

Design, Fabrication And Analysis Of Robotic Arm

Sayali Gosavi ^{*1}, Suhani Khobragade ^{*2}, Devdutt Bhoir ^{*3}, Aditya Diwale ^{*4}, Surendra Rathod ^{*5}

^{*1,2,3,4}Students, Datta Meghe college of engineering, Airoli, Maharashtra India.

^{*5}Professor, Datta Meghe College of Engineering, Airoli Maharashtra India.

ABSTRACT

This project focuses on replacing the plastic body of a robotic arm with aluminium in a simple and efficient way. The model is facing a common issue encountered is the slipping of the robotic arm or its end effector during gripping or manipulating objects. This can lead to loss of control, decrease accuracy, and potential damage to both the object and robotic system. By analysing this issue, we conclude that to improve grips stability and control during various manipulation tasks. For this reason, we have to change Robotic arm's plastic body into an aluminium body to improve strength. By using lightweight aluminium and maintaining the original dimensions, the new body can be easily integrated with existing parts like motors and sensors. The process involved taking the original dimensions of all parts of the robotic arm. After taking dimensions, we designed 2D Drawing on AUTOCAD for ensuring smooth transition. After upgrading, the arm performs better, lasts longer, and can handle heavier tasks, making it ideal for both industrial and research applications.

The robotic arm consists of five degrees of freedom, powered by MG995 high-speed servo motors known for their torque and precision. The control system is built using a motor driver circuit, and powered through an SMPS (Switched Mode Power Supply) that converts 230-240V AC to 12V DC.

INTRODUCTION:

Robotic arms play a vital role in industries such as manufacturing, healthcare, and automation, where precision, durability, and strength are essential. Many entry-level and educational robotic arms are constructed using plastic due to its low cost and ease of manufacturing. However, plastic components often lack the strength and durability required for demanding applications, leading to deformation, reduced lifespan, and operational limitations. Replacing the plastic body with aluminium can significantly improve the structural integrity and load capacity of a robotic arm. Aluminium is lightweight, strong, corrosion-resistant, and easily machinable, making it an ideal alternative.

However, the challenge lies in transitioning from plastic to aluminium without redesigning the entire system or making complex modifications. With the integration of sensors, actuators, and control systems, aluminium robotic arms can be programmed to perform complex tasks autonomously or under human guidance. These robotic arms are a vital component in the evolution of smart manufacturing .

This project focuses on the design and fabrication of a 5-axis robotic arm controlled via software. The goal is to create an efficient and cost-effective robotic system that can pick and place objects, demonstrating the principles of motion control, servo actuation, wireless communication, and

embedded programming.

The robotic arm uses five MG995 high-speed servo motors, each responsible for controlling an individual joint or movement axis. These servos provide sufficient torque and speed for effective operation

1.1 **AIM:**

To design and fabricate a wirelessly controlled robotic arm on software , capable of performing pick-and-place operations using servo motors and replacing the body to withstand the weight of the arm.

1.2 **Objective:**

- To design a 5-degree-of-freedom robotic arm using MG995 servo motors.
- To fabricate a lightweight, functional frame for robotic motion.
- To integrate wireless communication through a software.
- To ensure stable and safe power supply using a 230V AC to 12V DC SMPS.
- To develop a user-friendly control system for real-time operations.
- To analyze the motion, torque, and structural behavior for functional efficiency

2. Problem Statement:

The problem is to design and fabricate a low-cost, versatile, and functional robotic arm using a lightweight material to carry out basic pick-and-place operations. The arm should be capable of performing precise movements and controlling a simple gripper, all while remaining cost-effective and easy to control.

The basic problem:

Previous model (made in 2016) 2025 inspection and analysis:

By visually inspection we got to know that the problem is in the plastic body of the robotic arm. The plastic body can't withstand the weight of the whole model was the final analysis by us. Plastic Spline flange wearing out and sleeping was the main problem; it could not withstand the weight of the elbow arm.

SOLUTION:

The solution is that we have installed an Aluminum plate in place of a plastic body for stability and better performance. All the motors can't work at the same time on one chip we conclude that one motor will work at one time. For increasing the strength of the arm we replace some components of the plastic body with aluminum.

