Design And Development of a Hybrid Pneumatic-Electric Burr Removal Machine for Industrial Applications

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Abstract—**Burr formation is a common challenge in industrial manufacturing, particularly in operations like milling, drilling, and turning. Burrs, which are unwanted protrusions of material left on a workpiece after machining, can cause issues such as reduced component functionality, poor surface finish, and difficulties during assembly. Conventional burr removal techniques involve pneumatic or electric systems, each offering distinct advantages and limitations. Pneumatic tools are known for their high speed and torque but often lack precision, while electric tools provide better control and energy efficiency but may not be as effective in removing larger burrs. The aim of this project is to design and develop a hybrid pneumatic-electric burr removal machine that combines the best features of both pneumatic and electric systems. This hybrid machine allows for the flexible switching between high-speed pneumatic operation for aggressive burr removal and controlled electric operation for precise finishing. The machine addresses the need for a versatile deburring solution capable of handling a wide range of materials and component geometries, while also increasing productivity and reducing downtime. The hybrid burr removal machine is designed with dual-mode functionality, which enhances operational efficiency and quality consistency. By integrating pneumatic and electric modes, the system offers improved adaptability for various manufacturing tasks.**
This ensures faster deburring for heavy-duty materials and more precise removal for delicate components. The design process includes conceptualization, CAD modelling, component selection, and prototype testing to validate its performance in real-world industrial settings. The machine development process also considers sustainability, as the hybrid design optimizes energy usage by dynamically selecting the most appropriate power source based on operational demands. Additionally, the integration of automation-ready controls ensures that the machine can be easily adapted to smart manufacturing environments, supporting Industry 4.0 initiatives. In conclusion, the hybrid pneumatic-electric burr removal machine represents a significant advancement in deburring technology, providing an adaptable, efficient, and high-quality solution for industries that require precise and efficient burr removal.
The resulting machine enhances operational flexibility, reduces deburring time, and ensures consistent quality across various materials and geometries. It is particularly beneficial in industries such as aerospace, automotive, and medical devices where precision and efficiency are critical. The hybrid solution not only improves productivity but also contributes to sustainable manufacturing practices through optimized energy use and reduced equipment redundancy

Keywords: **DA pneumatic Cylinder, De-Burring Tool, Power Supply Board, Pneumatic Toggle Switch Controller & AFR- 2000 PG controller Valve, DC Wiper Motors, DC motor speed controller, Display Digital Voltmeter and Ammeter Current Tester**

I INTRODUCTION

The Pneumatic-Electric Deburring Machine is a specialized tool designed for removing burrs and sharp edges from a work piece to achieve a smooth surface finish. This machine automates the deburring process using a combination of pneumatic and electrical components for precision and efficiency. In modern manufacturing industries, the quality of the final product is heavily influenced by the finishing processes applied after machining. One common and critical issue is the presence of burrs—small, unwanted projections of material that form on the edges of a workpiece during operations such as drilling, milling, turning, and stamping. If not properly removed, these burrs can affect the dimensional accuracy, surface finish, assembly integrity, and overall safety of the part.

Traditional burr removal methods include manual filing, grinding, and the use of either pneumatic or electric deburring tools. While pneumatic tools offer high-speed performance and are preferred for bulk material removal, electric deburring tools provide better control and precision, making them ideal for delicate components. However, using only one of these systems often results in limitations either in precision or power, depending on the complexity and material of the workpiece.

On the other hand, electric deburring tools, which are powered by electric motors, offer better precision, control, and energy efficiency. They are better suited for small and delicate workpieces where accuracy is critical. However, electric tools generally provide lower torque and can be less effective on harder materials or larger burrs. As a result, manufacturers often find themselves forced to choose between speed and precision, with neither system providing a comprehensive solution.

This dichotomy highlights a significant gap in the current state of deburring technology. There exists a pressing need for a versatile, adaptable system that integrates the advantages of both pneumatic and electric deburring mechanisms. The development of a hybrid pneumatic-electric burr removal machine aims to bridge this technological gap, providing manufacturers with a unified tool capable of performing a broad range of deburring tasks with high efficiency, precision, and adaptability.

