Design of a Robotic Arm for Carrying a Shield

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1 ABSTRACT

This study introduces an engineering approach for designing a robotic arm capable of carrying a shield with specific dimensions, using the SolidWorks software. The aim is to facilitate the efficient delivery of shields during a company's closing ceremony. The arm's design involves stages like determining shield dimensions, selecting appropriate joints for movement, configuring arm lengths, and creating clamp designs for secure shield retention. The arm's overall structure prioritizes durability and lightweight construction. Materials like aluminum alloys and steel are considered for their lightweight and corrosion-resistant properties. Key references, such as "Mechanics of Machines" and "Shigley's Mechanical Engineering Design," aid in calculating joints, selecting gears, and guiding material testing. This research underscores the importance of precision engineering and proper material selection for successful robotic arm design.

Keywords

Robotic Arm, Mechanical Design, SolidWorks, Joint Selection, Materials, Engineering.

2 INTRODUCTION

The significance of mechanical engineering and robotics has grown across various fields, emphasizing the need for designing mechanical devices that cater to diverse requirements. This research aims to present an engineering approach to design a robotic arm capable of carrying a shield with specific dimensions using the SolidWorks software, facilitating the delivery of shields to trainees at a company's closing ceremony.

3 ROBOTIC ARM DESIGN

The design of the robotic arm for carrying the shield involves several crucial stages:

3.1 Requirements Determination

Precise dimensions of the shield (15 cm height, 17 cm width, 5 cm thickness) must be specified, in addition to defining the arm's function in smoothly and securely delivering the shields.

Figure 1. Dimensions of the shield.

3.2 Selection of Appropriate Joints

Joint design is a fundamental element in achieving arm movement. Revolute joints can be used for rotary motions, and Prismatic joints for linear motions.

3.2.1 Revolute Joint:

Revolute joints, as Shown in Figure 2, [1] Allows rotational movement around a specific axis, like the elbow joint.

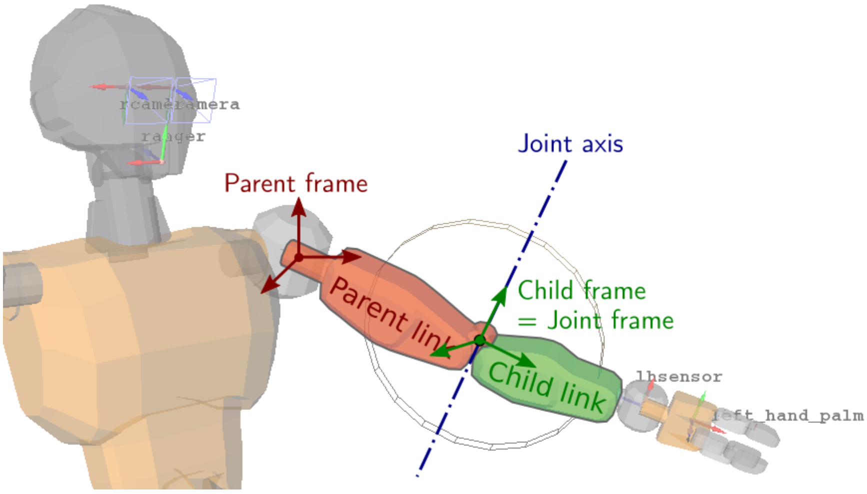

Figure 2. Revolute joints.

3.2.2 Prismatic Joint:

Prismatic Joint, as Shown in Figure 3, [2] Permits semi-linear motion, suitable for arm movement and shield delivery.

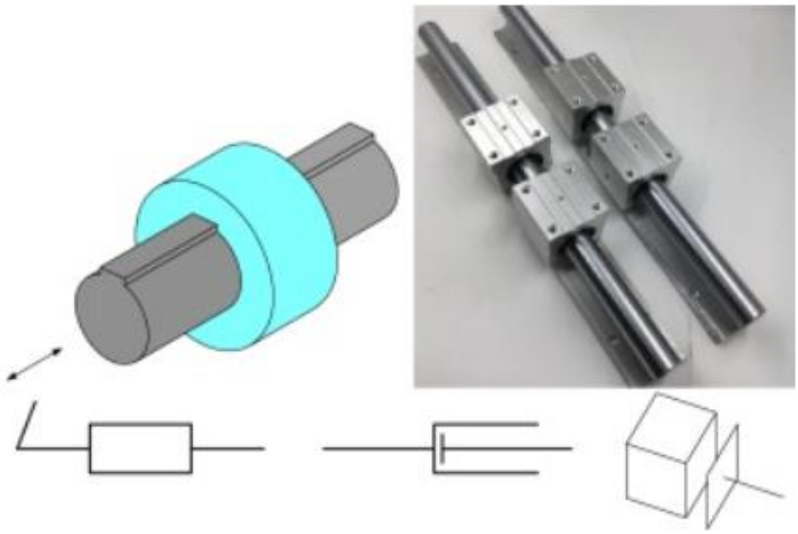

Figure 3.Prismatic Joint.

