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A Robotic Manipulator's Design and Performance Using in Casting Industry to Manage a Shell Adapter

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Abstract

The original objective of creating a robotic gripper has been revised. A new approach has been suggested and sanctioned for designing a robotic arm. The methodology involves the gradual construction of prototypes for mechanical arms. The optimization process integrated into the methodology guarantees the successful development of the robotic arm. Identifying the hand application serves as the primary step in defining the parameters and prerequisites for the subsequent phase in the design process. The incorporation of human hand research plays an essential role in devising anthropomorphic architectures as it showcases their versatility, flexibility, and manipulation capabilities. The decisive goal of this method is to formulate successful robotic arm architectures and systems that meet the design proposals' requirements.

Keywords

Grippers, Manipulator, Robot Arm, Right Gears, Wrist.

INTRODUCTION

A robotic gripper must be versatile and capable of performing reliable grips and manipulations in unstructured environments, for example. The high cost and excessive layout complexity prevent robotic grippers from penetrating the product. To alleviate these limitations, researchers have proposed a low-power robotic gripper with a tendon drive mechanism (TDM). budget. However, designing a robotic gripper is a very complex method involving many parameterized simulations. Automation systems use robotic grippers as one of their main components. The pick-up module allows the robot to pick up, move, and place objects to pick, transport, and place workpieces. Robotic arms usually have sensors mounted near the workpiece. A wide range of tasks can be performed using automation components such as robotic arms and software. This allows the production of multiple product variants. Conversely, capture modules are often customized for specific tasks and come with tools to aid in customization.

LITERATURE REVIEW

The capability of selecting and grasping microscopic objects with a pneumatically actuated microgripper that can provide tactile feedback was tested by Alogla et al. Their experiment involved testing a device that has a maximum tip opening amplitude of 1 mm, and a maximum force of 50 MN. Additionally, the device was tested to perform pick-and-place operations with 200 μm microspheres [1].

Huixu Dong et al developed a mathematical model to determine the efficiency of transmitting tension force when using geometrical relationships. A Genetic Algorithm is used to optimize gripper and tendon routes [2].

Matteo Russo et al focused the design of a gripper for horticulture product grasping. Design decisions were made using a systematic method using an evaluation of all possible architectures. Prototypes were built and tested in the laboratory [3].

Alaa Hassan et al. proposed methods for modeling robots and optimizing their structures. They provide a comprehensive step-by-step demonstration of their design methodology and conduct dedicated capture studies to describe the interactions between those steps. Their goal is to determine the optimal force developed by a robotic gripper at the bottom of a captured solid object under geometric and functional constraints [4].

Bos et al. developed a lightweight suction grip. In the microcosm, assembly issues related to forces were mentioned. A gripper design with a delivery mass of less than 1 g is proposed for needles with a diameter of 6 mm with a delivery mass of less than 1 g [5].

Anurag Singh et al analyzed and investigated the stresses and strains caused by selected payloads. A mechanism arm with 5 degrees of freedom was selected for stress and strain analysis [6].

The remaining sections of the paper are arranged as follows: Chapter 2 covers recommended models and optimal approaches for robot designing. Section 3 outlines the experimental design for the robotic gripper and includes a review of the geometric modeling. Following the description and modeling of the gripper and corresponding design calculations, Section 4 explores the results. Lastly, Section 5 provides a summary of the findings presented in this article.

METHODS

According to Figure 1, the product design process consists of five sequential steps

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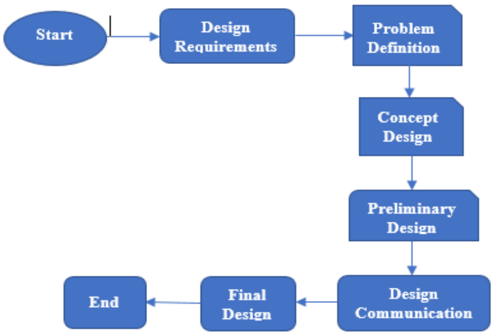

Figure 1. Design Process of a Product

The product design process is made up of five sequential steps, as shown in Figure 1. The first step involves identifying design problems and clarifying the design's purpose. This leads to the definition of requirements. During the concept draft stage, specifications and design preferences are established, and alternatives are modeled, analyzed, and evaluated. These options can be exported at a later stage. The element design stage focuses on defining design details to create manufacturing specifications for an optimized design. Finally, design implications follow a detailed description of the final design and its characteristics.