A hybrid deburring machine combines the high-speed performance of pneumatic tools with the fine control and efficiency of electric tools in a single, cohesive system. Such a system can be adjusted based on the material type, burr size, and desired finish quality. For instance, the pneumatic mode can be engaged for rapid removal of larger burrs, while the electric mode can be used for detailed finishing work. The result is a significant reduction in production time, improved consistency in deburring quality, and increased operational flexibility.

The machine's design includes an integrated control unit, enabling operators to switch between pneumatic and electric modes seamlessly. Additionally, it features adjustable tool heads, multi- speed settings, and safety interlocks to protect both the operator and the workpiece.

The hybrid approach also supports sustainability goals in manufacturing. By allowing energy- efficient operation through the selective use of electric tools, and reducing air compressor dependency, energy consumption can be optimized. Moreover, the ability to adapt the machine for a wide variety of components reduces the need for multiple specialized machines, thereby minimizing equipment footprint and investment.

Industries such as aerospace and automotive manufacturing, which handle complex components with both fine and heavy burrs, stand to benefit significantly from the implementation of hybrid deburring solutions. Similarly, in the medical device industry, where cleanliness and precision are paramount, this hybrid system can ensure burr-free, high-quality parts that meet strict regulatory standards.

To address these challenges, this project proposes the design and development of a hybrid pneumatic-electric burr removal machine. This system combines the strengths of both pneumatic and electric technologies, offering an adaptable solution capable of handling a wide range of deburring tasks. The hybrid approach aims to increase operational flexibility, reduce cycle times, and enhance the overall quality and consistency of the deburring process.

The machine will be designed with dual-mode functionality, allowing operators to switch between pneumatic and electric operation depending on the material type, burr size, and required precision. With an emphasis on automation, safety, and energy efficiency, the proposed system seeks to improve productivity while reducing the physical strain on operators and minimizing rework.

This introduction lays the foundation for an innovative industrial solution that bridges the gap between speed and precision in deburring—contributing to higher standards in manufacturing and finishing processes.

The development of such a system follows a structured engineering design process that involves requirement gathering, conceptualization, CAD modeling, prototype fabrication, and rigorous testing. It begins with an analysis of the types of burrs, materials, and product geometries typically encountered in industrial applications. Based on this data, the functional specifications of the machine are defined, including power requirements, torque output, speed range, tool compatibility, and safety features.

Feedback from testing is used to iterate and refine the design. Factors such as vibration control, heat dissipation, noise reduction, and tooling life are evaluated to ensure the machine meets industrial standards. The final product is a robust, user- friendly, and highly versatile deburring machine that can seamlessly fit into modern production lines

The significance of this hybrid system extends beyond productivity gains. It enables a leaner, smarter manufacturing environment where tool adaptability and process integration are key to competitive advantage. Moreover, as industries increasingly move toward Industry 4.0 practices, such intelligent, adaptable systems become crucial in achieving automation and digitalization goals.

In conclusion, the development of a hybrid pneumatic-electric burr removal machine represents a forward-thinking solution to a long-standing industrial problem. By merging the speed and force of pneumatic tools with the precision and efficiency of electric systems, this hybrid approach offers unmatched flexibility, improved quality control, and better resource utilization. It empowers manufacturers to meet higher standards of quality, safety, and efficiency in their finishing processes, thus reinforcing the value of innovation in mechanical engineering and industrial design.

The key elements of this system include 100mm Stroke Length Pneumatic Cylinder

- The pneumatic cylinder provides linear motion, enabling the controlled movement of the electric mini grinder.
- It ensures consistent pressure and stroke length (100mm), allowing for precise deburring operations.

Toggle Switch Mechanism

- The toggle switch controls the pneumatic cylinder’s forward and backward motion.
- This manual or automated control makes it easier to engage or retract the mini grinder as needed during operation.

Electric Mini Grinder

- The mini grinder is the primary deburring tool. It removes excess material and smooths the edges of the workpiece.
- It is mounted on the pneumatic cylinder and moves in the direction of the cylinder’s stroke to contact the workpiece.

