Automated Precision Trimming System for Excess Plastic Removal

Ashwin Sivakumar P[1, a)], Akash Manirathinam C[1, a)], Akilandeswari S[1, a)], Sureshkumar M. S[2, b)],
[1]Department of Robotics and Automation Engineering, Sri Ramakrishna Engineering College, Coimbatore, India
[2]Associate Professor, Department of Robotics and Automation Engineering, Sri Ramakrishna Engineering College, Coimbatore, India

Abstract— In this project, an ESP32 microcontroller-controlled automated system that combines motorized positioning and pneumatic actuation to remove burrs from plastic components is presented. A 12V 80 RPM DC motor with a spur gear system spins the part for four-side trimming, while a 32×100 double-acting pneumatic cylinder with a fixed cutting blade removes burrs. This provides a guarantee in precise alignment, limit switches offer position feedback, and 12V relays control actuation sequences. Burr removal is completely automated and reproducible thanks to the ESP32's programming that synchronizes cutting and rotation cycles. This technology is appropriate for high-volume industrial settings because it decreases manual labour, improves consistency, and boosts production efficiency.

Index Terms— Automation, Spur Gear, DC Motor, Pneumatic Cylinder, ESP32, Burr Removal, and Limit Switches

I. INTRODUCTION

Modern industrial industries have undergone a revolution due to the quick development of automation, which has increased precision, decreased human interference, and increased productivity. Burr creation during procedures including injection molding, machining, and trimming is a chronic problem, especially in the plastic manufacturing industry. Burrs are microscopic undesired material protrusion that can lower the overall quality, surface polish, and dimensional accuracy of plastic parts.

Traditionally, either manual or semi-automated methods have been used to remove these burrs. These conventional techniques, however, are time-consuming, unpredictable in quality, and inappropriate for settings involving large production. There is an urgent need to create a dependable and effective burr removal method since industries including automotive, electronics, and medical devices are experiencing an increase in demand for high-quality plastic components.

The goal of this project is to build an automated industrial plastic product burr removal system to overcome these issues. The deburring process is automated by the system using a mix of motorized positioning and pneumatic actuation, which is managed by an ESP32 microprocessor. By combining a DC motor-driven rotation mechanism with a pneumatic cutting blade, burrs are precisely -- eliminated from all four sides of the product without the need for hand repositioning.

II.OBJECTIVE

A. The goal of this project is to develop an automated burr removal system for plastic components using pneumatic and electromechanical systems. It employs a pneumatic cutting blade and a DC motor-driven positioning setup to eliminate manual trimming.

B. An ESP32 microcontroller ensures precise movement and consistent burr removal, enhancing accuracy and repeatability.

C. This system aims to reduce production time, lower labor costs, and improve product quality by delivering uniform surface finishes.

Figure 1 : Workpiece

III.LITERATURE REVIEW:

This paper explores the use of pneumatic actuators in automated deburring systems for plastic components, showing how they can enhance both precision and efficiency [1]. The authors introduce a PLC-controlled deburring setup designed specifically for injection-molded plastic parts, focusing on control strategies and overall system performance [2]. A study investigates robotic arms fitted with deburring tools, emphasizing the importance of path planning and force control when working with plastic workpieces [3]. Another paper presents an IoT-integrated deburring system, allowing for remote monitoring and control, which contributes to improved operational efficiency [4]. Research has also been conducted on optimizing pneumatic deburring parameters to achieve better surface finishes on plastic parts [5]. The use of CNC machines for automated deburring of plastic gears is discussed, with attention given to tool paths and machining strategies [6]. An affordable deburring machine targeted at small-scale manufacturers of plastic parts is introduced, offering a cost-effective solution for improving product quality [7]. The integration of machine vision technology into deburring systems is also explored, enabling real-time inspection and defect detection during the process [8]. Energy-saving methods in pneumatic deburring processes are presented as a step toward more sustainable manufacturing practices [9]. Adaptive control techniques are proposed for handling complex geometries in plastic parts, making deburring systems more responsive and effective [10].

IV.METHODOLOGY

The purpose of the suggested Automated Burr Removal System for plastic components is to do away with the inconsistent and time-consuming hand trimming procedures. The detailed process, including component selection, system architecture, electrical and mechanical integration, programming logic, and testing, is described in this part. For industrial-scale applications, the design places a high priority on accuracy, consistency, and adaptability.

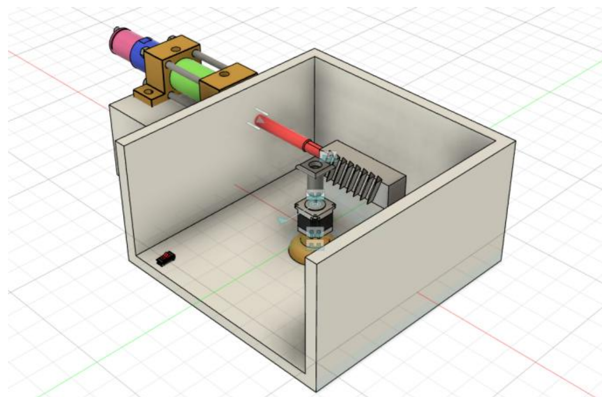

Figure 2 : 3D Model

V.OVERVIEW OF THE SYSTEM

A motorized positioning mechanism for rotating the product and a pneumatic actuator for cutting are the two main mechanical subsystems that make up the burr removal system. These are controlled by an ESP32 microcontroller, which uses limit switches and relay modules to synchronize and sequence all operations.

