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Research Article

Design and Analysis of Industrial Robotics Arms for Material Holding Processing in Manufacturing System

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ABSTRACT

The research focuses on the modeling and study of an adaptable robotic arm for material management activities. The Articulated Robotic Arm is gaining popularity in the industry due to its high accuracy and ability to carry out heavy operations. To design and simulate the robotic arm with an object handling effectors, SOLIDWORKS software was used. In the initial stages of modeling, researching the finite element approach was considered crucial. This analysis helped identify the strengths and weaknesses of the design. The numerical simulation analysis was conducted using ANSYS software workstation on a prototype of the robotic arm, allowing investigation of different components and loading situations. The findings from this investigation were then examined to select the appropriate material and ensure the feasibility of the articulated robotic arm.

Keywords: ANSYS, SOLIDWORKS, Finite Element, Material Handling Gripper, Robotic Arm etc.

INTRODUCTION

Robotics is a fascinating field of science that focuses on the design, modeling, analysis, and implementation of robots. Robots are used in various industries and production processes, such as welding, spray coating, machining, assembly, cutting, and more [1]. While lightweight architecture is preferred in many technological disciplines today, most studies have been limited to the automotive and aerospace industries [2]. To reduce weight, researchers have explored replacing commonly used materials with lighter alternatives that still provide the same functionality. Pupaza et al. [3] made geometric adjustments to the robotic arm's second plane and conducted a strength-based study, resulting in a lighter arm with no distortion under the same load. Chong et al. [4] and Rueda [5] investigated new materials and arm topologies, evaluating stress and shear deformations to determine suitable motor and weight quantities. Industrial robots consist of connectors, joints, motors, detectors, a processor, and a hardware or software emulator. The robot arm is attached to the robot base on one end and equipped with an end effector, such as a hand or grip, on the other [6]. The robot is controlled by computers and electronic software, typically connected to a PC that drives the robot's motor movements [7]. The arm is responsible for directing the grabber arm to complete tasks, but this may not be possible if the arm architecture is too large or small [8]. The primary purpose of using a robotic arm is to reduce human errors and effort. Mechanical grippers are attached to the end of robotic arms for object selection, positioning, and materials management [9]. Grippers are used for unloading and loading tasks, such as handling metal sheets, pallets, and food products [18-26]. In industries where physically unloading and loading heavy items is tiresome, a robotic arm can be utilized [10]. The objective of this project is to design a six-jointed articulated robotic arm with a single mechanical grip movement and select a suitable material capable of handling heavy loads. The SOLIDWORKS® program will be used to design the robotic arm [27-38]. ANSYS® software workbench will be used for numerical simulations to optimize the arm and select critical assembly portions and appropriate materials for industrial use [39-49]. Furthermore, the research findings will support the strategy and development of robotic arms [50-55].

METHODOLOGY

a. First, the needs for the robotic arm are gathered and developed into a 2D sketch.
b. Next, a complex 3D solid view is created in SOLIDWORKS, using specific instructions and constraints.
c. Then, the model is opened in the ANSYS program workstation and imported.
d. The input parameters are determined by selecting the appropriate materials for this industrial application, after importing the data.
e. Once imported, a mesh is created and boundary conditions are applied.
f. Finally, the mechanical assessment of the robotic arm is conducted under different load scenarios, in order to examine distortion and stress patterns and analyze the design.

Kinematic analysis

The RoboAnalyzer 3D Model-based robotics program is used to determine the basic design parameters of a specific type of robot. It determines the location and rotations of the robot's End-effector, as well as the speeds of various articulations and the length of the required link by resolving the analysis of the nonlinear equations. Robo Analyzer collects the DH data of a Serial robot. It takes the revolute articulations of the manipulator as input and generates a 3D model of the robot for each of the DH values. The 3D tracking window provides zoom, pan, and tilt capabilities that can be used. The dynamic CAD prototype is developed by observing the 3D model from multiple perspectives. According to the conclusions of the inverse dynamical analysis of the 3D Model, a dynamic CAD model is created using the Solid Works application. This model can replace the time-consuming process of architectural remodeling. The structure is capable of parametrically generating a model using one of its tools, ensuring that the model's shape cannot be changed by altering the constraints. As a result, a CAD model can be employed in the design process. The effective architecture of the robot can be achieved by changing the model's restrictions in each iteration. In technological design challenges, parametric modeling has become a competent and vital tool.