DESIGN OF EXPERIMENTS

The accurate handling of the shell adapter depends on the design of the robotic manipulator. The manipulator has multiple components, including the arm, end effector, and control system. The arm helps with the necessary movement and positioning needed to handle the shell adapter, while the end effector holds onto and releases the adapter. The robot's gripper is made up of four main parts: wrist, base, nails or fingers, and Earth, and has two degrees of freedom. This component connects the robot's gripper and arm.

Wrist

The wrist enables twisting of the handle and has three components - two connected parts and one that connects to the rotation axis of the servo motor. Other details aid in transmitting movement across the wrist, which is connected to the handle base and floor. Figure 2 displays the wrist assembly with an additional connector for the base and hook at a 90° angle to the horizontal axis. It has three holes for connection, an outward step for gear insertion, and three more holes for other parts. Precise calculation of element spacing is crucial for the mechanism to function correctly.

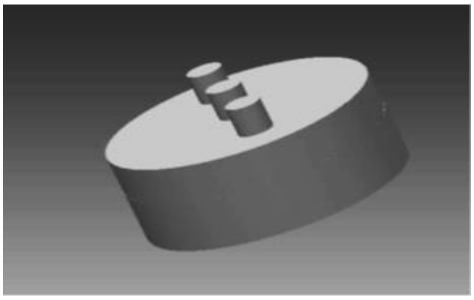

Figure 2. Assembly of Wrist

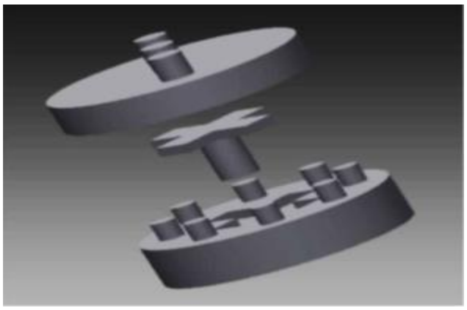

Figure 3. Exploded view of the Wrist.

We will also use another connector that will be part of the base and hook whenever we hold the hook at a 90º angle to the horizontal axis. In the image, we can see three holes to connect the wrist, an outgoing step to insert the gears, and three other holes that have the function of connecting other parts. This is the hardest part because all the parts are connected. The distances of these elements must be accurately calculated to obtain accurate operation of the entire mechanism. Several important aspects must be considered when designing this element.

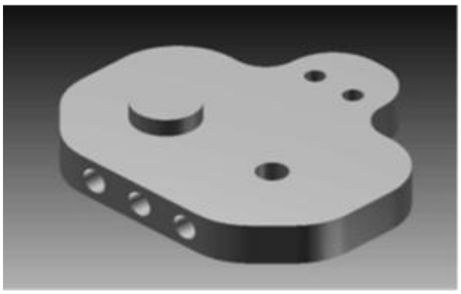

Figure 4. Base

The base links the robot handle parts and has two gears attached, with one connected to another servo motor via a linkage to provide gear movement and handle motion.

Grippers or Fingers

The handle, which can come in various shapes and materials, is capable of holding items with differing contours and weights. It should be noted that there will be a movement of translation. The gripper serves as the final component, and the function of each part (including the servo motor, clutch, and gear) culminates in its action. The design of the handle allows for a secure grip on even the thinnest objects, and holes found in planes are utilized to connect the gears and handles.

