

# FABRICATION AND TESTING OF AN ELECTRO MAGNETIC ABRASIVE MACHINING SYSTEM FOR IMPROVING SURFACE ROUGHNESS

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**Abstract:** Advanced finishing processes are essential in modern industry to achieve the surface integrity required for high-strength materials used in aerospace and medical applications.

This project presents the design and fabrication of an Electro Magnetic Abrasive Finishing (EMAF) machine, a non-conventional finishing system capable of achieving "mirror-like" surface quality. The system utilizes a suspension tank where an electromagnetic field drives abrasive particles, across the workpiece to precisely remove material from complex geometries.

To ensure precise control, the machine integrates an Arduino-based microcontroller platform to manage system operations and motor outputs. The performance of the EMAF process was evaluated by analyzing the influence of key parameters, including rotating speed, feed rate, depth of cut, and the number of passes, on the surface roughness of aluminum and wood workpieces.

Experimental results demonstrate that systematic calibration of these parameters significantly improves fatigue strength and wear resistance by eliminating surface irregularities. This project aims to provide a high-precision, cost-effective, and scalable finishing solution for industries where traditional grinding methods fail to meet stringent design requirements. Hassan El-Hofny et al [1] focused on the material removal rate (MRR) and the physics of the abrasive-workpiece interface, establishing the "Flexible Magnetic Abrasive Brush" (FMAB) as a multipoint cutting tool. P.C. Pandey and H.S. Shah et al [2] categorized EMAF as a vital super-finishing process. Recent reviews confirm its necessity for medical implants and aerospace components where "mirror-like" finishes are required to improve fatigue life.

**Keywords:** Abrasive Machining, Electromagnetic Machining, Surface roughness, non-conventional finishing process.

## 1.0 INTRODUCTION

The increasing demand for high-precision components in advanced industries requires sustainable and high-accuracy finishing solutions. Electro Magnetic Abrasive Finishing is a modern, non-conventional process that can be effectively harnessed to achieve mirror-like surface integrity on complex geometries. Surface texture refers to the characteristic quality of a surface resulting from small departures from its intended geometric form, which can impact a component's functional performance. Electro Magnetic Abrasive Finishing (EMAF) is an advanced finishing process that utilizes a controlled electromagnetic field to drive abrasive particles across a workpiece to remove material with high precision. Arduino-Based Control System integrates an Arduino microcontroller to manage technical parameters, allowing for automated and cost-effective control over the finishing performance. Industrial application includes controlled material removal provided by this system is vital for enhancing the fatigue strength and wear resistance of critical components in the aerospace, medical, and automotive sectors.

## 2.0 METHODOLOGY

The methodology involves the systematic design of the machine and the execution of experiments to analyze the finishing characteristics of the selected materials.

**System Components:** The machine consists of an electromagnetic coil, a power supply unit, a suspension tank for abrasive particles, and an Arduino-based controller to regulate the process.

**Abrasive Preparation:** A flexible abrasive brush is created using a composite of Aluminum Oxide and iron particles (0.3 mm diameter) to provide the cutting action under the influence of a magnetic field.

**Experimental Procedure:** The workpiece is placed in the magnetic field, and the process is conducted under wet conditions by applying oil every two minutes to reduce friction and heat.

**Parameter Selection:** The study evaluates the process based on four key input factors:

- Rotating Speed
- Feed Rate
- Depth of Cut
- Number of Passes

**Surface Measurement:** After the finishing process, the surface roughness is measured and compared using direct instrument methods like the Profilometer and visual inspection techniques.

## 3.0 HARDWARE

### 3.1. ARDUINO BOARD

- **Role:** Acts as the primary Microcontroller (MCU).
- **Details:** It processes the G-code or programmed instructions and sends pulse/direction signals to the motor drivers. It synchronizes the movement of the abrasive brush relative to the workpiece.



**Fig 1. Arduino Board**

### 3.2. Stepped Motors:

- **Quantity:** 4 Units.
- **Role:** These provide the multi-axis movement (likely X, Y, Z, and a rotational axis for the magnetic head).
- **Details:** Unlike DC motors, steppers allow for **discrete positioning**, which is vital for maintaining a consistent "Working Gap" between the magnet and the surface



Fig 2. Stepped Motor

### 3.3 CNC / Stepper Motor Shield

- **Role:** The interface between the Arduino and the motors.
- **Details:** It sits on top of the Arduino and holds the A4988 or DRV8825 driver carrier chips. It simplifies wiring and prevents the high current needed by the motors from frying the Arduino.