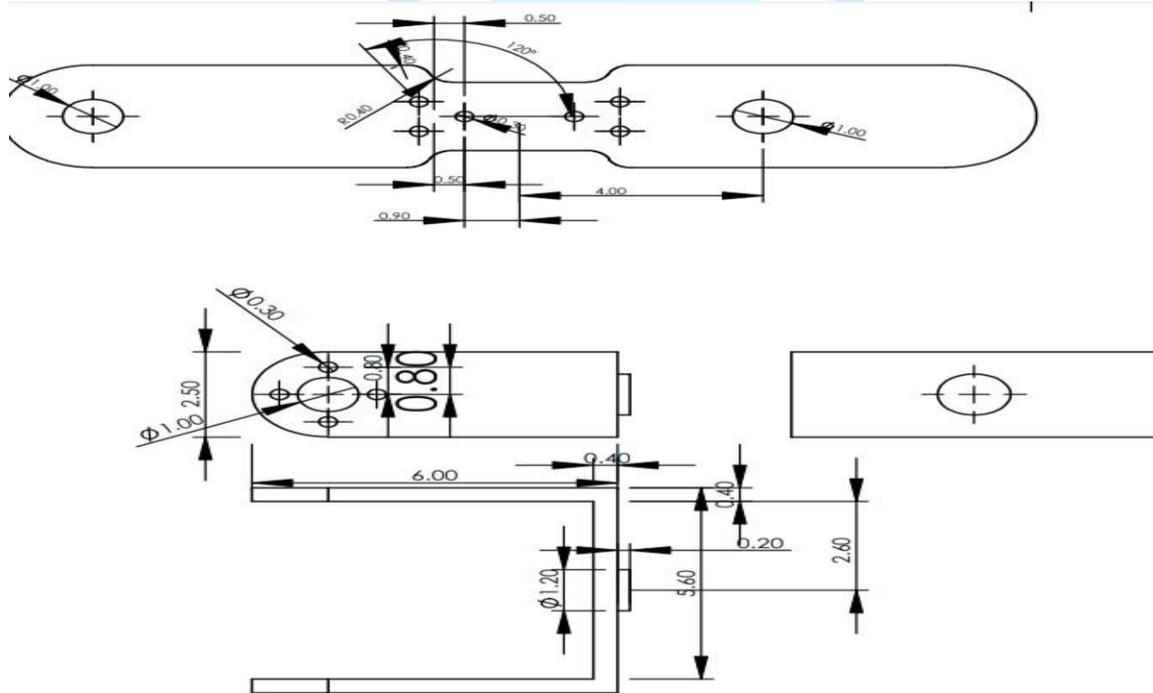
2.1 Concept Development:

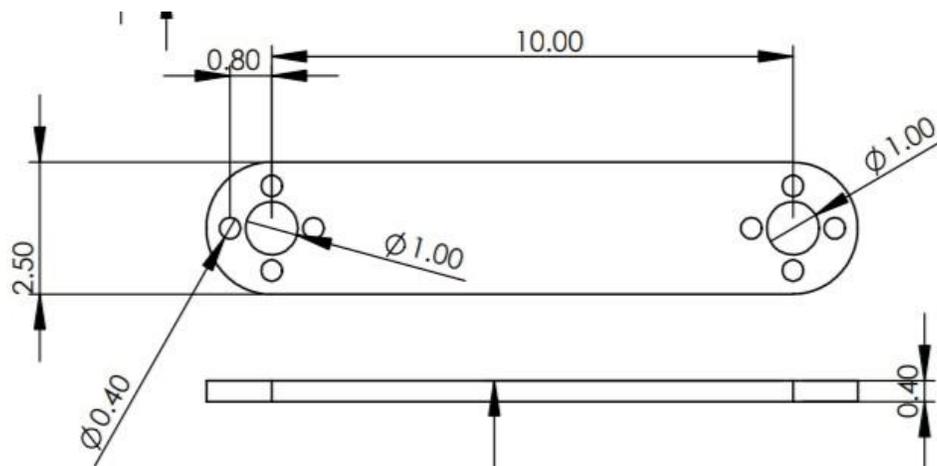
The concept was to design a 5-DOF robotic arm using servo motors, which mimic human arm movements and are easy to control via an ATmega328P Microcontroller and software . The mechanical structure should be light, sturdy, and easy to fabricate using commonly available materials.

3. DESIGN METHODOLOGY:

3.1 CAD Modelling:

Software used: AUTOCAD Design constraints: Size, weight, joint limits





3.2 Fabrication of the Aluminium Body

Material Selection:

- Aluminium is chosen due to its lightweight properties, which help in reducing the overall weight of the robotic arm, making it more efficient in movement. Additionally, it has good strength, durability, and is resistant to corrosion, making it ideal for the arm's structure.
- Aluminium's ease of machining also ensures that precise and accurate cuts can be made to fit the required dimensions.