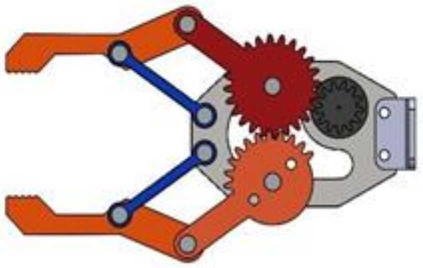


Fig. 1. Base Model of older version

Fig. 2. The base model of the newer version

Figure 1 and 2 shows the base model sample of an industrial robot with the older version and new version of it.

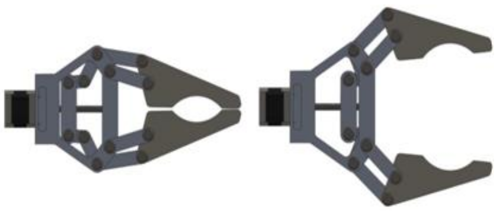


Fig. 3. Top view of the rack and pinon Mechanism

Figure 3 shows The material holding region of the industrial robots' top view. In this part where the robot can carry the weight and distribute it to the other region without any manual effort.

Fig. 4. Connector 2 Model

Fig. 5. Gripper Model

Figure 4 shows the robot with 2 point connector which can carry more number of objects whereas figure 5 shows the gripper model because the gripper plays an important role while carrying a material if the gripper model of the robot fails to carry material from the destination properly.

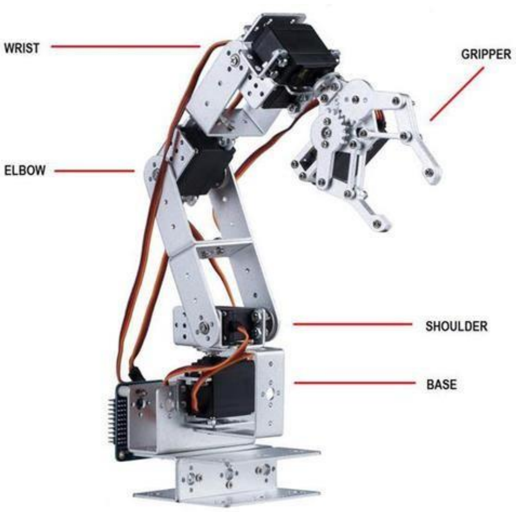


Fig. 6. Arm Assembly

Figure 6 gives a detailed description of the Robot Arm assembly. The robot's arm is made up of the wrist, elbow, gripper, shoulder, and the base.

All the components of the robotic arm are created separately in SOLIDWORKS® and then combined using conditions and restrictions. SOLIDWORKS® was chosen because it has recently been utilized by several studies and has been shown to assist in cutting robot development and design time, enhancing designer efficiency, and increasing the performance and quality of robot modeling. Figures 1–5 depict the various components of the robotic arm. Figure 6 depicts the assembly of these various elements into a fully articulated robotic arm.

STRUCTURALANALYSIS: The findings of the FE analysis define the pressure condition of a structure under a certain load. The input data for the FE study includes the arm shape with the FE analysis, model parameters, and loading criteria. The loading factors are determined by the direction and position of each weight input to the element. To solve different linkages under pressure due to loading situations, the finite element approach was used. The material qualities and component behavior are considered to be linearly flexible [12]. The usage of FEA is a fantastic method. Simulation has the advantage of taking less time, costing less money, and being easier to compare to the experimental technique. The robotic arm's SOLIDWORKS assembly is changed to STEP or IGS file format before being imported into the program. The structural analysis toolbox in ANSYS® software is used to estimate component pressures and distortion.

MESHING: The practice of splitting a model into a number of parts such that when a load is applied to it, the weight is distributed uniformly is known as meshing. Typically, this is called discretization. A finite number of items must be discretized from the continuum.