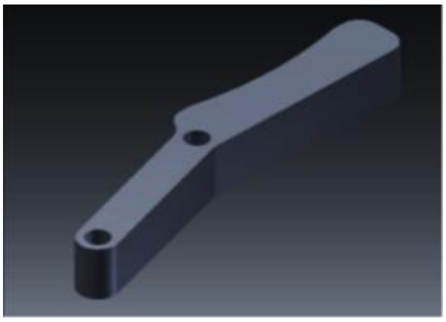

Figure 5. Gripper

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Earth

The earth is responsible for holding the servo motor that moves the wrist, making it a crucial component. If this part malfunctions, the grip's behavior will become unstable. Additionally, this part attaches the entire robot handle to an already existing robot arm.

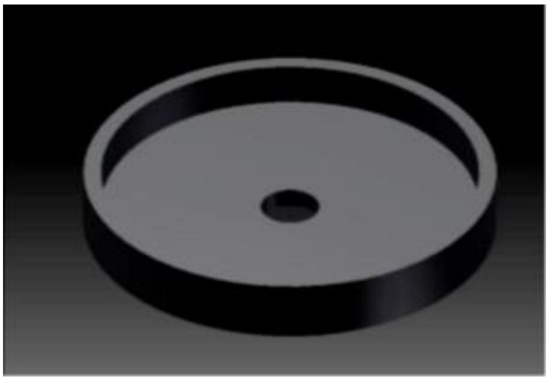

Figure 6. Earth

Calculation of Force on Gripper

This section will compute the gripper's force. The robot's gripping moment will produce forces, resulting in three claw positions: minimum nail opening, middle nail opening, and maximum opening. First, the torque-generated force must be calculated. This force should be perpendicular to the radius of gyration and denoted as F. The torque formula is also necessary.

Least Aperture

First, we need to calculate the force produced by the torque. This force must be perpendicular to the turning radius and this force is called F. The torque formula is:

$$T = F \cdot r \quad (1)$$

Having obtained the servo motor information, we can determine that the torque is equal to 0.078Nm or 78Nmm. The distance between each point can be measured, as well as the radial distance r, which is equal to 51.72 mm. By utilizing the formula F = T/r, we can calculate the force, which is equal to 1.5075 N. However, since this force is not directly applied to the handle, we need to calculate the F1 component using the following formula after measuring the angle α using the Autodesk program inventor:

$F1 = F * \cos(\alpha)$.

$F1 = F \cos(\alpha)$ where α is 69.78° and

$F1 = 1.5075 \cos(69.78) = 0.521$ N

Now we need to solve a system containing two equations and two unknowns. The first equation is After obtaining information about the servo motor, we can deduce that the torque equals 0.078Nm or 78Nmm.

We can measure the distance between each point and the radial distance r, which is 51.72 mm. Using the formula F = T/r, we can determine that the force is 1.5075 N.

However, this force isn't directly applied to the handle, so we must calculate the F1 component using the following formula:

$F_1 = F * \cos(\alpha)$.

After measuring the angle α using the Autodesk program Inventor, where α is 69.78° and

$$F_1 = F * \cos(\alpha) \quad (2)$$

we can calculate that F_1 equals 0.521 N. We need to solve a system containing two equations and two unknowns. The first equation is

$\Sigma F_x = 0$

$$- F_1 \cdot \cos(\alpha + \beta) - F_2 \cdot \cos(\varphi) + F_{gripper} = 0 \quad (3)$$

Where β = 3.64° and φ = 86.36°, so:

$F_{gripper} = 0.521 \cdot \cos(73.42) + F_2 \cdot \cos(86.36)$

The second equation is:

