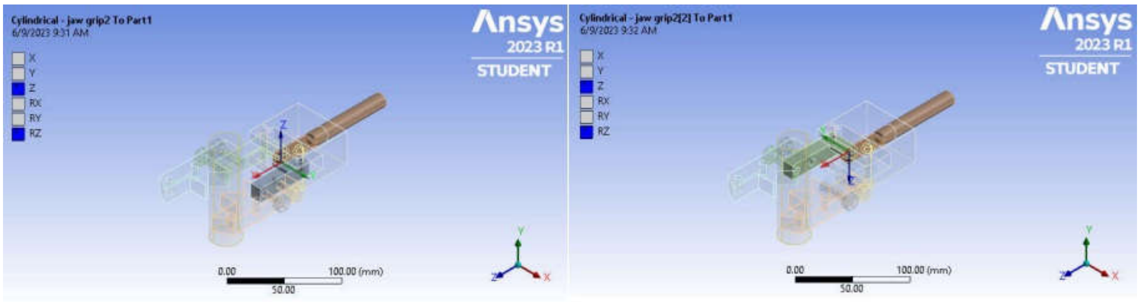


Fig 7 Cylindrical connections

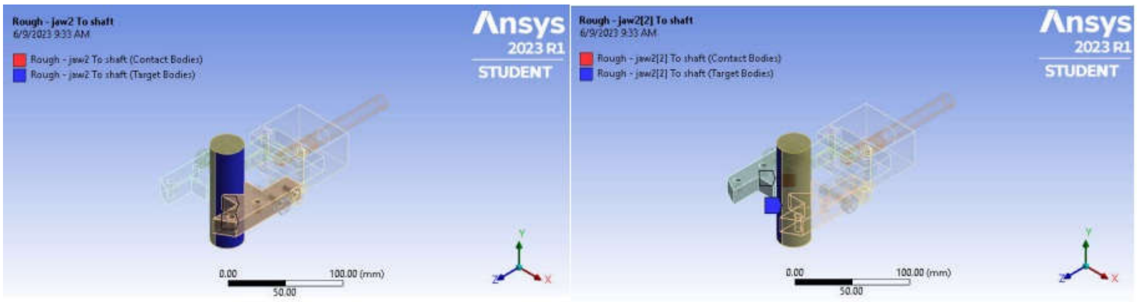


Fig 8 Rough Contacts

d. Meshing

Meshing is the main step in performing an accurate simulation using FEA. Mesh consists of number of nodes and elements that represent the geometrical modelling shape (fig 9 and table 2). The process of converting geometric modelling into FE modeling where the most complex and irregular shapes are discretized into more recognizable volumes (elements) is called meshing.

Table 2 Meshing Statistics

Statistics	
No of Nodes	23243
No of Elements	12571

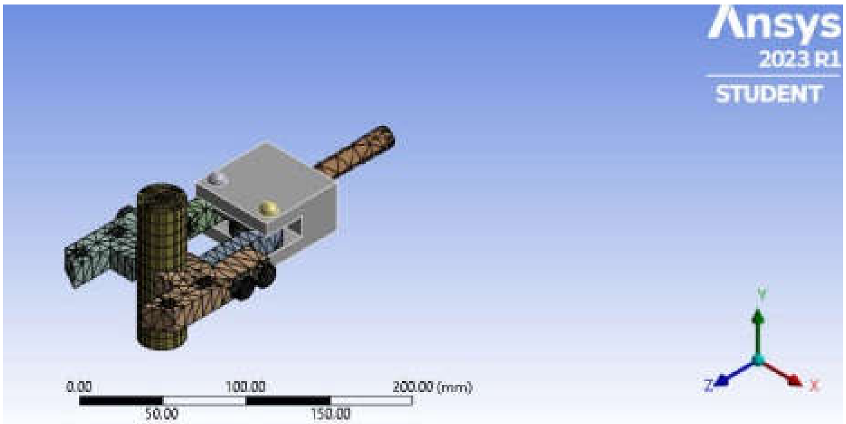


Fig 9 Mesh Plot

e. Analysis Settings and Loading

Transient analysis involves the study of time-dependent behavior of physical systems or structures. Transient analysis of end effector in ANSYS Workbench allows us to study the dynamic response of end effector subjected to time-varying loads. It helps us to determine the stress, strain and deformation of the end effector under 5mm displacement with respect to 0 to 5 seconds (fig 10 and table 3).