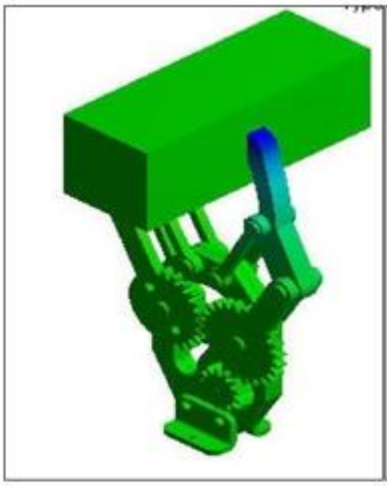


Fig. 7. Combination of Robotic Arms

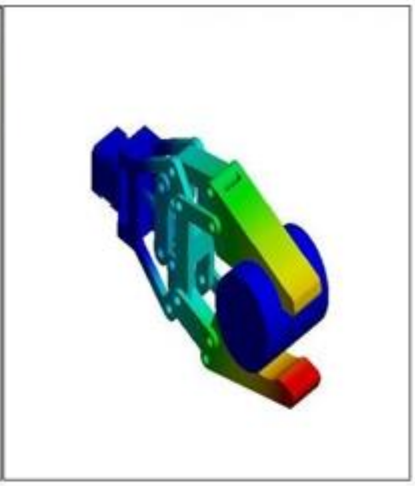


Fig. 8. Gripper symbiosis

With a change in the number of components and component size, the structure of the FEA findings can be significantly altered. Triangular pieces are used to fine-tune the robotic arm's meshing. The entire number of elements is 46193, while the total number of nodes is 76424. The meshing was depicted in Fig. 7 and 8.

PROPERTIES: Because of their high strength and ability to withstand huge forces, steel plate and Aluminum Composite 356 have been chosen as the robotic arm materials. The features of both materials are shown in tables 1 and 2 below.

Tab. 1: Structural Steel Properties

Properties	Tensile Yield Strength	Tensile Ultimate Strength	Compressive Yield Strength	Density
Values	$2.5\times10^{8} Pa$	$4.6\times10^{8} Pa$	$2.5\times10^{8} Pa$	$7850 Kg/m^{3}$

Table 1 shows the structural analysis of the steel with certain important properties like tensile yield strength, tensile ultimate strength, Compressive yield strength, and density.

Tab. 2: Aluminum Alloy 356 Properties

Properties	Tensile Yield Strength	Tensile Ultimate Strength	Shear Strength	Density
Values	$2.05\times10^{8}Pa$	$2.5\times10^{8}Pa$	$2.05\times10^{8}Pa$	$2680Kg/m^{3}$

Likewise table 1, table 2 shows the properties for Aluminum alloy of 356 value. The properties of aluminum356 alloys includes tensile yield strength, tensile ultimate strength, Compressive yield strength, and density.

RESULTS AND DISCUSSION

Kinematics refers to the study of how objects move. In the context of robot manipulators, understanding the kinematics is crucial for automated control. In this section, we will discuss the theoretical foundation of kinematics, specifically focusing on the kinematics of an instructional robotics arm using the KUKA KR5. Firstly, let's consider the concept of the joint. The robotic arm we are examining is a six-rotation revolution robot. The offset (b) is the length of the baseline perpendicular to the connections on the joint axis.

The length of the connection (a) is determined by measuring the length between the perpendicular axis of the two objects. The torsion angle is the angle formed between the orthogonal axes. Next, we will discuss predictions in a plane that is perpendicular to the standard along the pivot axis. The joint refers to the perpendicular projections that are not parallel to the standard. The pivot axes plane is also perpendicular to the standard.Now, let's consider the variables that come into play. Each DE factor, known as the joint factor, can be changed for different types of connections. The other three variables are considered constant variables for a specific connection. Moving on to the analysis of force, we have chosen to use two different materials: Structural Steel and Aluminum Alloy 356. Varying forces, ranging from 300N to 600N, are applied to the robotic arm's end effectors or gripper under four different loading circumstances. If the ultimate tensile value exceeds the shear stress, the structure will collapse

Figures 9-12 depict the deformation and stress fluctuation of the Structural Steel robotic arm, while Figures 13-20 show the same for the Aluminum Alloy 356 robotic arm.

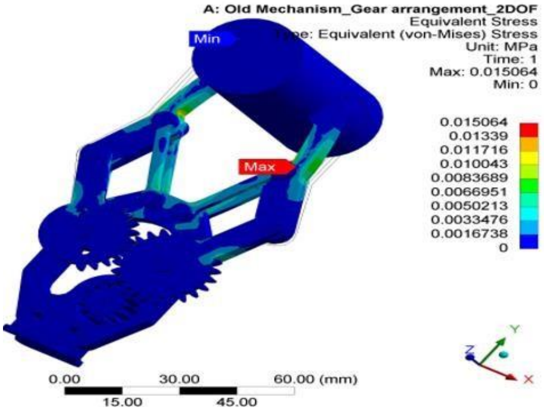


Fig. 9. Deformation in the 300N range with stress analysis at 300 N

Figure 9 shows the robot arm with a weight of 300 N through which the stress analysis of the robot with this weight must be analyzed.