3.3 Arm Design

Arms must be designed with lengths and shapes that ensure shield stability and protection. Connected arms with joints can achieve more precise movement, as Shown in Figure 4, [3]

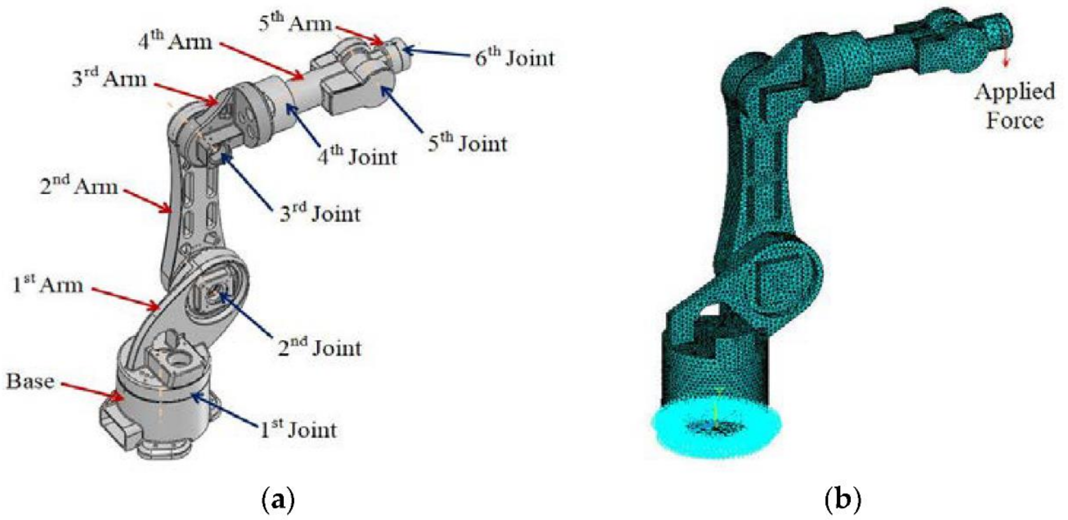

Figure 4. Robot configuration: (a) Schematic description of the robot architecture; (b) Finite element analysis FEA model.

3.4 Kinematics and Arm Design

The study of kinematics is vital in arm design. Kinematics involves analyzing the motion of bodies without considering the forces that cause that motion. Designers need to determine how the arm's joints interact to produce the desired motion of the shield. This involves concepts such as forward and inverse kinematics, which help determine joint angles and positions required to achieve a specific end-effector (shield) position.

3.5 Shield Protection and Ergonomics

In addition to stability, arm design should also focus on shield protection and ergonomic considerations. The arms should prevent the shield from being damaged during movement, including minimizing any vibrations or impacts that might occur. Furthermore, the design should consider human interaction, ensuring that the shield is easy to load onto and remove from the arm, and that the overall design is user-friendly.

3.6 Overall Structure

The arm's structure should be durable and lightweight, with attention to improving load distribution and shock resistance.

4 CLAMP DESIGN: Ensuring Secure Shield Retention

In the design process of the robotic arm aimed at carrying a shield, one crucial aspect that demands special attention is the clamp design. Clamps serve as the means by which the shield is securely held in place throughout the arm's movement and operation. The effectiveness of the clamp design directly impacts the overall functionality, safety, and efficiency of the robotic arm in its intended task.

Figure 5. Robot DH Robotics 3 Finger Adaptive Gripper [4]

4.1 Purpose of Clamps

The primary purpose of the clamps is to provide a stable and reliable means of securing the shield to the robotic arm. Given the dynamic nature of the arm's movements and the potential variations in orientation and angles, it's imperative that the shield remains firmly attached at all times. This ensures that the shield doesn't dislodge, fall, or interfere with the arm's movements during its operation, particularly in scenarios where the arm's motion might involve sudden accelerations or decelerations.