Workpiece Holding and Rotation Mechanism

- The workpiece is securely held in a mini drill chuck to prevent movement during the deburring process.
- A DC motor with a chain and sprocket mechanism rotates the workpiece to ensure uniform deburring around its edges.

AFR-2000 Pneumatic Air Filter Regulator Compressor & Pressure Reducing Valve

- The AFR-2000 Pneumatic Air Filter Regulator Compressor & Pressure Reducing Valve plays a crucial role in maintaining optimal air pressure and quality in pneumatic systems.
- It combines three essential functions: filtering, regulating, and lubricating compressed air to ensure efficient operation of air tools and machinery.
- The AFR-2000 operates by allowing compressed air to enter the unit, where it first passes through the filter element.

DC5-30V 12V 24V 5A DC Motor Controller PWM Adjustable Speed Digital display encoder duty ratio frequency MAX 15A ZK-MG

- The DC5-30V 12V 24V 5A DC Motor Controller (ZK- MG) is a PWM (Pulse Width Modulation) adjustable speed controller designed for efficient and precise control of DC motor speed.
- It operates within a voltage range of 5V to 30V and supports a current of 5A (max 15A peak), making it suitable for a wide range of applications, including electric fans, pumps, and industries applications.

Display Digital Voltmeter and Ammeter current tester

- A digital voltmeter and ammeter current tester is a compact device used to measure voltage and current in electrical circuits.
- Typically featuring a dual LED display, it allows users to monitor both parameters simultaneously.
- It supports a continuous output of 5A and a maximum surge capacity of 15A, ensuring stable and efficient motor control.

Testing and Evaluation

- Testing the machine's performance on a variety of workpieces (metals, plastics, etc.) with different burr characteristics.
- Evaluating the efficiency, precision, and quality of burr removal compared to traditional methods. Assessment of machine safety, energy consumption, and maintenance requirements.

Optimization and Finalization

- Fine-tuning the machine's design based on test results to improve efficiency and adaptability.

Ensuring compliance with industrial standards and safety regulations.

Documentation and Reporting

- Preparation of detailed technical documentation, including machine schematics, operational procedures, and maintenance guidelines. Final project report covering design methodology, testing outcomes, and future recommendations.

Cost Analysis and Feasibility

- Budgeting and cost analysis for machine development, production, and operation. Evaluation of the economic feasibility of deploying the machine in industrial settings.
- This scope ensures that the project covers the complete cycle of research, design, fabrication, and evaluation, resulting in a functional pneumatic burr removing machine tailored to industrial deburring needs.
- The “pneumatic-Electric deburring machine” represents an innovative solution for automating the removal of burrs from machined workpieces. Burrs are undesirable remnants that occur as a byproduct of various machining processes such as drilling, milling, grinding, and casting. Effective removal of these burrs is crucial for improving product quality and ensuring proper assembly, functionality, and aesthetics. This literature survey focuses on existing deburring techniques, the role of pneumatics in manufacturing, and the advantages of pneumatic-based deburring systems.

Traditional Deburring Techniques

Traditional methods of deburring include manual, mechanical, thermal, and chemical processes. Each of these methods has advantages and disadvantages depending on the material and type of burr involved:

Manual Deburring: Involves using handheld tools such as files, abrasive stones, and brushes. Though effective for small production runs and complex shapes, it is labor-intensive, inconsistent, and unsuitable for high-volume production.

Mechanical Deburring: Methods such as grinding, brushing, and vibratory finishing are commonly used for removing burrs in mass production. These techniques can handle a larger volume of workpieces but are limited by the need for precise setup and increased tooling wear.

Thermal and Chemical Deburring: Thermal deburring uses a combustion process to remove burrs, while chemical deburring involves chemical reactions that dissolve burrs. Both are highly effective for complex geometries, but they involve high operating costs and strict safety controls.

II LITERATURE REVIEW

The study carried out by Kakde D. V. and Lokawar V. L. on “Design and Manufacturing of Pneumatic Burr Removing Machine” This paper discusses the development of a pneumatic burr removing machine aimed at enhancing the efficiency of wheel clutch applications. It highlights the advantages of pneumatic systems over hydraulic ones, emphasizing speed, flexibility, and improved worker safety.