Fabrication Process:

Cutting the Aluminium Plates:

- **Tools Required:** Bandsaw, CNC Machine, or Laser Cutter.
- **Process:** First, the aluminum sheets are cut into rectangular or custom-shaped pieces using a bandsaw or CNC machine. The dimensions depend on the specific design of the robotic arm's sections (e.g., forearm, upper arm, and joints).
- **Objective:** The cuts should be smooth and precise to avoid the need for excessive post-cutting finishing.
- **Drilling Holes:**
- **Tools Required:** Drill press or CNC drill.
- **Process:** After cutting the aluminium plates, holes are drilled at specified points for mounting the motors, joints, and other components. The holes should be accurately positioned to ensure the proper alignment of components.
- **Objective:** Ensure the holes are clean and uniform in diameter for proper screw insertion.
- **Milling and Shaping:**
- **Tools Required:** Milling machine, CNC router.
- **Process:** Some sections of the aluminium parts may require milling to create grooves, slots, or other custom shapes for fitting other components such as the servos and mounting brackets.
- **Objective:** Achieve a smooth, flat surface and remove excess material for perfect fitting.
- **Deburring and Polishing:**
- **Tools Required:** Hand files, deburring tool.
- **Process:** Once the pieces are cut and drilled, the edges are smoothed using hand files or deburring tools to remove any sharp edges.

- Objective: Ensure smooth edges for safe handling and to avoid cutting hands while assembling.
- Assembly:
 - Process: The aluminium body parts are connected using screws, bolts, or rivets. Motors, sensors, and joints are mounted using appropriate brackets and supports.
- Objective: Ensure all parts are securely fixed and aligned correctly.



Fig 1: OLD MODEL



fig.2 Aluminium parts

3.4 Key Points:

- Cutting Force: Even for 1 mm aluminium, a robotic mechanism must apply 20–50 N of shear force depending on the length of the cut.

3.6 EXPERIMENTATION

Part	Material	Weight (Est.)	Role
Servo Motors	Plastic/metal gear	~50g each	Joint actuation
Arm Segments	3D printed plastic	~100–200g	Movement & reach
Base Platform	Metal/Plastic	~500–1000g	Stabilizes the arm
Control Board	PCB	~50–100g	Controls signals to servos

4. Design and Calculation:

The design of a robotic arm involves careful selection of each component to ensure the system functions efficiently, remains cost-effective, and fulfills the required degrees of freedom for pick-and-place tasks. In this project, the robotic arm is wirelessly operated, uses servo motors for motion control, and is powered through an SMPS. Below is a detailed explanation of the design logic, component selection, and relevant calculations.

1. MG995 Servo Motors (5 Nos)

Purpose: To provide rotary motion to each joint of the robotic arm including base rotation, shoulder, elbow, wrist, and gripper.

Selection Justification:

- Torque: 9.4 kg·cm at 6V, sufficient to lift light-to-medium weight objects.
- Rotation: Up to 180°, ideal for pick-and-place tasks.
- Speed: ~0.2 sec/60° rotation provides responsive motion.
- Cost-Effective: Available at low price with good durability for prototyping.

Torque Calculation Example:

Let's assume the gripper needs to lift a 300g object at a distance of 10 cm from the axis of rotation:

Torque

required=Force×Distance=(0.3 kg×9.81 m/s²)×0.10 m=0.2943 Nm=2.997 kg·cm

$\text{Torque required} = \text{Force} \times \text{Distance} = (0.3 \text{ kg} \times 9.81 \text{ m/s}^2) \times 0.10 \text{ m} = 0.2943 \text{ Nm} = 2.997 \text{ kg} \cdot \text{cm}$

Since MG995 provides ~9.4 kg·cm, it is sufficient to lift up to ~900g at the same distance. Thus, it meets the application needs with a safety margin.

2. Motor Driver / Servo Shield

Purpose: Provides stable PWM control signals to the servo motors. Selection Justification:

- Compatible with Arduino.
- Allows current handling per motor.
- Prevents overloading the Arduino board directly.

3. SMPS (Switched Mode Power Supply)

Purpose: Converts AC mains (230–240V) to DC (12V) to power the servo motors.

Selection Justification:

- Stable output voltage, ensuring motor protection.
- High efficiency, low heat loss.
- Rated for at least 5A output current, enough to run all five servos simultaneously.

Power Requirement Calculation:

Each MG995 draws up to 2.5A on stall. Assuming only 2 motors run under full load at once (worst-case scenario):

Total Current=2×2.5A+3×1A=8.5A(peak) Recommended SMPS Rating=12V,10A

$\text{Total Current} = 2 \times 2.5A + 3 \times 1A = 8.5A \text{ (peak)}$

$\text{Recommended SMPS Rating} = 12V, 10A$

4. Robotic Arm Structure (Material: Aluminium)

Purpose: Physical frame that holds the servo motors and acts as the mechanical skeleton.

Selection Justification:

- Lightweight reduces load on motors.
- Easy to machine and cut.
- Aluminium is cost-effective; Aluminium provides strength for

heavy-duty use.