4.2 Versatility in Clamp Design

The design of the clamps should take into consideration the diverse range of shields that the robotic arm might need to carry. Shields can come in various shapes, sizes, and dimensions, each potentially requiring a slightly different clamp configuration. As such, the clamp design needs to be versatile enough to accommodate different shield geometries while maintaining a secure grip.

4.3 Ease of Installation and Removal

Apart from ensuring secure retention, the clamps should also be designed for practicality. They should be easy to install and remove, allowing for efficient shield swapping or maintenance. Clamps that are overly complex or time-consuming to operate could lead to operational inefficiencies, potentially slowing down the process of attaching or detaching shields.

4.4 Material Selection and Ergonomics

The choice of materials for the clamps is also significant. They should be durable enough to withstand the mechanical stresses imparted during the arm's movements, as well as any potential external forces the robotic arm might encounter in its operational environment. Moreover, ergonomic considerations play a role; the clamps should be designed in a way that facilitates intuitive and quick manipulation by operators.

4.5 Validation and Testing

To ensure the effectiveness of the clamp design, it's crucial to subject it to thorough validation and testing. Simulations and physical testing can help verify the clamps' ability to hold the shield securely under different conditions. This validation process contributes to the overall reliability and safety of the robotic arm's operation.

5 Material Selection for the Arm

Selecting suitable materials for the arm is a crucial aspect of ensuring its performance, durability, and longevity. The choice of materials should align with the arm's functional requirements and the environmental conditions it will be subjected to. The following subsections elaborate on the various material options available:

5.1 **Aluminum Alloys:** Lightweight and corrosion-resistant**.**

Aluminum alloys are widely recognized for their excellent combination of low density and high strength-to-weight ratio. These materials offer the advantage of reducing the overall weight of the arm without compromising structural integrity. Additionally, aluminum alloys exhibit natural corrosion resistance due to the formation of a protective oxide layer on their surface. This characteristic is particularly beneficial when the arm is exposed to humid or corrosive environments.

5.2 **Steel:** Lightweight and corrosion-resistant**.**

Certain types of steel, such as stainless steel, provide a balance between strength, ductility, and corrosion resistance. Stainless steel variants, like 304 and 316, are commonly used in engineering applications where resistance to corrosion and staining is essential. Stainless steel's robustness and longevity make it suitable for arms that may come into contact with moisture, chemicals, or varying temperatures.

5.3 **Composite materials:** Lightweight and corrosion-resistant**.**

Composite materials, composed of two or more distinct materials combined to harness their advantageous properties, offer an attractive option for arm design. These materials can be tailored to meet specific requirements by selecting appropriate reinforcement materials and matrix resins. Composites exhibit high strength-to-weight ratios, corrosion resistance, and the ability to dampen vibrations, making them suitable for arms subjected to dynamic loads or harsh environments.

5.4 **Titanium Alloys:** High Strength and Corrosion-Resistant**.**

Titanium alloys boast exceptional strength-to-weight ratios, making them suitable for applications where both durability and weight reduction are critical. Their resistance to corrosion, particularly in aggressive environments, makes them suitable for arms used in marine or aerospace applications. However, titanium's high cost may be a consideration in material selection.

5.5 **Plastics and Polymers:** Lightweight and Versatile**.**

Certain plastics and polymers, like nylon and polyethylene, can be employed in arm design due to their lightweight nature and versatility. These materials are characterized by their low friction coefficients, electrical insulation properties, and ease of machining. While not as robust as metals, they can find application in arms that require minimal weight and less demanding environments.

5.6 **Hybrid Materials:** Tailored Properties.

Hybrid materials, created by combining different classes of materials, allow for tailored properties that suit specific arm requirements. For instance, a hybrid composite-metal arm could combine the lightweight advantage of composites with the strength of metals in critical areas.

Ultimately, material selection should be guided by a comprehensive understanding of the arm's intended use, load conditions, environmental factors, and cost considerations. Each material option presents a trade-off between various properties, and the final choice should align with the arm's functional goals and design constraints.

6 BOOKS SOURCES

6.1 Mechanics of Machines for Joint and Connection Calculations

The book “Mechanics of Machines” provides a strong foundation in machine mechanics and aids in better understanding the calculation of joints and connected points in mechanical devices. It assists in analyzing part movements and designing joints with precise engineering methods.