$\Sigma F_y = 0 \; F_1 \cdot \sin(\alpha + \beta) - F_2 \sin(\varphi) = 0$

$F_2 = F_1 \sin(\alpha + \beta) / \sin(\varphi) = 0.5003$ N

$F_{gripper} = 0.1804$ N

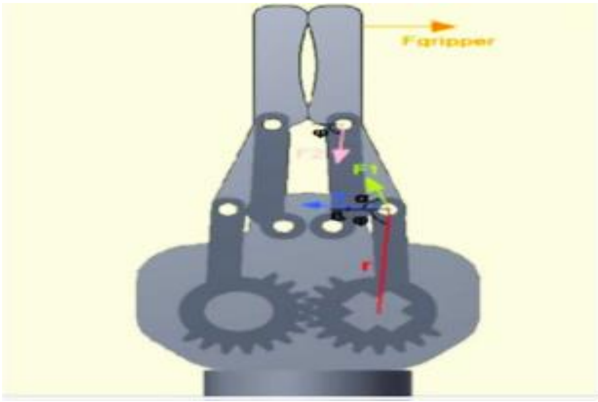

Figure 7. Least Aperture

Standard Aperture

Perform the identical task, yet execute it in the manner illustrated in Figure 8. The force's orientation is inverted, and as such, the angle and force quantities differ. Nonetheless, the force factor F persists as constant and solely hinges on the torque's magnitude and the radius of the gyration's value.

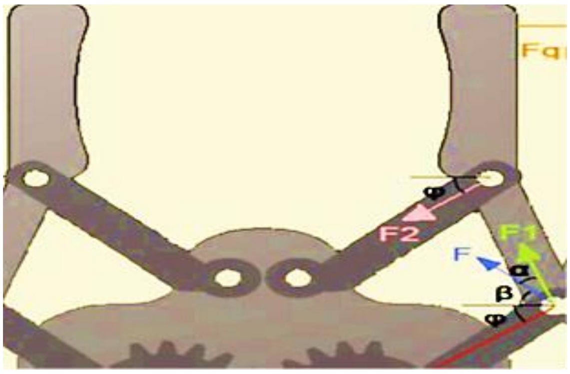

Figure 8. Standard Aperture

$F_1 = 1.3901$ N

In this case, β = 50.55° and φ = 39.45°,

$F_{gripper} = 1.3901 \cdot \cos(73.31) + F_2 \cdot \cos(39.45)$

$= 2.0174$ N

$F_2 = 2.0956$ N

Extreme Aperture

Figure 9 displays the extreme aperture, where β is 73.28°, φ is 16.72°, and the gripping force is 5.2399 N. The gripper's

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force augments with larger nail openings. In the casting industry, the robotic manipulator's efficiency is critical for managing the shell adapter. Accuracy, precision, and speed are used to evaluate the manipulator's effectiveness. The new gripper design features improved grips, additional rivets, and a round handle for easy 3D printing. The small distance between the handles makes it an optimal design. The gripper assembly is both visually appealing and efficient in performance.

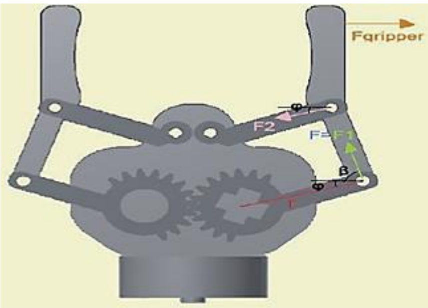

Figure 9. Extreme Aperture

$F_{gripper} = 1.5075 \cos(73.28)\, F_2 \cos(16.72)$
$= 5.2399$ N
$F_2 = 5.018$N

The size of the nail opening correlates with the amount of force needed from the gripper.

RESULT & DICUSSION

The performance of the robotic manipulator in the casting industry is critical in ensuring that the shell adapter is managed effectively. The robotic manipulator is programmed to perform specific tasks, including gripping and releasing the shell adapter, rotating the shell adapter, and moving the shell adapter to the desired location. The manipulator's performance is measured based on its accuracy, precision, and speed. In developing the product, we experimented with different designs and finally found the most effective grip.

The grip has been enhanced to reduce the minimum distance between the components and fasten them together with rivets. Additionally, the clips have been rounded for simpler 3D printing. This design is optimal due to the minimal distance between the handles. We evaluated various models and determined this to be the most suitable. It should be noted that studs are exclusively utilized for modeling, while rods are employed when producing a clip.

