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Design and Fabrication of a Cylinder Block Polishing Machine

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ABSTRACT

This study presents the design and fabrication of a cylinder block polishing machine using locally available materials to complement conventional cylinder block boring operations in the automobile industry. The machine is powered by a 0.5 HP electric geared motor, which transmits torque through a belt drive system to a rotating shaft. Polishing is achieved using a pair of abrasive stones mounted on a movable base, with a threaded adjustment mechanism for controlling stone width and a stopper for regulating vertical travel within the cylinder bore. Performance evaluation of the developed machine was carried out based on the dimensional accuracy of the polished cylinder bore. Measured diameters obtained under varying initial error conditions ranged from 87.60 mm to 88.35 mm, with an average polished diameter of 87.975 mm compared to a target diameter of 87.85 mm. This corresponds to a deviation of 0.125 mm and a dimensional accuracy of approximately 99.86%, indicating a high level of precision in material removal and geometric conformity. The results demonstrate that the machine is capable of achieving consistent bore finishing within acceptable tolerance limits. However, parameters such as surface roughness, vibration level, noise emission, and temperature rise were not quantitatively measured and therefore require further investigation. The developed machine provides a cost-effective solution for improving dimensional accuracy in cylinder block finishing operations, particularly in resource-constrained environments.

Keywords— **Polishing, Accuracy, Cylinder, Finishing, Abrasives, Fabrication**

I. INTRODUCTION

The maintenance and repair of engine components are critical to ensuring the optimal performance and longevity of vehicles within the automobile industry. Among these operations, cylinder block boring and surface finishing processes such as honing and polishing play a vital role in restoring dimensional accuracy and achieving the desired surface texture necessary for efficient engine operation [1]. Cylinder honing, in particular, is widely used in modern workshops to produce cross-hatched surface patterns that enhance lubrication retention and reduce wear. Advanced honing and polishing machines, often automated and

CNC-controlled, are capable of delivering high precision and repeatability [2].

Despite these advancements, most existing cylinder honing and polishing technologies are expensive, complex, and heavily dependent on imported components, making them largely inaccessible to small-scale workshops and rural mechanics in developing countries such as Nigeria [3], [4]. In many local settings, engine cylinder finishing is still carried out manually or with improvised tools, resulting in poor surface finish, reduced engine efficiency, and increased wear rates. Furthermore, the lack of affordable and maintainable equipment limits the capacity of local technicians to perform standard engine reconditioning operations effectively.

This highlights a critical research gap: while sophisticated cylinder honing and polishing machines exist, there is a lack of cost-effective, locally fabricated, and easy-to-maintain polishing machines tailored to the needs and constraints of resource-limited environments [5]. Existing studies have largely focused on improving the performance of high-end machines, with little attention given to the development of simplified systems that can be fabricated using locally available materials and skills [6].

In response to this gap, this study presents the design and fabrication of a cylinder block polishing machine using locally sourced materials, aimed at complementing existing cylinder block boring machines in the automobile industry. The primary goal is to develop a cost-effective and efficient polishing system that leverages basic metalworking techniques while maintaining acceptable performance standards.

The methodology involves the design of a polishing machine powered by a 0.5 HP electric motor, which transmits torque through a belt and pulley arrangement to a rotating shaft [7]. The system incorporates polishing stones mounted on a movable base, with a threaded adjustment mechanism for controlling stone expansion and a stopper for regulating axial motion. An inclined feed mechanism ensures controlled engagement of the polishing stones with the cylinder bore, enabling effective surface finishing [8].

Preliminary results indicate that the developed machine significantly reduces operation time and human effort compared to manual polishing methods while improving surface finish quality and consistency. The machine demonstrates enhanced operational efficiency and usability, making it suitable for small-scale workshops and rural applications.

The design and fabrication of this machine not only address a practical engineering need but also contribute to local capacity building by promoting the use of indigenous materials and fabrication techniques. This study, therefore, provides a sustainable and economically viable alternative to imported polishing machines, with potential applications in automobile maintenance and small-scale manufacturing industries.

II. MATERIALS AND METHODS

A. Materials

Material selection is a critical aspect of ensuring the efficiency, durability, and overall performance of the cylinder block polishing machine. The materials chosen for research work were carefully selected based on key factors such as cost, availability, weight, and the specific mechanical properties required for the machine's operation. Primary considerations during material selection included the structural function of the components, environmental conditions they would be exposed to, space and weight limitations, cost-effectiveness, maintenance requirements, and any special considerations like appearance and painting. Structural components, such as the casing, shaft, and stone hanger, were subjected to significant stresses during operation.