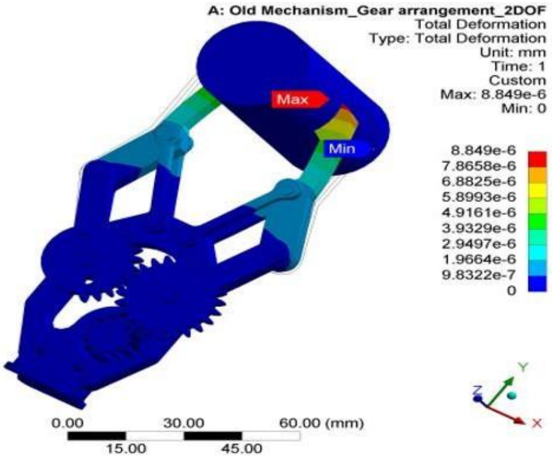


Fig. 10. Deformation in the 400N range with stress analysis at 400 N

The above figure 10 describes the weight carrying capacity of the robot at 400N where the stress estimation ofthe robot with 400 N is also analyzed.

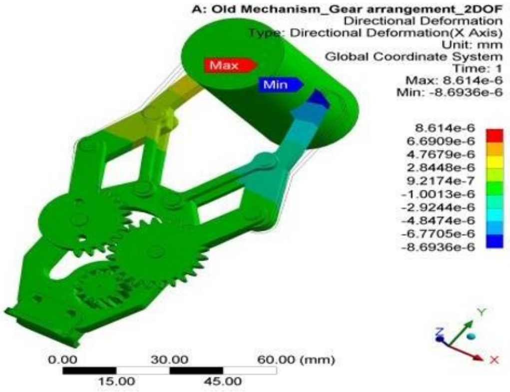


Fig. 11. Deformation in the 500N range with stress analysis of 500 N

Figure 11 shows the robot arm with a weight of 500 N through which the stress analysis of the robot with thisweight must be analyzed.

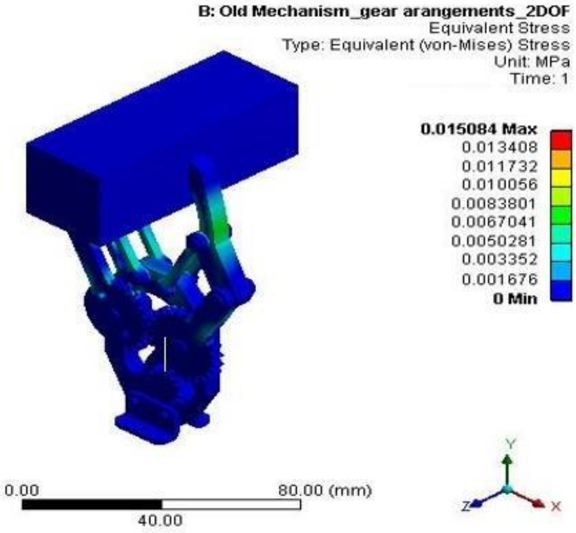


Fig. 12. Deformation in the 600N range with stress analysis of 600 N

As shown in figure 12 the robot is carrying more weight when the weight of the material get increased its load-carrying capacity also increases and more stress may arise in the region.