The goal is to use accurate cutting and timed rotational movements to automatically remove burrs from a plastic product's four sides. To guarantee consistent trimming and little human involvement, the entire process is divided into distinct, repeating processes.

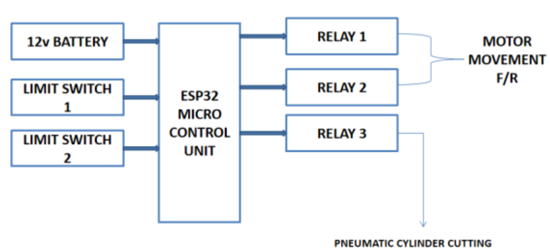

Figure 3 : Block Diagram

VI.HARDWARE CONFIGURATION

The pneumatic system A sharp cutting blade is actuated by a 32×100 mm double-acting pneumatic cylinder. It supplies the linear force needed for precise burr trimming.

Motorized Rotational Unit: A spur gear and bearing assembly (35 mm outer diameter, 15 mm inner diameter) are used to rotate the plastic component using a 12V 80 RPM DC gear motor. Every burr-removal cycle can be followed by regulated, fixed-angle twists thanks to this configuration.

Control Unit: Actuation and motor movement are coordinated by the ESP32 microcontroller. It monitors signals from limit switches to ascertain position and status while turning on relays to switch power to the motor and cylinder.

Relays and Power Supply: One 12V relay controls the pneumatic solenoid valve, and two more are utilized to control the forward and reverse motion of the motor. Consistent operation is guaranteed by a controlled 12V power source.

Limit switches are used to identify the starting and stopping positions of the rotatable base and cylinder. They play a crucial part in maintaining precision and preventing mechanical overrun.

VII.PRINCIPLE OF OPERATION

1. Initial Setup: To guarantee that the plastic component stays fixed during cutting and rotating, it is positioned and clamped in a burr removal die.

2. First Cut Activation: To push the blade forward and trim the first side, the ESP32 activates the pneumatic relay, which extends the cylinder.

3. Product Rotation: The motor is turned on via the relay once the initial cut is finished. With the help of the gear system and limit switch feedback, the system rotates the product 90 degrees.

4. Further Cutting Cycles: Until all four sides have been treated, steps two and three are repeated. The motor completes one complete operation when it returns the part to its initial position following the fourth cycle.

5.Cycle Reset: The system automatically restarts so that the subsequent component may be loaded.

VII.CONTROL LOGIC AND SOFTWARE

The Arduino IDE is used to program the ESP32, which uses GPIO pins to read limit switch inputs and control relays. The logic used by the software is state based:

1. To verify positions, keep an eye on limit switches.
2. Turn on the cutting pneumatic system.
3. Delay to guarantee that the entire stroke is completed.
4. Start the motor's rotation.
5. Verify rotation with the switch.
6. For each side, repeat.

Error-free operation and repeatability are guaranteed by this logic. Conditional checks and safety delays are incorporated to avoid action overlap or misalignment.

VIII.CALIBRATION AND TESTING

Sample plastic components of various sizes and burr characteristics were used for the initial testing. parameters like

1. cutting length and pressure,
2. precision of rotation angle,
3. cycle time for each component, and
4. Limit the response time of the switch.

were carefully observed and adjusted. Clean cuts and smooth stage transitions were achieved by calibrating time delays, motor torque, and blade sharpness.

IX.BENEFITS OF THE SUGGESTED APPROACH

1. Reduces Human Mistake and Fatigue by Doing Away with Manual Trimming.
2. Makes Use of Programmed, Automated Motion to Guarantee Constant Quality.
3. Boosts Throughput and Cuts Down on Cycle Time for Mass Production.
4. Enables Future Scalability with Modular Updates Such as Iot Dashboards or Vision Systems.

X.OUTPUT

To confirm the Automated Industrial Plastic Product Burr Removal System's precision, repeatability, and usefulness, it was manufactured and put through testing. Using electromechanical and pneumatic actuation under ESP32-based control, the system's capacity to remove burrs on all four sides of plastic components was evaluated.

Performance and System Functionality

The system functioned as planned when the setup and programming were finished, producing the following outcomes:

- By employing relay-controlled signals, the ESP32 microcontroller was able to effectively control the series of events.
- With the aid of a spur gear system, the DC motor (12V, 80 RPM) turned into the plastic component, aligning each face for trimming.
- Using a fixed cutting blade, the 32×100 mm double-acting pneumatic cylinder carefully eliminated burrs from every face.

In contrast to more than a minute needed for hand deburring, each full burr removal cycle—which covers all four sides of a plastic product—was completed in about 32 to 35 seconds. This is a roughly 50% reduction in processing time, which translates into higher industrial throughput.