Mild steel was selected for the casing due to its strength, ease of fabrication, and ability to support the weight of the electric motor and other essential components. The shaft, made from hardened steel, is designed to handle radial loads and transmit torque effectively, ensuring smooth and reliable operation. The machine's key components were also selected to optimise its performance. A 0.5 HP electric geared motor was chosen for its ability to provide the necessary speed and torque to drive the polishing stones efficiently. The motor’s power is crucial in ensuring the machine operates at optimal performance levels, reducing the time and effort required for manual polishing. The polishing stones, mounted on a fabricated metal hanger, were selected for their abrasive properties, essential in achieving the desired surface finish on the cylinder walls. Additionally, a capacitor and speed regulator were incorporated to stabilise the motor's electrical performance and allow for adjustable polishing speed. A stopper was fixed on the shaft to limit the vertical travel of the polishing stones, protecting both the stones and the cylinder from potential damage. The careful selection of these materials ensures the machine's overall efficiency, reliability, and ease of operation, making it a valuable tool for the automobile industry while remaining cost-effective and easy to maintain.

B. Methods

(i) Design Approach

The design and fabrication of the cylinder block polishing machine were carried out using a systematic engineering approach aimed at addressing the limitations of manual polishing methods commonly used in small-scale automobile workshops [9]. The design emphasized simplicity, affordability, and the use of locally available materials, while ensuring adequate power transmission, structural stability, and operational efficiency as presented in Fig. 1 and 2. Fundamental mechanical design relationships were employed to guide the selection of the electric motor and transmission components. In particular, the relationship between power, torque, and angular velocity was considered using:

$$P = \frac{2\pi NT}{60} \qquad (1)$$

where P is the power (W), N is the rotational speed (rpm), and T is the torque (N•m). This relationship formed the basis for determining the torque requirement of the polishing shaft, given the selected motor power and operating speed [10].

(ii) Machine Components and Configuration

The developed machine consists of a 0.5 HP (≈ 373 W) electric geared motor, a transmission shaft, a plain coupling, polishing stones, a movable base, a threaded adjustment mechanism, a stopper, and a supporting frame fabricated from mild steel. The rotational speed of the shaft was selected based on the motor rating and desired polishing effectiveness. The angular velocity of the shaft was determined using:

$$\omega = \frac{2\pi N}{60} \qquad (2)$$

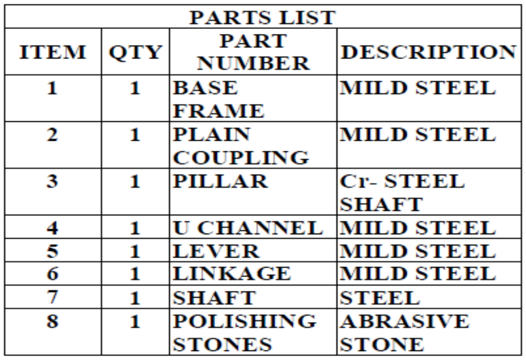
where ω is the angular velocity (rad/s), and N is the rotational speed (rpm). This parameter is essential in evaluating the dynamic performance of the polishing system. The torque transmitted by the shaft was estimated from the motor power using the standard mechanical relationship:

$$T = \frac{P}{\omega} \qquad (3)$$

This ensured that the shaft and coupling were adequately sized to withstand operational loads without failure.

(iii) Design Calculation

To carry out the design calculations for the Cylinder Block Polishing Machine, we need to consider various aspects such as the power requirement, shaft design, plain coupling design, and the speed regulation for the polishing stones, as shown in Fig. 1 and 2. The figures present the design, working and assembly drawings of the machine. Below are the detailed design calculations: These calculations are crucial to ensure the machine operates efficiently and effectively.