The study carried out by Song Yong Jin, A. Pramanik, and S. Debnath. On “Burr Formation and Its Treatments-A Review” This paper discusses This comprehensive review examines the mechanisms of burr formation in various machining processes and explores methods to minimize or eliminate burrs, including the use of pneumatic systems for deburring. The study carried out by Akshay Kshatriya, Dhanraj Mane, and Rohit Patil. On “Improvement in Millipore and Implementation of Pneumatic System for Burr Removal” This paper discusses the authors investigate the implementation of a pneumatic system to enhance burr removal processes, focusing on improving component cleanliness and reducing engine contamination. The study carried out by Young-Gwan Kim, Kwang-Joon Kim. On “Efficient Removal of Milling Burrs by Abrasive Flow” This paper discusses This study explores the use of abrasive flow machining as an effective method for removing milling burrs, highlighting the potential integration with pneumatic systems for improved efficiency. The study carried out by Kudrat Sharma. On “Literature Review on Abrasive Jet Machining” This paper discusses This literature review delves into abrasive jet machining techniques, discussing parameters that influence material removal rates and the potential application in burr removal processes.

III WORKING PRINCIPLE

THE MACHINE OPERATES AS FOLLOWS

- The workpiece is clamped in the mini drill chuck and rotated by the DC motor through a chain and sprocket drive.

- The pneumatic cylinder, activated by a toggle switch, pushes the electric mini grinder towards the workpiece.
- As the grinder contacts the rotating workpiece, it removes burrs along the edges, achieving a clean and polished finish.
- Once the deburring is complete, the toggle switch retracts the pneumatic cylinder, and the workpiece can be removed.

BRIEF- EXPLANATION

- When the system starts working, the hold the work piece in fixture provides at the bed. Then supply the compressed air to the system. Compressed air passes through a number of components when it is provided, including the direction control valve, the FRL unit, and the actuator.
- The piston begins to move forward or backward when air is provided from the top side of the actuator. As a result, the punch holder and the punches attached to it move automatically in that direction, completing the burr removal process in forward motion.
- We now need to supply compressed air from the cylinder's bottom side in order to return the piston in a backward direction after removing the work piece from the fixture. This requires us to adjust the direction control valve's location. The piston then begins to move backwards as a result of the direction control valve changing the flow direction and supplying the air to the bottom side. A second work piece was then replaced, and the same process was followed. Compared with the manual burr removal method, that approach requires less time to remove burrs. Additionally, the operation is extremely safe for the workers. Furthermore, it improves productivity and accuracy.

3D-DESIGN AND ASSEMBLED PARTS IN CATIA V5R20 SOFTWARE

Mechanical 3D Design: Design of the machine structure, including the frame, tool holder, and material handling system.

Pneumatic-Electric System Design: Selection and configuration of pneumatic components such DAC, frames, supported Frame, valves, actuators, and pressure regulators, electric motor, etc.,