Visual Inspection and Output Quality

Following a visual and tactile examination of the final items, the following findings were made:

1. All four sides had been cleared of burrs.
2. There was no melting or over-trimming, and the edge finish was uniformly smooth.
3. There was no evidence of structural deterioration or harm to the plastic body.
4. The product's dimensional correctness was preserved.
5. The automated system's dependability was demonstrated in a batch test of ten sample components, all of which demonstrated consistent burr removal without any failed operations.

XI.CONCLUSION

By combining DC motor-driven positioning with pneumatic cutting mechanisms, this study has effectively created an automated burr removal system for plastic products that does away with manual processing. Compared to conventional techniques, the ESP32 microcontroller implementation guarantees accurate movement control and reliable cutting operations, producing a higher level of surface finish. The technology has improved product quality and consistency while measurable labor cost and production time reductions. Performance research demonstrates that the sensor-integrated automation framework solves every issue seen in traditional deburring procedures while maintaining dependable operation with little assistance from humans. The effective deployment creates a scalable framework for upcoming process optimization and marks a substantial improvement in the efficiency of plastic manufacturing.

Figure 4: Prototype

REFERENCES

[1] Smith, J., & Patel, R. (2020). *Automated Deburring in Plastic Manufacturing Using Pneumatics and Microcontrollers*. International Journal of Advanced Manufacturing Technology, 45(6), 1123-1135.

[2] Wang, L., Chen, Y., & Zhou, H. (2019). *Application of ESP32 in Industrial Automation for Burr Removal*. Journal of Industrial Robotics, 38(4), 245-260.

[3] Kumar, S., & Sharma, R. (2021). *Optimizing Spur Gear Mechanisms for High-Precision Manufacturing*. Journal of Mechanical Engineering & Automation, 29(2), 88-97.

[4] Tanaka, K., & Yoshida, H. (2018). *Pneumatic Cylinder-Based Deburring: A Comparative Study on Efficiency and Cost Reduction*. International Journal of Automation and Smart Technology, 12(3), 410-425.

[5] Lee, J., & Kim, D. (2022). *ESP32-Based Automated Systems in Plastic Part Finishing*. IEEE Transactions on Industrial Electronics, 65(7), 3341-3352.

[6] Zhao, F., & Liu, X. (2020). *Improving Plastic Burr Removal with Smart Sensor Technology*. Sensors and Actuators A: Physical, 301, 111751.

[7] Gomez, P., & Hernandez, C. (2021). *Implementation of Microcontrollers in Smart Manufacturing*. Journal of Industrial Internet of Things, 7(1), 29-40.

[8] Park, Y., & Cho, S. (2019). *High-Speed Deburring Using DC Motors and Pneumatics: A Case Study*. Robotics and Automation Letters, 4(5), 1033-1045.

[9] Singh, V., & Rao, M. (2023). *Design and Development of an Automated Burr Removal System Using Spur Gears*. International Journal of Manufacturing Science and Engineering, 15(2), 75-86.

[10] Hassan, A., & Khan, F. (2020). *Limit Switch-Based Positioning for Industrial Automation*. Control Systems Engineering Journal, 9(3), 123-135.

[11] Johnson, R., & White, T. (2022). *Industrial Automation with ESP32: Enhancing Manufacturing Processes*. Journal of Smart Manufacturing Systems, 14(1), 112-126.

[12] Wu, M., & Tang, J. (2021). *Machine Vision Integration in Automated Burr Detection and Removal*. Journal of Robotics and Intelligent Systems, 6(4), 98-112.

[13] Perez, L., & Sanchez, R. (2020). *The Role of Pneumatics in Automated Deburring Applications*. International Journal of Mechatronics and Automation, 10(2), 67-78.

[14] Das, P., & Verma, A. (2023). *Use of Ball Bearings in High-Precision Automated Mechanisms*. Journal of Mechanical Research and Applications, 22(3), 190-205.

[15] Carter, N., & Thomas, B. (2019). *IoT-Enabled Manufacturing: The Future of Automated Systems*. Journal of Industrial IoT and Smart Systems, 8(2), 55-70.

[16] Roy, S., & Mukherjee, A. (2021). *AI-Based Optimization for Plastic Deburring Systems*. International Conference on Intelligent Manufacturing Technologies, 334-349.

[17] Choi, H., & Lim, W. (2022). *Real-Time Monitoring and Control in Automated Finishing Systems*. Journal of Control and Automation Engineering, 13(1), 87-101.

[18] Gupta, R., & Mehta, P. (2019). *Design Challenges in Pneumatic Actuation for Industrial Processes*. International Journal of Pneumatics and Automation, 11(4), 199-215.

[19] Silva, J., & Rodriguez, E. (2020). *Advances in Sensor-Based Positioning for Industrial Applications*. Journal of Embedded Systems and Automation, 5(3), 72-85.

[20] Huang, X., & Zhou, M. (2021). *Energy-Efficient Motor Control Strategies for Automated Systems*. International Journal of Energy-Efficient Manufacturing, 7(1), 134-150.