6.2 Example from Page 152 of “Mechanics of Machines” - Degrees of Freedom Calculation:

“When analyzing the robotic arm, the degree of motion freedom must be calculated using the relationship between the number of links and the number of joints. For instance, if a robotic arm is connected by only two joints, the degree of motion freedom will be (number of links × 3) - (number of joints × 2) = (3 × 3) - (2 × 2) = 5.”

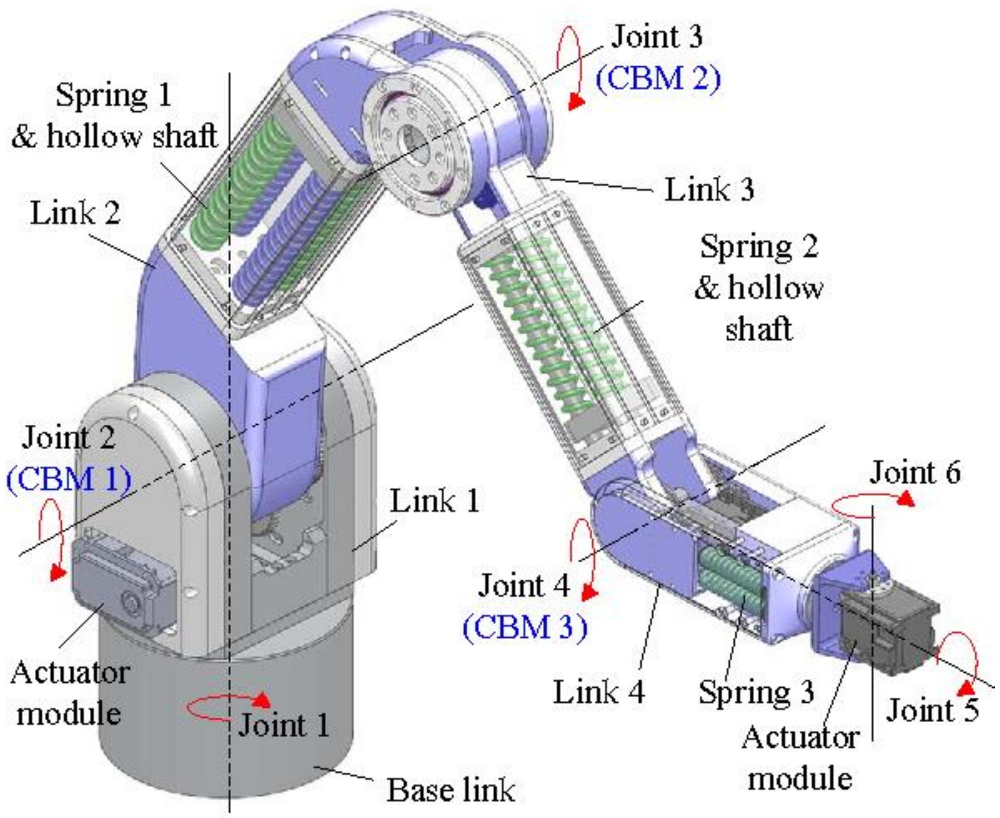

Figure 6. Design of 6-DOF articulate counterbalance robot arm [5]

6.3 Shigley's Mechanical Engineering Design - Optimal Gear and Joint Selection:

“Shigley's Mechanical Engineering Design” is an essential reference for comprehending the design of mechanical parts, aiding in the selection of suitable gears and joints in arm design. It presents computational and practical concepts to ensure effective transmission of desired motions.

6.4 Example from Page 310 of “Shigley's Mechanical Engineering Design” - Gear Selection:

“When designing the robotic arm, appropriate gears should be chosen to achieve the desired motion transmission. For example, if rotational motion needs to change direction, bevel gears can be used with pinions to ensure effective motion transfer.”

6.5 Materials Science and Engineering - Material Testing:

“Materials Science and Engineering” offers advanced insights into the mechanical and structural properties of materials. It can be used to understand suitable tests for selecting materials that align with arm design, such as tensile and bending tests.

6.6 Example from Page 240 of "Materials Science and Engineering" - Tensile Testing:

“The tensile test can be used to determine tensile strength and elongation of materials. For instance, if the materials used in arm design need to withstand high mechanical loads, they should be tested using the tensile test to verify their durability.”

7 CONCLUSION

This research demonstrates that designing a robotic arm for carrying a shield requires a precise engineering approach and the use of three-dimensional design techniques like SolidWorks. Utilizing appropriate joints and selecting the right materials play a crucial role in achieving optimal performance. Reliable sources should be consulted to support information and confirm results.

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