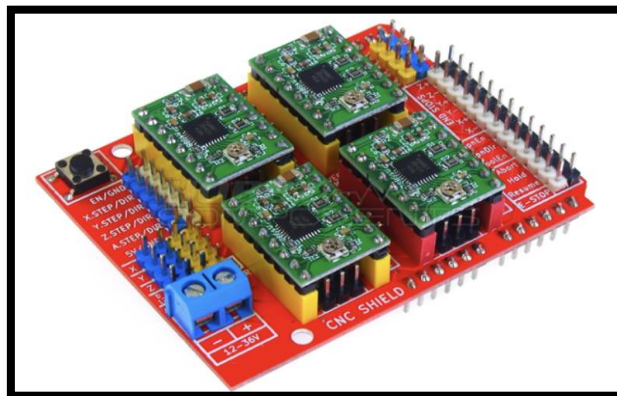


Fig 3. CNC / Stepper Motor Shield

### 3.4 Speed Controller Module (PWM)

- **Role:** Controls the rotation of the Finishing Tool or the Electromagnet intensity.
- **Details:** Likely a Pulse Width Modulation (PWM) controller. It allows you to manually or digitally adjust how fast the abrasive brush spins without losing significant torque.

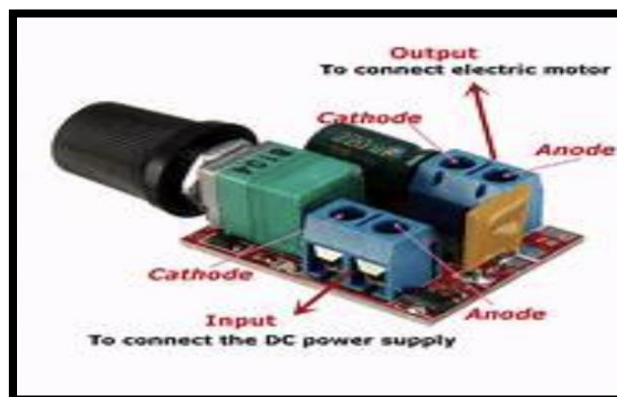


Fig.4. Speed Controller Module (PWM)

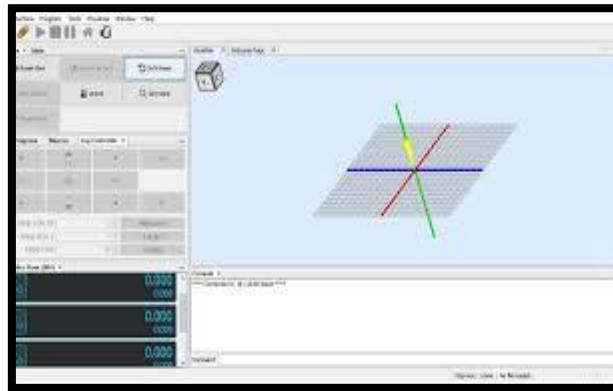
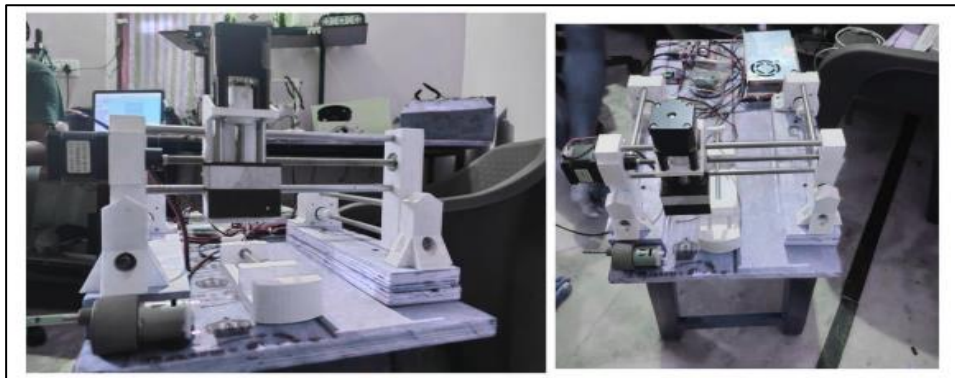


Fig 5. Universal G-Code System



#### 4.0 RESULTS AND DISCUSSION

From the rigorous experimentation it has been observed that for the materials aluminium, mild steel and Wood Surface roughness has been improved with increase in time interval for all the three materials for variable speeds low medium and high at various depth of cut 1mm, 1.5mm and 2mm respectively. This is due to intensified centrifugal forces causing abrasive scattering, unstable magnetic brush formation, and increased thermal effects. While moderate speed increases typically improve surface finish, exceeding an optimal speed threshold often leads to deterioration in quality for materials like aluminium, mild steel, and wood.