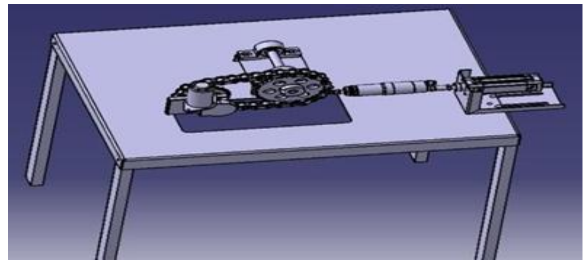

Fig. 3D-Top Isometric view of Assembled Part

SPECIFICATION OF COMPONENTS

SL NO:	PART NAME	MATERIAL	QTY	SPECIFICATION
1	Frame	Mild Steel	1	MS-IS277
2	Pneumatic Toggle Switch Controller & 8mm Pipe-4m.	Not Applicable	1	Min=1bar to Max=6 bar Pneumatic controller
3	DC Wiper Motors & Support plate	Not Applicable	1	12V, RPM:35, DC geared motor
4	Double-Acting Pneumatic Cylinder	Standard	1	Stroke Length-100mm, Bore Dia-35mm
5	Pillow Block Bearing	Standard	2	Shaft Dia=⌀20 mm
6	De-burring Tool	Standard	1	135 Watts, 220Volts~50Hz Speed=10000-30000rpm
7	Power Supplyboard	Standard	1	Input Voltage-220V, Output-15A, 12 Volts,
8	AFR-2000 Pneumatic Air Filter Regulator Compressor & Pressure Reducing Valve	Standard	1	Inlet Pressure: 150 PSI (10.3 bar) Outlet Pressure: 0-150 PSI (0-10.3 bar) Flow
9	DC speed controller	Standard	1	Input Voltage: DC 5V-30V (Supports 12V, 24V operation) Output Current: Rated 5A, Maximum 15A
10	Display Digital Voltmeter and Ammeter current tester	Standard	1	Output Voltage: 0V-100V Output Current: Rated 0A, Maximum 10A

EXACT-DESIGN, DEVELOPED AND ASSEMBLED

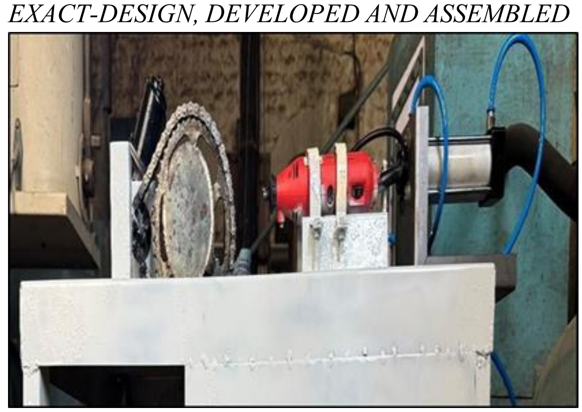

Fig. Front View of Assembled Part

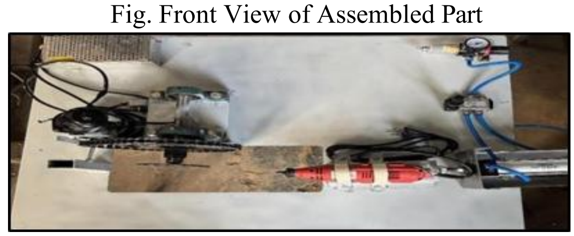

Fig. Top View of Assembled Part

Fig. Left Side View of Assembled Part

CALCULATIONS & RESULTS

Motor Power Calculation

P=V·I

Where:

V=12.5 I=1.44

P=12x5=18 Watts

Torque Required

ω=2π·N/18 Where:

N=25 rpm

ω= [2πx25]/18=8.72 rad/s ω ≈8.72 rad/s

T=P/ω = T=18/8.72 Nm= T≈2.064 Nm

FINAL RESULTS

- Motor Power: 18 Watts
- Torque Required: 2.064 Nm

OBJECTIVES OF THE WORK

- To increase the performance of machining processes on metal components by removing the burr pieces from coolant.
- To get highly polished machining surfaces by eliminating scratches due to burr pieces in coolant.
- To eliminate the manual work of filtration by introducing Pneumatic-Electric burr separation from coolant.
- To supply the correct amount of coolant to machining parts.
- To save the time of manual filtration and increase the overall efficiencies of the operation.
- The greatest advantage of Pneumatic punches is their speed. Pneumatic punches are approximate 10 times faster than hydraulic punches and they can perform on many jobs faster and more efficiently.
- They can also be stopped at any time by opening the valves to release the air. Pneumatic punches are extremely flexible, that they can be placed in a factory in any required position, even upside down.

IV CONCLUSION

The present study has successfully developed pneumatic- Electric Deburring machine for industrial applications. The pneumatic-electric deburring machine offers a significant improvement over traditional deburring methods, particularly in high-volume, precision-driven industries. By combining the advantages of pneumatic power with automation and intelligent control systems, pneumatic-electric deburring machines can deliver consistent, efficient, and cost-effective solutions. Continued advancements in this area are expected to further enhance performance, sustainability, and integration with smart manufacturing systems.

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