



Design and Fabrication of Pneumatic Robotic Arm

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Abstract This project focuses on building a robotic arm that uses air-powered (pneumatic) cylinders to move, similar to how a human arm works. It can lift, rotate, and place objects with several different types of movement. Pneumatic actuators were chosen because they're simple, affordable, and powerful for their size. The arm is controlled by solenoid valves and a microcontroller, which allow for quick and adjustable movements. One of the key benefits of using air-powered systems is that they work cleanly and respond quickly, making them ideal for automation. However, there are some challenges, such as the complexity of controlling air pressure and the need for a constant supply of compressed air. This kind of robotic arm is useful in areas like factory automation, material handling, and educational demonstrations. Overall, the project shows that pneumatic robotic arms can be a good alternative to electric ones, especially for fast and repetitive tasks that don't require extreme precision.

I. INTRODUCTION

Robotic arms have changed the way many industries work by taking over tasks that are repetitive, dangerous, or need to be done very precisely. Most robotic arms use electric motors or hydraulic systems, but there's another option—pneumatic actuators, which are powered by compressed air. They're lighter, cheaper, and safer to use around people. This project looks at how to build a robotic arm that uses these air-powered systems, aiming to combine the advantages of pneumatics with the flexibility and usefulness of robotic arms.

While pneumatic actuators have benefits like being safe and affordable, using them in robotic arms also comes with some challenges:

- **Limited accuracy:** It's hard to control their movements very precisely because air pressure can behave unpredictably.
- **Needs constant air:** They rely on a steady supply of compressed air, which can make the system less portable or harder to use in places without built-in air systems.
- **Tricky to set up:** Getting pneumatic parts to work smoothly with electronics and control systems takes careful planning and design.

II. OBJECTIVES

- **Design:** Build a robotic arm structure that can use pneumatic actuators and move in several directions (degrees of freedom), similar to a human arm.
- **Control System:** Create a control setup that can operate the pneumatic cylinders to perform smooth and accurate movements.
- **Testing:** Test how well the robotic arm performs by measuring its speed, accuracy, and ability to lift or move objects

III. ECONOMIC OBJECTIVES

- **Cost-Effectiveness:** Use budget-friendly materials and parts to keep the overall cost of building the robotic arm as low as possible.
- **Easy Maintenance:** Design the system so it's simple to maintain and repair, helping to save money on long-term upkeep.

IV. ENVIRONMENTAL OBJECTIVES

- **Energy Efficiency:** Design the pneumatic system to use as little energy as possible while still performing effectively.
- **Sustainable Materials:** Choose recyclable and eco-friendly materials for building the robotic arm to reduce environmental impact.

V. SCOPE

This project involves building a robotic arm with **three degrees of freedom (3-DOF)**, powered by **pneumatic actuators**. The main focus areas include:

- **Design and Fabrication:** Building the arm's structure and installing pneumatic actuators.
- **Control System Development:** Creating a control setup using solenoid valves and microcontrollers to manage the arm's movements.
- **Testing and Evaluation:** Testing how well the arm performs in tasks like lifting, moving, and positioning objects.

VI. METHODOLOGY

Design Phase

- **Mechanical Design:** Use CAD (Computer-Aided Design) software to create a detailed model of the robotic arm, making sure it fits well with pneumatic actuators.
- **Component Selection:** Select the right pneumatic cylinders, solenoid valves, and sensors based on the required movement range, speed, and load capacity.

Development Phase

- **Fabrication:** Build the robotic arm using the chosen materials and pneumatic components.
- **Control System Implementation:** Program and integrate microcontrollers to operate the pneumatic cylinders effectively.
- **Literature Review:** Study existing research and similar projects to guide system design and improve performance.

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Testing Phase

- **Performance Evaluation:** Test the robotic arm on tasks like pick-and-place operations to assess its functionality.
- **Data Collection:** Measure and record key metrics such as speed, accuracy, and how much weight the arm can handle.

VII. LITERATURE REVIEW

Research shows that pneumatic actuators, like **McKibben muscles**, are commonly used in **soft robotics** because they are lightweight and flexible. These actuators have been proven effective in a wide range of applications, from **industrial automation** to **assistive devices** for people with disabilities. However, there are still challenges, particularly when it comes to **precisely controlling** these actuators and **integrating** them smoothly into robotic systems. The complexity of their behavior makes achieving accurate movement and coordination difficult.

VIII. OPERATION

- Air Supply:** A **compressor** generates compressed air, which is then regulated by an **FRL unit** (Filter, Regulator, Lubricator) to ensure proper air pressure and flow. An air compressor is a machine that takes energy from a motor (like electric, diesel, or gas) and uses it to squeeze air into a tank. This packed air can then be used to power tools, inflate tires, or do other jobs when you let it out.
- Solenoid Valve Control:** **Solenoid valves** (either manual or solenoid-controlled) direct the airflow to the pneumatic cylinders, controlling the movement of the arm. A solenoid valve is a kind of switch for liquids or gases. It opens or closes automatically when you turn electricity on or off, using a small magnet inside to move a part that controls the flow.
- Cylinder Activation:** When air flows into one side of a **double-acting cylinder**, the **piston extends**. Reversing the valve sends air to the other side, causing the piston to **retract**. A single acting cylinder is a device that uses air or fluid to push something in one direction, and then a spring or outside force pulls it back to where it started.



- Motion Transfer:** The piston's **linear motion** is transferred to the robotic arm's segments through **mechanical linkages or levers**, which then make the joints **rotate or slide**. A motion transfer linkage is a set of connected parts that help move something from one place to another in a machine. It lets one part of the machine move another part — like turning, pushing, or pulling — and can also change the direction or type of movement.



- Gripper Actuation:** A pneumatic cylinder or **air muscle** is used to **open and close the gripper for pick-and-place operations**. A **gripper** in a robotic arm is like the "hand" of the robot. It's the part that grabs, holds, and moves objects. Just like how your hand picks up things, a gripper can be used to pick up items and move them around. It can have different designs, like two or three fingers, or even suction cups, depending on what the robot needs to pick up.



- Control:** Manual valves allow human operation. For automated control, **microcontrollers** like Arduino send signals to **solenoid valves**, which control air flow based on programmed logic. The controller sends a signal to the solenoid valve to open, letting air into a part of the robot arm, which makes it stretch out.

Once the arm grabs the box, the controller sends another signal to close the valve, stopping the air, so the arm can hold the box.

When the arm needs to move or let go of the box, the controller sends a signal again to adjust the air, and the arm moves as needed.



IX. CONCLUSION

The fabrication of a robotic arm using pneumatic power demonstrates the effectiveness of compressed air in automation and robotic applications. The designed system efficiently converts pneumatic energy into mechanical motion through the use of actuated cylinders and valves. This approach offers advantages such as fast response times, simple control, and cost-effectiveness. The robotic arm can perform basic operations such as pick-and-place tasks and repetitive motion sequences, making it suitable for educational, industrial, and prototype automation systems. Furthermore, the modular and scalable design allows for future improvements, including the integration of sensors, programmable logic controllers (PLCs), or microcontrollers for enhanced automation and feedback control.

X. REFERENCES

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