5. Gripper (Servo-Actuated Claw)

Purpose: To grab and release objects during pick-and-place operation. Selection Justification:

- Simple parallel-jaw gripper powered by 1 servo.
- Capable of handling various shaped objects.
- Offers sufficient grip strength using friction pads or rubber lining.

6. Base Plate (Wooden / Aluminium)

Purpose: Provides stable mounting for the robotic arm. Selection Justification:

- Stability is critical to prevent tipping.
- Wood is cheap and effective; Aluminium for long-term durability.

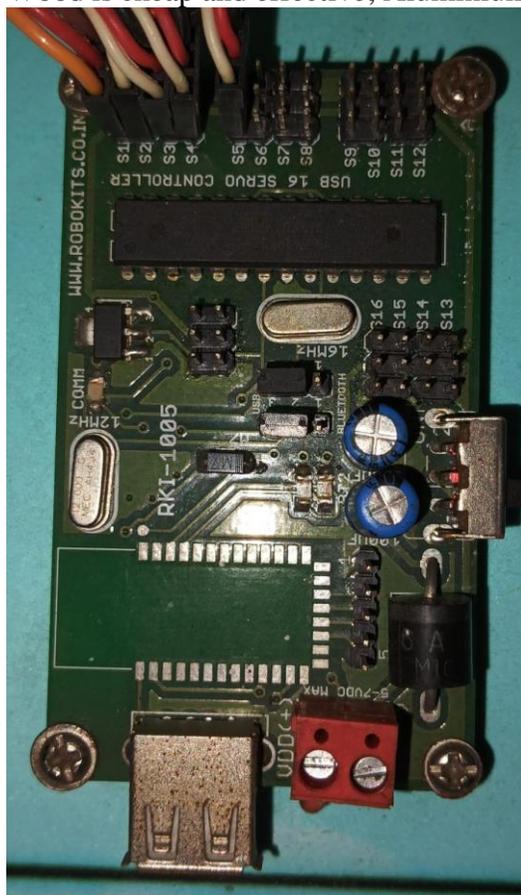


fig. 3 ATmega328P Microcontroller

4.1 Fabrication of the Aluminium Body

Degrees of Freedom (DOF):

- Base Rotation
 - Shoulder Lift
 - Elbow Movement
 - Wrist Rotation
 - Gripper Control
- 5 DOF are sufficient for basic 3D space pick-and-place tasks.

4.2 Weight and Load Considerations

Each joint is designed to bear the weight of the following segments + load. MG995 motors are selected with proper torque margins for safety.

4.3 Summary Table of Component Selection

Component	Quantity	Reason for Selection
MG995 Servo Motor	5	High torque, affordability, ease of control
Servo Motor Driver	1	Provides controlled power to servos
SMPS 12V, 10A	1	Safe, efficient power source
Aluminium Frame	-	Lightweight and durable support
Gripper (servo-controlled)	1	Enables object gripping and releasing
Base Plate (wood/aluminium)	1	Stable support structure for the arm

9. Bill of Materials (BOM) and Cost Estimation for Robotic Arm for Pick and Place Application

In this section, we will outline the Bill of Materials (BOM) for the design and fabrication of the robotic arm and provide an estimation of the cost associated with each component. The total cost is calculated based on the average prices of materials in the local market. The prices provided below are indicative and may vary based on location, availability, and suppliers.

10.1 Bill of Materials (BOM)

S.No	Component	Quantity	Unit Price (₹)	Total Cost (₹)	Description
1	MG995 High-Speed Servo Motor	5	500	2500	Used for controlling the movement of the robotic arm's joints.
2	Motor Driver (L298N)	1	200	200	Used for controlling the direction and speed of the motors.
3	SMPs Power Supply (230V-12V)	1	800	800	Converts 230V AC to 12V DC to power the motors and Arduino.
4	Jumper Wires	1 set	100	100	Wires used for connecting the components (Arduino, motor driver, etc.).
5	Chassis Frame (Metal or Plastic)	1	600	600	The frame that holds the motors, Arduino, and other components.
6	Plywood or Sheet Material	1	400	400	Used for crafting the arm structure and base.
7	Bearings and Support Frames	4	50	200	Bearings for smooth rotation and support frames to mount the motors.
8	Power Cables	1 set	100	100	Cables to supply power to motors and Arduino.
9	Mobile App for Wireless Control	1	0	0	Free app (or minimal cost) used for controlling the arm wirelessly via Bluetooth.

10	Miscellaneous Items (Screws, Nuts, Bolts, etc.)	1 set	100	100	Fasteners and other small parts required for assembly.
11	IR Sensors (Obstacle Detection)	2	200	400	IR sensors used to detect obstacles for the pick and place task.

12	Gripper or End-Effector	1	500	500	The gripping mechanism used for picking up and placing objects.
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