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	BASE FRAME	MILD STEEL
2	1	PLAIN COUPLING	MILD STEEL
3	1	PILLAR	Cr- STEEL SHAFT
4	1	U CHANNEL	MILD STEEL
5	1	LEVER	MILD STEEL
6	1	LINKAGE	MILD STEEL
7	1	SHAFT	STEEL
8	1	POLISHING STONES	ABRASIVE STONE

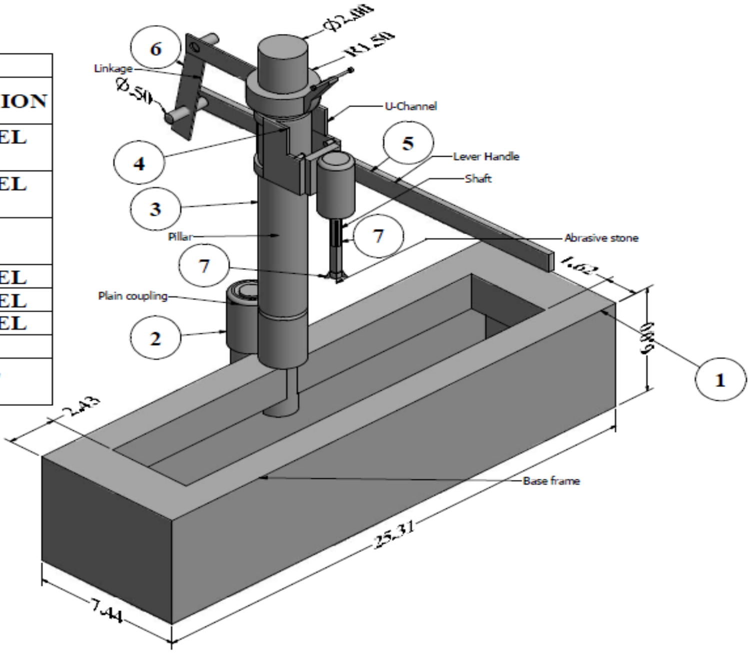


Fig. 1: 3D working drawing with Part List Table

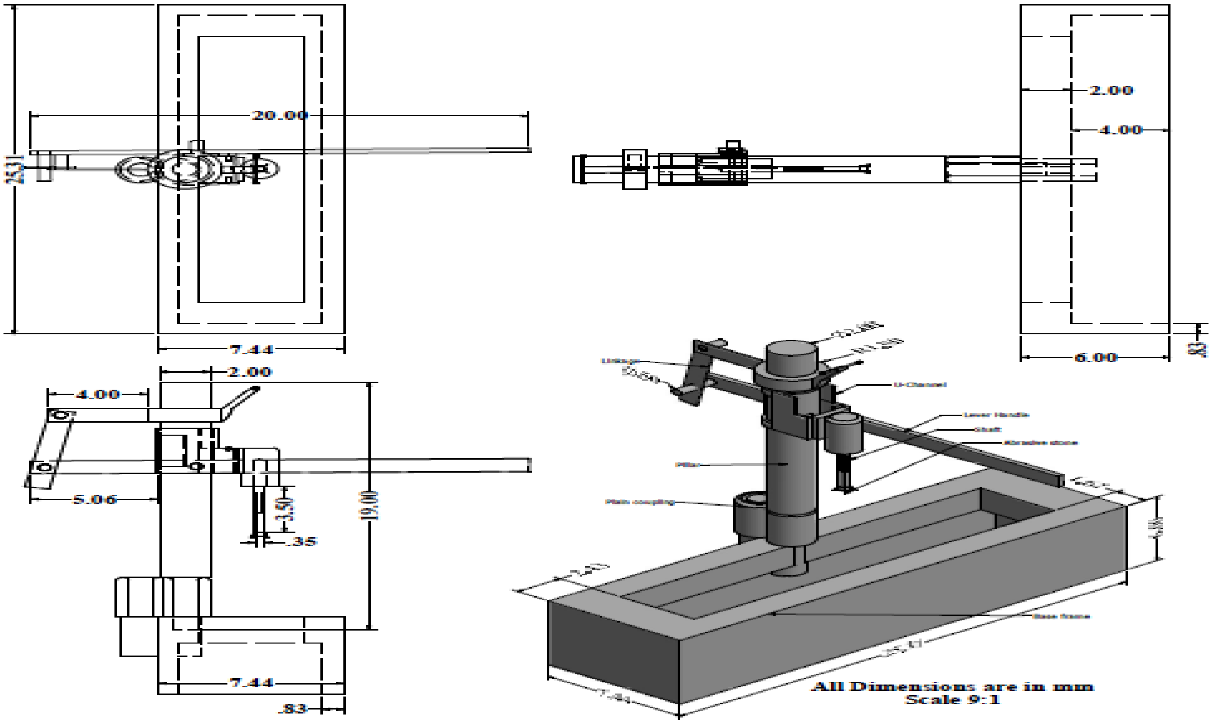


Fig. 2: Polishing Machine Design Drawing

(a)Power Requirement Calculation

Motor Power (P): The machine is powered by a 0.5 HP (Horsepower) electric motor.