First Design of the Gripper

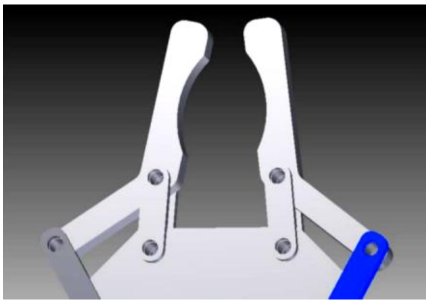

Figure 10. The first design of the Gripper

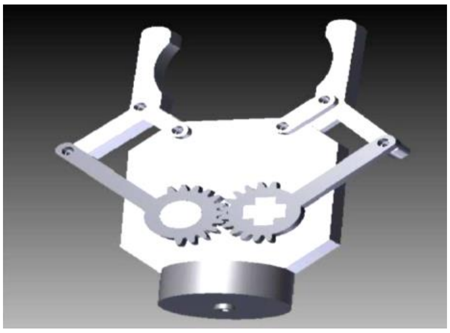

Figure 11. Appreciate the Rotation's Problem.

Figure 11 depicts rotational issues that need identification. The design was abandoned because of excessive material usage. The gripping action was slightly modified. The image displays the misalignment of the steering wheel, which is the result of the gear's turning radius rotation caused by the different turning radii of the base and crank. This required adding a single connector with the same radius as the gear to modify the multinational robotic arm.

Second Design of the Gripper

Figure 12. Second Design of the Gripper

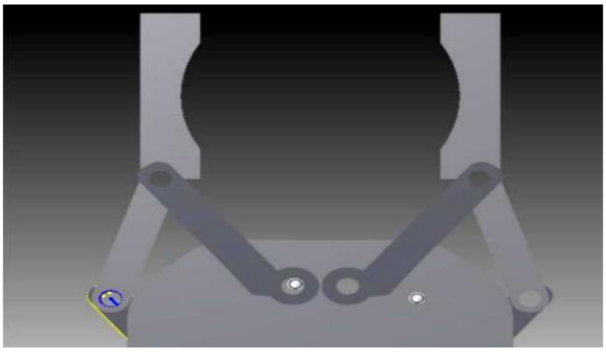

Figure 13. Width of the Base

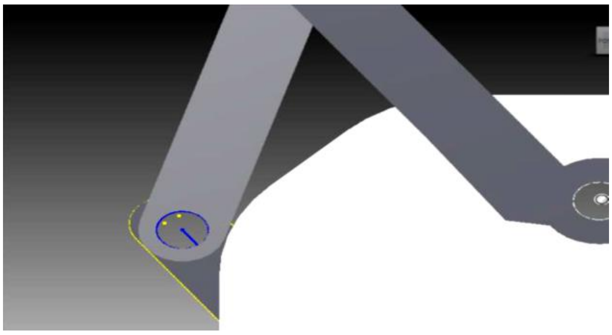

Figure 14. Collisions of the Gripper and Base

The collision between the claw and the base was resolved, and the team proceeded to enhance the efficiency of the robotic gripper whilst minimizing material usage. Nevertheless, the broad top of the base causes the handle to strike prematurely, resulting in a significant minimum opening of the robot. The poor quality of the recording is attributed to the gadget's ability to only detect very large objects.

Third Design of the Gripper

Figure 15. Third Design of the Gripper.