Table 3 Joint Displacement

Steps	Time (s)	Displacement (mm)
1	0	=1
	1	1
2	2	=2
3	3	=3
4	4	=4
5	5	5

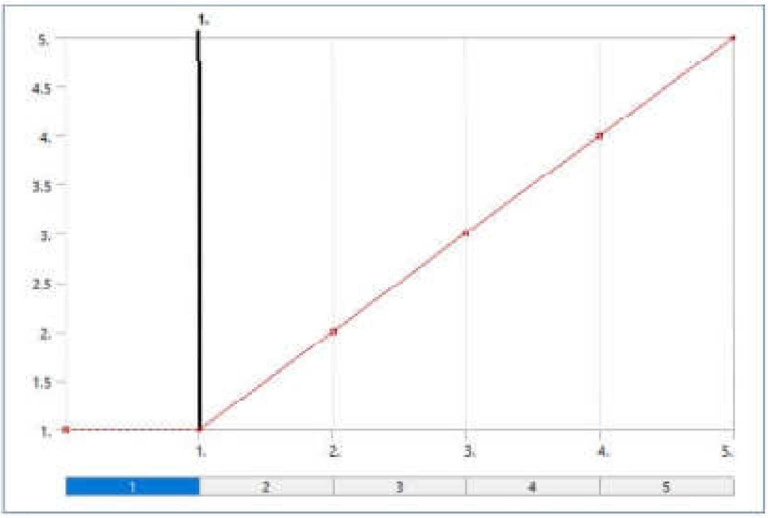


Fig 10 Joint Displacement

IV. RESULTS AND DISCUSSIONS

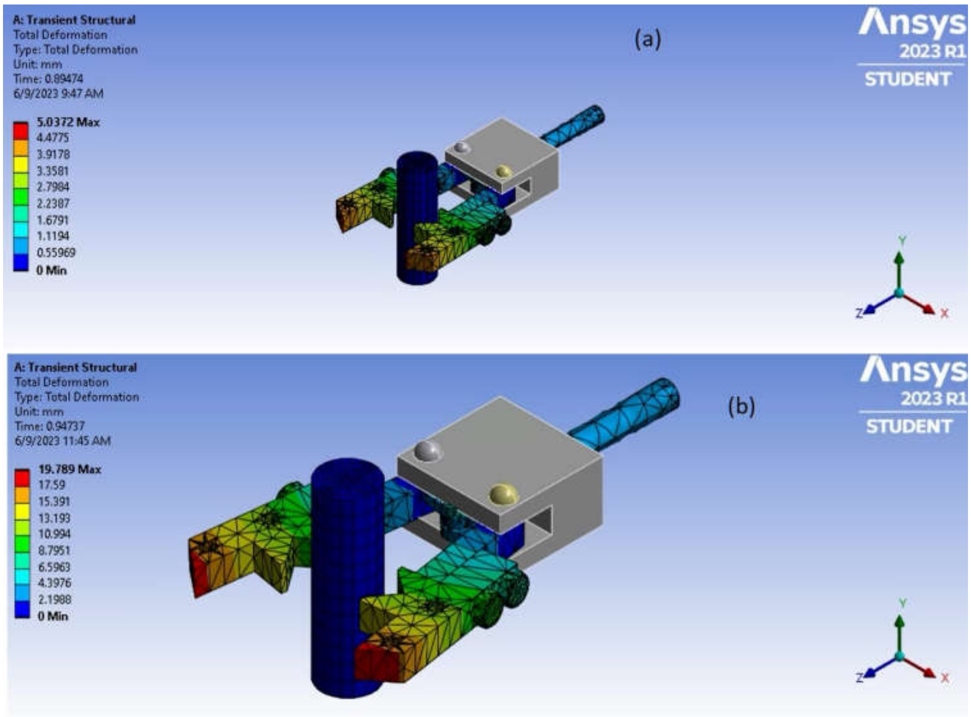


Fig 10 Deformation Results (a) Structural steel (b) Titanium alloy

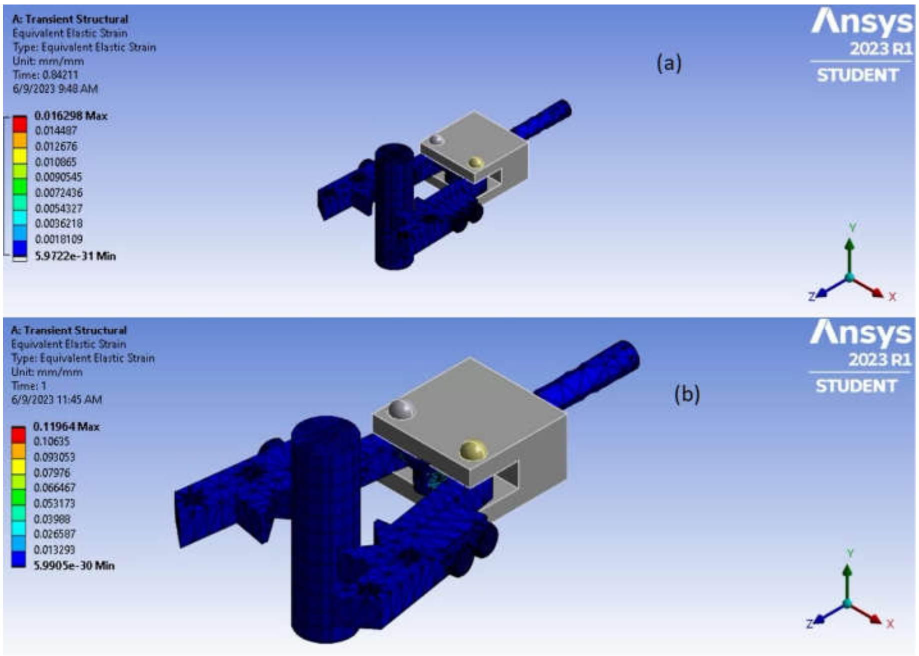


Fig 11 Strain Results (a) Structural Steel (b) Titanium Alloy

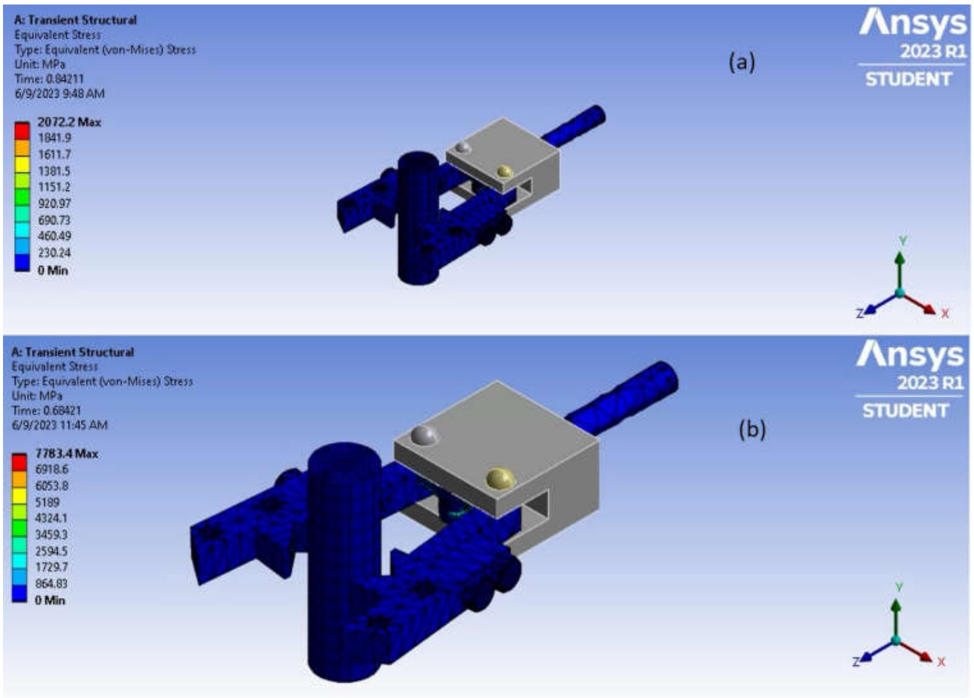


Fig 12 Stress Results (a) Structural Steel (b) Titanium Alloy

Table 4 Results

Type of material	Total deformation (mm)	Total Equivalent Strain	Equivalent stress (Mpa)
Structural steel	3.309	7.3576e-004	110.49
Titanium Alloy	3.3344	7.8052e-004	78.395
Percentage variation	0.76%	5.7%	29.04%

From the table 4 observed that the equivalent stress is less in Titanium alloy compared to Structural steel by 29.04%, the total deformation and equivalent total strain changes very slightly that is 0.76% and 5.7% respectively. Based on these results titanium alloy is preferable for this type of end effector since the stresses induced are less however taking the cost into consideration structural steel is preferable but only for small displacements that are less than 5mm.

V. CONCLUSION

ANSYS is most cost efficient tool that helps in simulation and gives satisfactory results in less time using discrete approach. One of the great benefits of FE analysis is that it allows for the safe simulation of conditions that are sophisticated, dangerous or difficult to replicate in a physical test environment. The results produced by FEA software are extremely detailed and accurate, offering a wide variety of conditions to test against.

Based on this analysis of end effector, it is concluded that titanium alloy shows better results when compared to structural steel material. For displacements which are less than 5mm, then structural steel is sufficient considering the factor but when the displacement is more than 5mm titanium alloy is needed to withstand though the cost is on higher side compared to structural steel.

VI. ACKNOWLEDGMENT

I wish to thank my wife, Dr. Harini, who has stood by me, gave me love, support and help throughout my project work.
Finally, I would like to express my gratitude to everyone who assisted me in this research, either directly or indirectly.

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