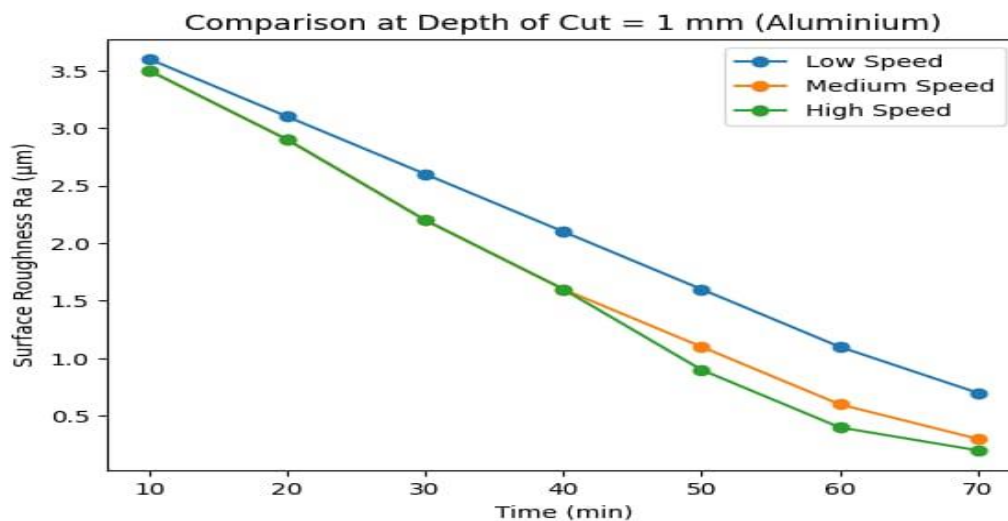


Fig 7. Surface roughness vs Time at depth of cut 1.0 mm of Aluminium

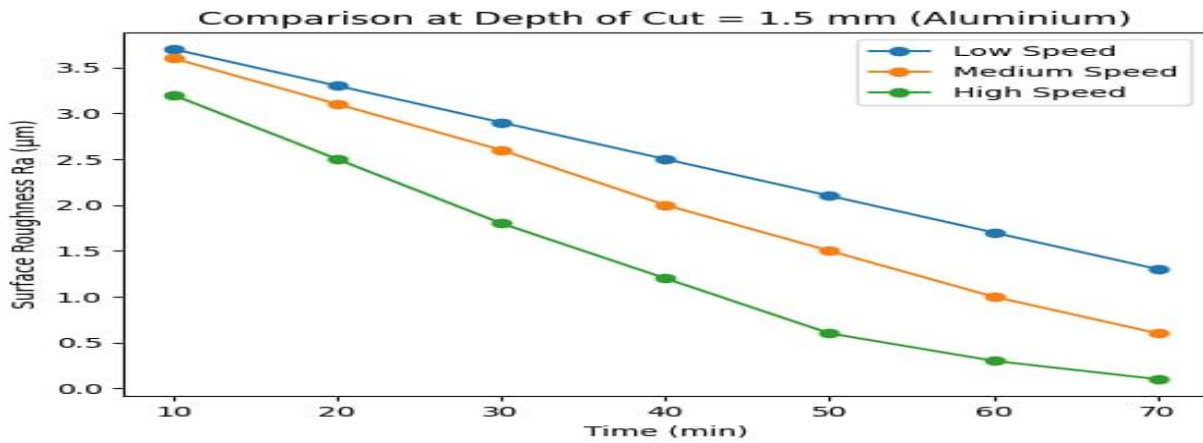


Fig 8. Surface roughness vs Time at depth of cut 1.5 mm of Aluminum

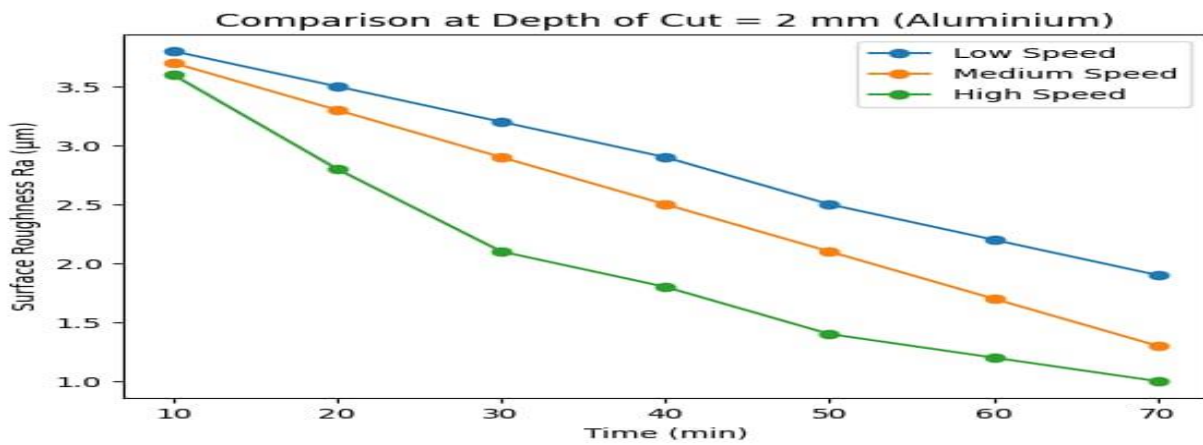


Fig 9. Surface roughness vs Time at depth of cut 2.0 mm of Aluminum

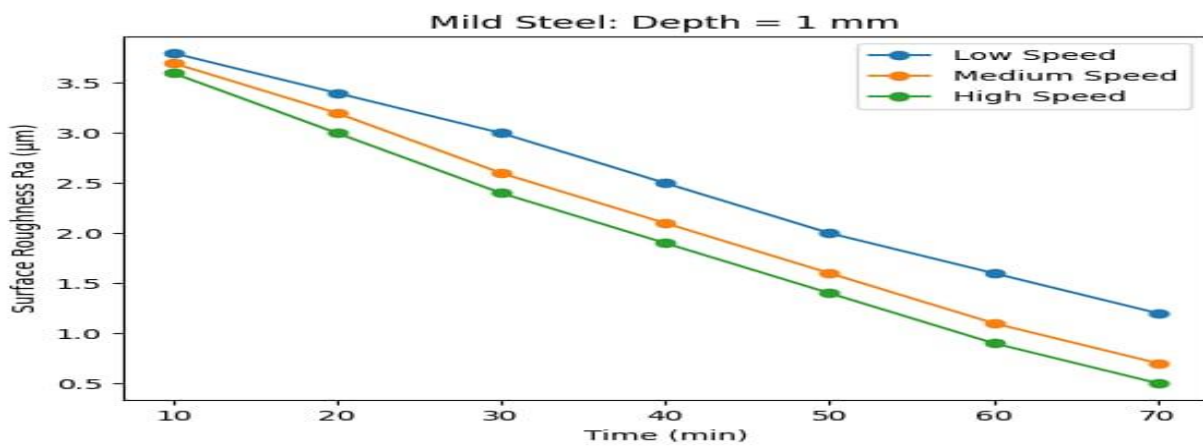


Fig 10 Surface roughness vs Time at depth of cut 1.0 mm of Mild steel

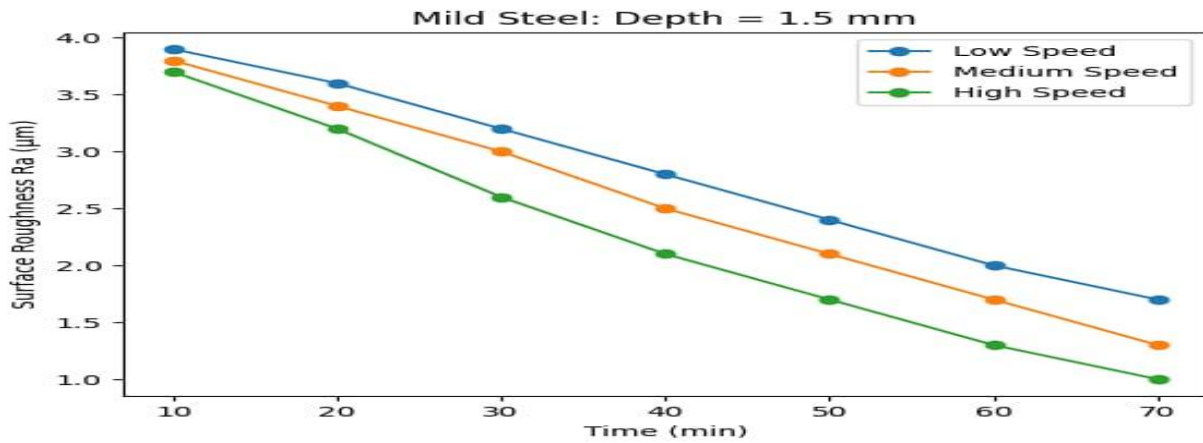


Fig 11 Surface roughness vs Time at depth of cut 1.5 mm of Mild steel

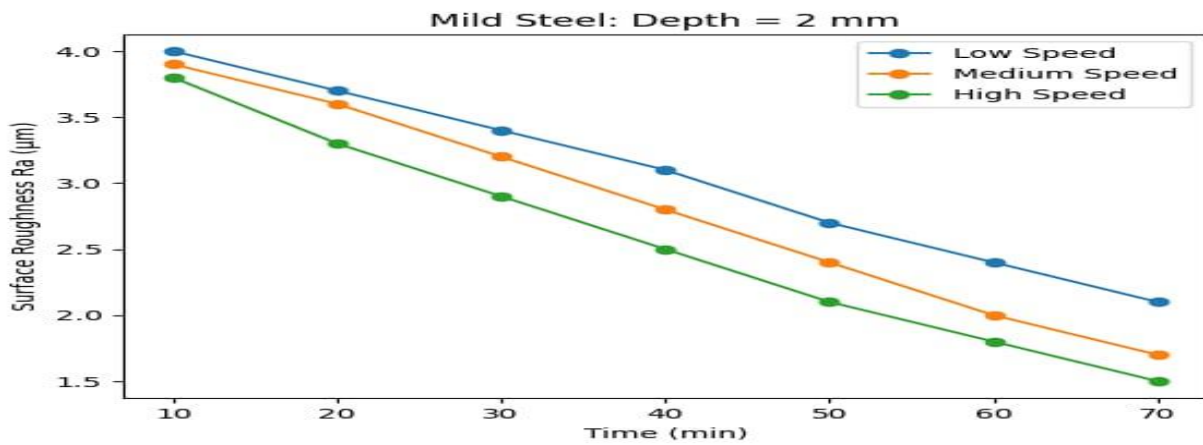


Fig 12 Surface roughness vs Time at depth of cut 2.0 mm of Mild steel