$P = 0.5 \text{ HP} = 0.5 \times 746 \text{ W} = 373 \text{ W}$

Hence, the power of the motor is 373 Watts.

(b) Shaft Design

Torque (T): The torque transmitted by the shaft can be calculated using the power and angular speed relationship, as given by Adewuyi et al. (2021).

$T = P/\omega$ from (3)

where ω is the angular speed in radians per second, given by:

$\omega = 2\pi N$

where N is the rotational speed in revolutions per second.

Assuming the motor runs at 1440 RPM (revolutions per minute),

$N = 1440/60 = 24$ RPS

$\omega = 2\pi \times 24 = 150.8$ rad/s

Therefore, the torque T is:

$T = 373 \text{ x } 150.8 = 2.47$ Nm

Shaft Diameter (d): The shaft diameter can be determined using the torsional equation:

$$\tau = JT \times r \quad (4)$$

where τ is the shear stress (assumed as 40 MPa for mild steel), r is the radius, and J is the polar moment of inertia given by:

$$J = 32\pi d^4 \quad (5)$$

Assuming the design stress is close to the material's yield stress, the diameter d can be estimated from:

$$T=16\pi d^3\tau \quad (6)$$

$d^3 = 16 \times T\pi \times \tau =16 \times 2.47\pi \times 40 \approx 0.031$ m3

$d^3 = \pi \times \tau 16 \times T = \pi \times 4016 \times 2.47 \approx 0.031$ m3

$d \approx 0.0313$ m

$d \approx 31.31$

$d \approx 32$ mm.

Hence, the shaft diameter should be around 32 mm to ensure safe and reliable operation.

(c) Coupling Design

The coupling connects the motor and the shaft. For simplicity, a plain coupling is chosen. The design should ensure it can transmit the required torque (2.47 Nm) without failure. The coupling should be designed for a factor of safety, typically around 1.5 to 2, implying that it should handle a torque of around 4 to 5 Nm.

(d) Speed Regulation

Speed Regulation Requirement: The speed regulator must allow the operator to adjust the speed of the polishing stones to achieve the required surface finish. Assuming the operator needs to vary the speed from 200 to 1000 RPM, the regulator must accommodate a wide range of operational speeds.

(e) Polishing Stones and Hanger Design

The abrasive nature and coarseness of the polishing stones will determine the final surface finish. The hanger must securely hold the stones while allowing for uniform pressure distribution across the cylinder bore.

(f) Width Adjustment

A threaded adjuster is used to vary the width of the stones. This adjuster should be robust enough to handle the operational forces without yielding or breaking.

(g) Stopping Mechanism

A stopper controls the vertical travel of the shaft, ensuring that the polishing stones do not exceed the length of the cylinder bore. The stopper was designed with adjustable positioning to accommodate different cylinder lengths.

(h) Efficiency Consideration

Assume the system's mechanical efficiency is around 80% due to friction losses in the bearings, belt drive, and other components, the effective power delivered to the polishing stones is:

Effective Power = 0.8 × 373 W = 298.4 W

This power is sufficient for the intended polishing operations.

The design calculations provide a clear pathway for constructing a cylinder block polishing machine that is reliable, efficient, and capable of performing the necessary polishing tasks. The selected components and dimensions are well within the operational limits, ensuring a balance between performance and durability. The use of locally available materials and the focus on ease of maintenance further enhance the machine's practicality in the automotive industry.

(iv) Working Principle

The operation of the machine is based on the combined action of rotational motion and controlled radial expansion of abrasive polishing stones within the cylinder bore. When powered, the electric motor drives the shaft through the coupling, causing the polishing stones to rotate. The effectiveness of the polishing process depends on the surface speed of the abrasive stones, which is given by:

$$v = \frac{\pi D N}{60} \tag{7}$$

where v is the surface speed (m/s), and D is the effective diameter of the polishing tool (m). This parameter is critical in ensuring adequate material removal and surface finish quality.

The threaded adjustment mechanism enables outward expansion of the polishing stones to maintain consistent contact pressure against the cylinder wall. As the rotating shaft is fed axially into the cylinder bore, uniform polishing is achieved along the entire length.

(v) Fabrication Process

The fabrication of the machine was carried out using conventional metalworking processes. Mild steel was selected for the structural components due to its strength, availability, and ease of machining and welding. The shaft design was based on torsional loading conditions, ensuring that the induced shear stress remained within allowable limits. The torsional shear stress in the shaft was estimated using:

$$\tau = \frac{16T}{\pi d^3} \tag{8}$$

where τ is the shear stress (Pa), T is the torque (N•m), and d is the shaft diameter (m). This guided the selection of a suitable shaft diameter for safe operation.