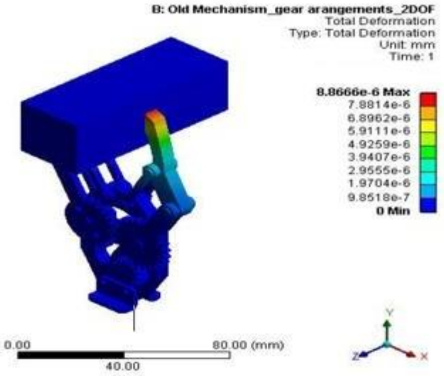


Fig. 13. Deformation in the 300N range

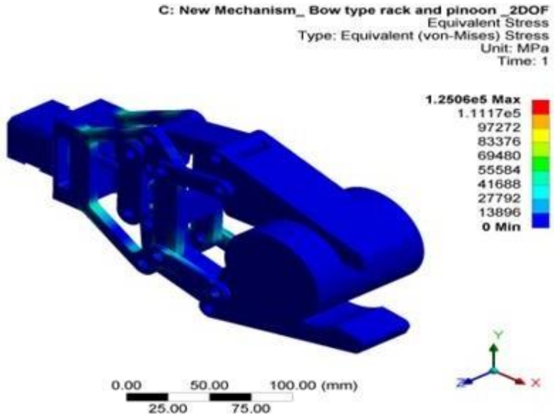
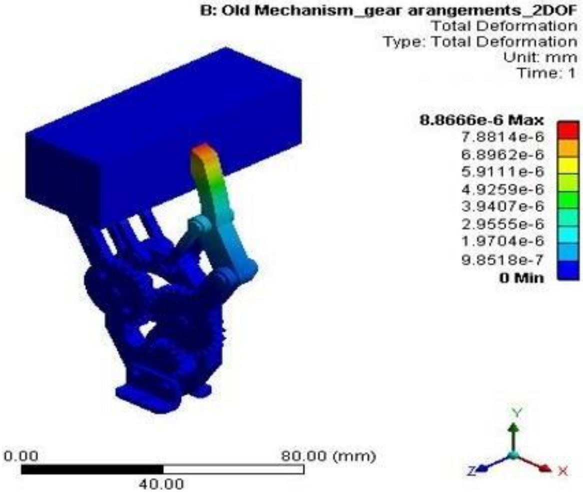


Fig. 14. Stress Analysis at 300*N*

Figure 13 and 14 shows the robot which a square shaped weight as a sample for testing its stress



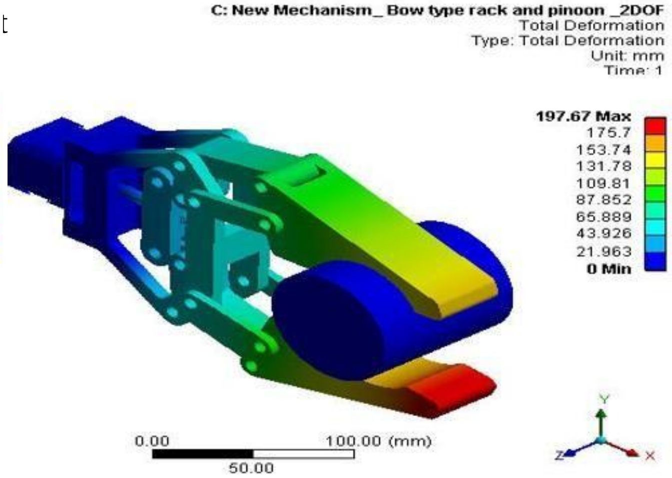


Fig. 15. Deformation in the 400N range **Figure 16.** Stress Analysis at 400*N*

Figure 15 and 16 shows the old mechanism and the new mechanism of load carriage by a robot. The stress evaluation may vary based on the mechanism.

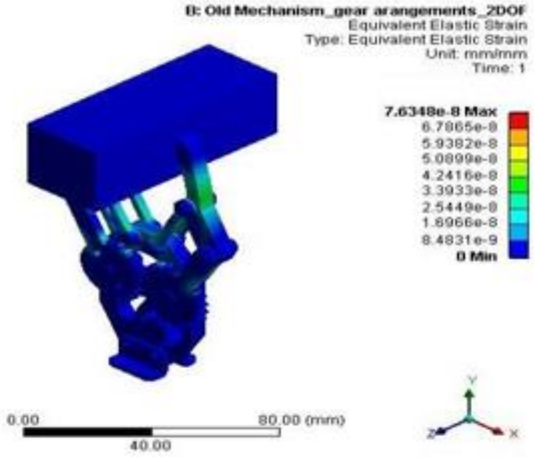


Fig. 17. Deformation in the 500N range

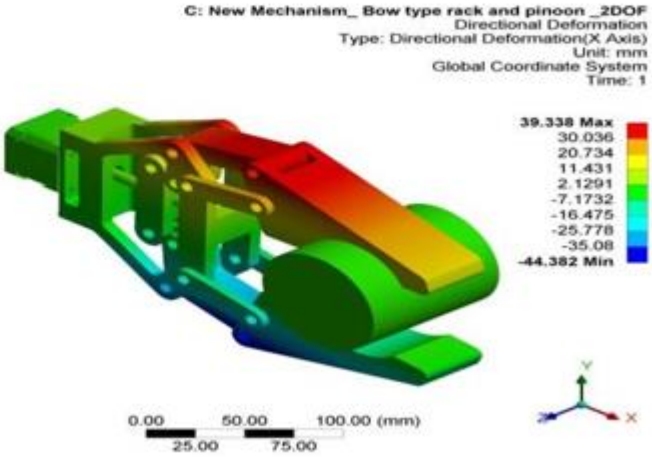


Fig. 18. Stress Analysis at 500*N*

Figures 17 and 18 show the load-carrying capacity of a robot with 500 N using the old and the new mechanism where the stress analysis for this process is analyzed to know the capacity of the robot for carrying weight.