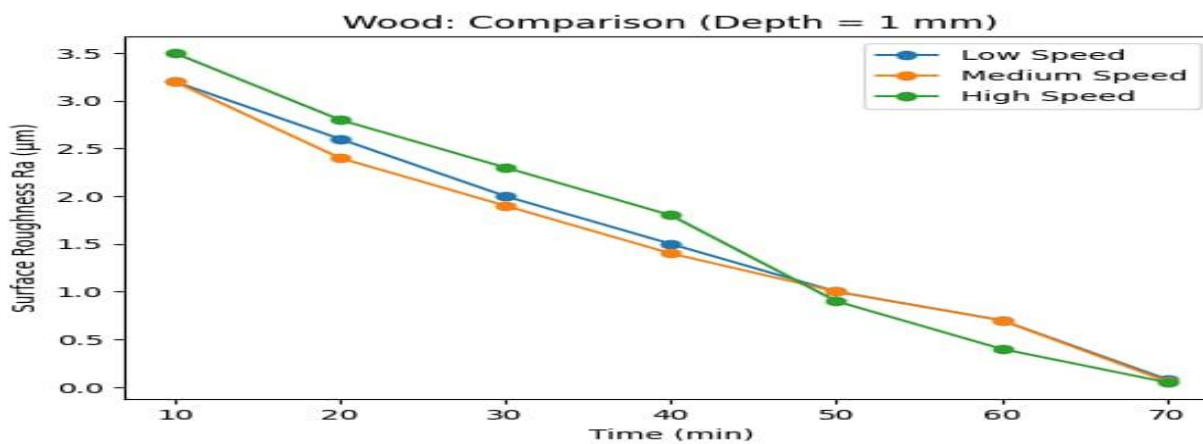


Fig 13 Surface roughness vs Time at depth of cut 1.0 mm of Wood

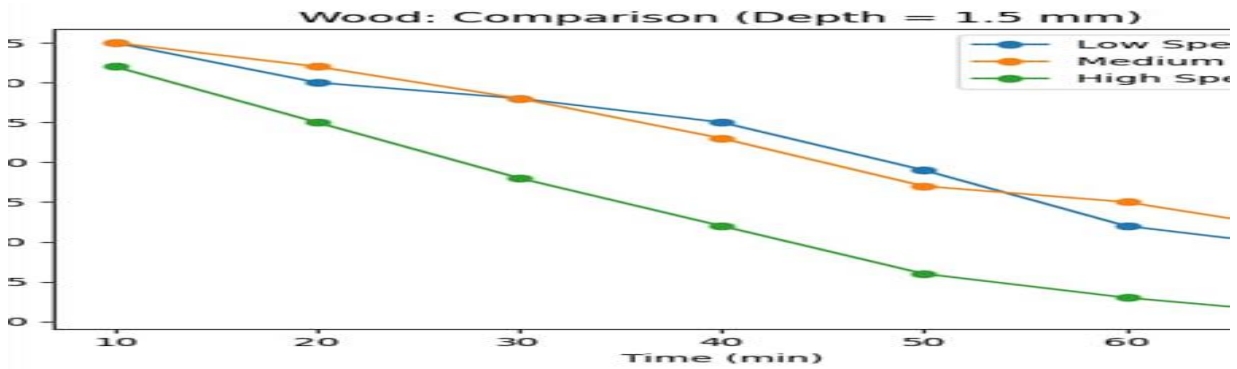


Fig 14 Surface roughness vs Time at depth of cut 1.5 mm of Wood

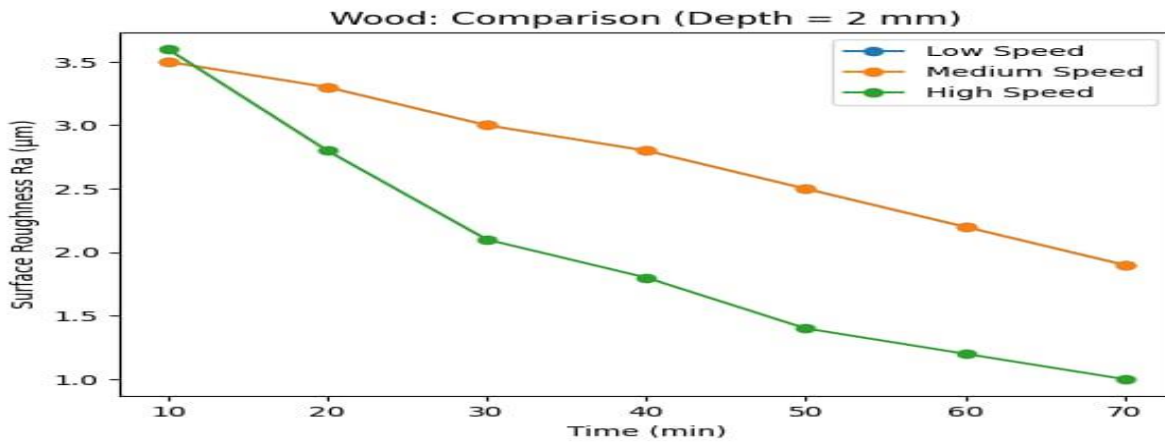


Fig 15 Surface roughness vs Time at depth of cut 2.0 mm of Wood

### 5.0 CONCLUSIONS

The design and fabrication of an Electro Magnetic Abrasive Finishing machine demonstrates an advanced and effective method for achieving high-precision surface integrity.

1. The system successfully improves surface quality by converting electromagnetic energy into a flexible abrasive force for material removal.
2. It eliminates surface irregularities and achieves a "mirror-like" finish, which significantly enhances the fatigue strength and wear resistance of components.
3. The use of Arduino-based automation makes the system highly controllable, repeatable, and easy to operate for complex geometries.
4. The EMAF process provides a cost-effective and efficient solution for finishing advanced materials where traditional grinding methods fail.

### 6.0 FUTURE SCOPE OF WORK

The development of the Electro Magnetic Abrasive Finishing machine provides a foundation for several advanced industrial enhancements. Integration with CNC and Robotic Systems for automated finishing of complex 3D industrial components and turbine blades. Optimization of Abrasive Composites using diamond-based particles or carbon nanotubes to achieve nano-level surface finishes on super-alloys. Implementation of IoT-based Monitoring to provide real-time feedback on surface roughness and magnetic field stability during operation. Scaling the System for Heavy Machinery to allow the finishing of large-scale aerospace parts and automotive engine components. Application in the Medical Sector for the high-precision polishing of surgical instruments and joint replacement implants.

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