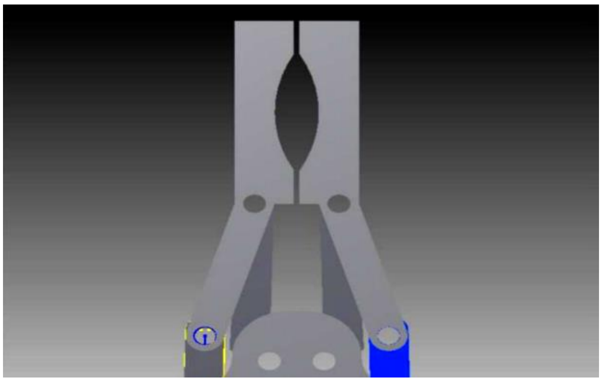

Figure 16. Minimum Aperture of the Gripper

Collisions between the claw and base took place. After resolving the rotation problem, the robotic gripper was redesigned to improve efficiency and reduce material consumption. However, the broad upper part of the base caused early contact with the handle, resulting in a considerable minimum opening of the robot. The recording quality is not optimal because only large objects can be detected.

Final Design of the Gripper

Figure 17. Final Design of the Gripper.

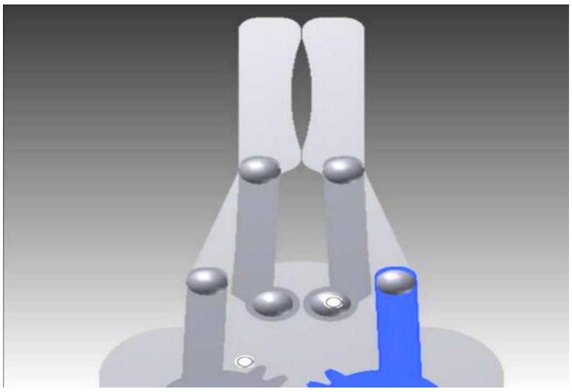

Figure 18. Minimum Aperture of the Final Design of the Gripper

The design of the final gripper features a minimum opening, which is illustrated in Figure 18. The grips have been enhanced to reduce the gap between them and rivets have been incorporated to connect all the pieces together. Moreover, the round handle is conducive to 3D printing. This design is highly optimal as it minimizes the distance between the handles. We conducted a comprehensive evaluation of multiple designs and eventually selected the best one. Please note that the rivets are solely employed for modeling purposes and the rod should be utilized when creating the handle.

The Gripper's Assembly

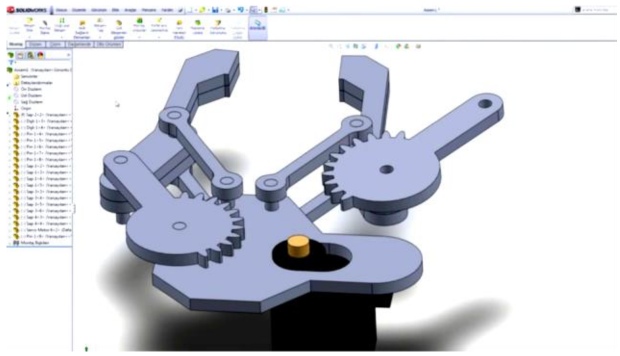

Figure 19. Gripper's Assembly

The gripper assembly, which includes all the previously mentioned parts, is shown in Figure 19. The overall appearance of the assembly is both pleasing and acceptable.

CONCLUSION

The task of creating a robotic gripper has been altered and a fresh approach for designing a robotic arm has been sanctioned. The process involves the production of various prototypes of the mechanical arm in a constant way. To make sure that the methodology is successful, the optimization cycle is carried out. The first step is to determine the intended hand application which sets the parameters and requirements for the consequent design phase. Research on the human hand is crucial to develop anthropomorphic architectures that have adaptability, flexibility, and manipulation abilities. The primary objective of this methodology is to manufacture robotic arm systems that fulfill the design proposal

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requirements. The use of robotic manipulators in the casting industry to supervise shell adapters has revolutionized the casting process. The design and performance of the manipulators ensure that the shell adapter is handled with precision and accuracy, thereby resulting in a better-quality end product. The advantages of using robotic manipulators in the casting industry are countless as they improve the speed, efficiency, and safety of the casting process. With technology continuously advancing, we can look forward to observing more innovations in the casting industry that will further upgrade the process.

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