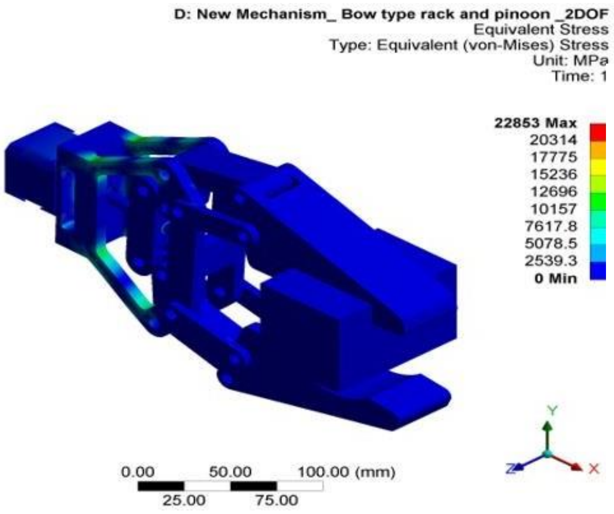


Fig. 19. Deformation in the 600N range

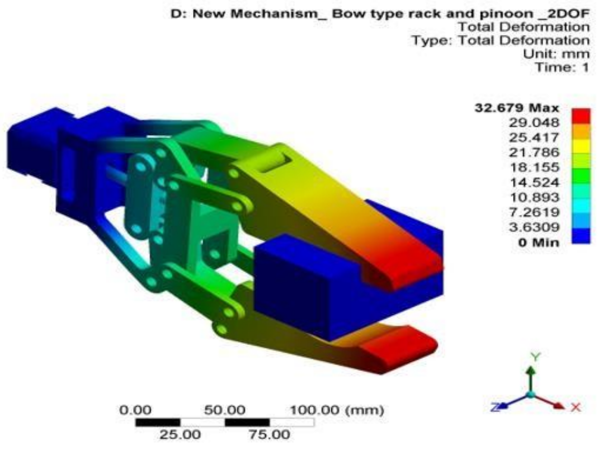


Fig. 20. Stress Analysis at 600*N*

Figures 19 and 20 show the robot with maximum weight carriage when the weight of the load increases in such case the stress in the arm region of the robot may increase.

Tab. 3. Results of Structural Steel Analysis

Sr. No. N)		**Max Equivalent Stress (MPa)**	**Max Deformatio (mm)**
1	350	90.9089	0.13577
2.	450	145.98	0.7858
3.	580	156.98	0.98751
4	650	165.98	0.86455

Tab. 4. Analysis Results for Aluminum Alloy 356

Sr. No.	**Force (N)**	**Max Equivalent Stress (MPa)**	**Deformation (mm)**
1.	400	89.097	0876552
2.	380	143.87	2.9897
3.	490	178.87	2.0958
4.	540	167.98	3.08697

Tables 3 and 4 indicate that the strain distribution statistics for both components are within authorized limits, meaning they are lower than the maximum shear stress. However, when comparing the same weight, the SSA performs better than the Aluminum Alloy Arm. Specifically, the Aluminum Alloy Arm exhibits slightly larger distortion. Consequently, a structural steel robotic arm is the most reliable choice. Moreover, both findings suggest that the structural integrity of these flexible robotic arms meets operational requirements and makes them suitable for further investigation.

CONCLUSION

Today's generation needs a versatile and affordable robotic hand that can imitate the movements of a human hand. To achieve this, we have designed an articulated robotic arm using SOLIDWORKS a 3D CAD application. The arm was then exported to ANSYS® for material analysis. By utilizing this robotic arm, various industries can benefit from its capabilities, such as picking and placing objects, assembling tasks, and more. The structural analysis has confirmed that the arm meets the required design specifications and is able to handle different types of payloads. This makes it suitable for hazardous environments within companies, where it can enhance production processes. In the future, we aim to further develop the simulation capabilities within the chosen workspace.

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