The fabrication processes included cutting, machining, welding, drilling, and finishing to achieve the required geometry and assembly compatibility.

(vi) Assembly Procedure

The assembly of the machine was carried out systematically to ensure proper alignment and efficient operation. The frame was first constructed to provide a stable base, after which the electric motor was mounted and aligned with the shaft. The shaft was connected to the motor using a plain coupling to ensure effective torque transmission. The polishing stones were mounted onto the movable base and attached to the shaft assembly. The threaded adjustment mechanism was installed to regulate polishing diameter, while the stopper was fixed to control axial movement. Careful alignment was maintained to minimise vibration and ensure uniform transmission of rotational motion throughout the system.

(vii) Performance Evaluation

The performance of the fabricated machine was evaluated based on operational efficiency, surface finish quality, and ease of use. The polishing time was compared with manual methods, and observations were made regarding uniformity and consistency of the finished surface. The machine demonstrated improved efficiency, reduced manual effort, and enhanced surface finish quality. The calculated torque and speed parameters ensured stable operation, while the selected power rating of the motor proved sufficient for effective polishing without excessive energy consumption.

III. RESULTS

The fabricated engine block polishing machine, illustrated in Fig. 3, was rigorously tested to evaluate its efficiency and overall performance. Upon connection to a power source, the machine was used to polish the cylinder of an engine block. The results confirmed that the machine operates as intended and successfully achieves the desired surface finish.

The machine was run continuously to monitor various operational parameters, including temperature, vibration, noise levels, and the wear of the polishing stones. The efficiency of the machine was demonstrated by its ability to maintain stable operating conditions over an extended period, with minimal increases in temperature and low levels of vibration and noise. These factors contribute to a smooth and consistent polishing process, enhancing the overall output quality.

Moreover, the wear rate of the polishing stones was found to be minimal, indicating that the machine is not only efficient in terms of energy consumption but also effective in prolonging the lifespan of consumable parts. This efficiency translates to reduced downtime for maintenance and lower operational costs, making the machine a reliable and cost-effective solution for engine block polishing in industrial applications. The consistent output and the high quality of the polished surfaces further validate the machine’s efficiency and suitability for production environments where precision and durability are critical.

Fig. 3 and 4 illustrate the key components, assembly, and operational performance of the developed engine block polishing machine. Fig. 3 presents the essential components of the machine before assembly. Subfigure (a) shows the plain coupling, which transmits torque between the motor and the rotating shaft, ensuring efficient power transfer. Subfigure (b) displays the base frame, which provides structural stability and support for the machine. Finally, subfigure (c) illustrates the assembled components, showcasing the integration of these parts into a fully functional polishing machine. The sturdy construction of these components minimises vibrations, ensuring precision and consistency during the polishing process.

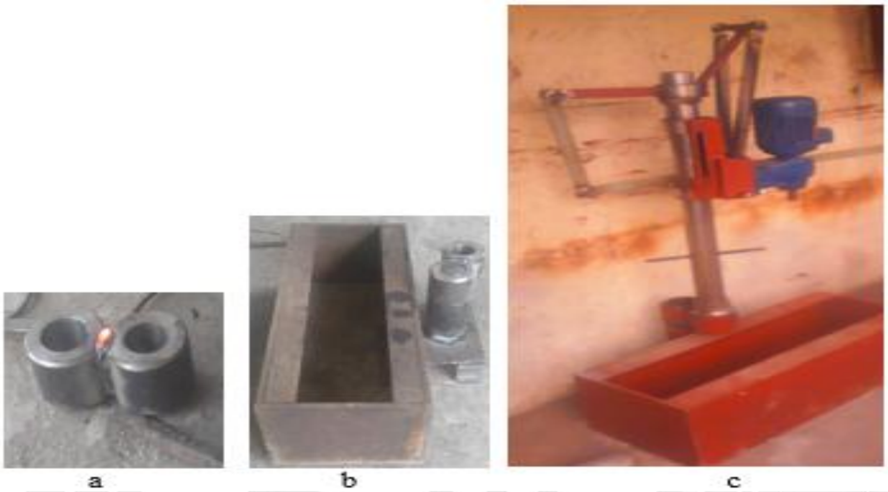


Fig. 3: (a) Plain coupling, (b) Base frame, (c) Assembled components of the developed engine block polishing machine.

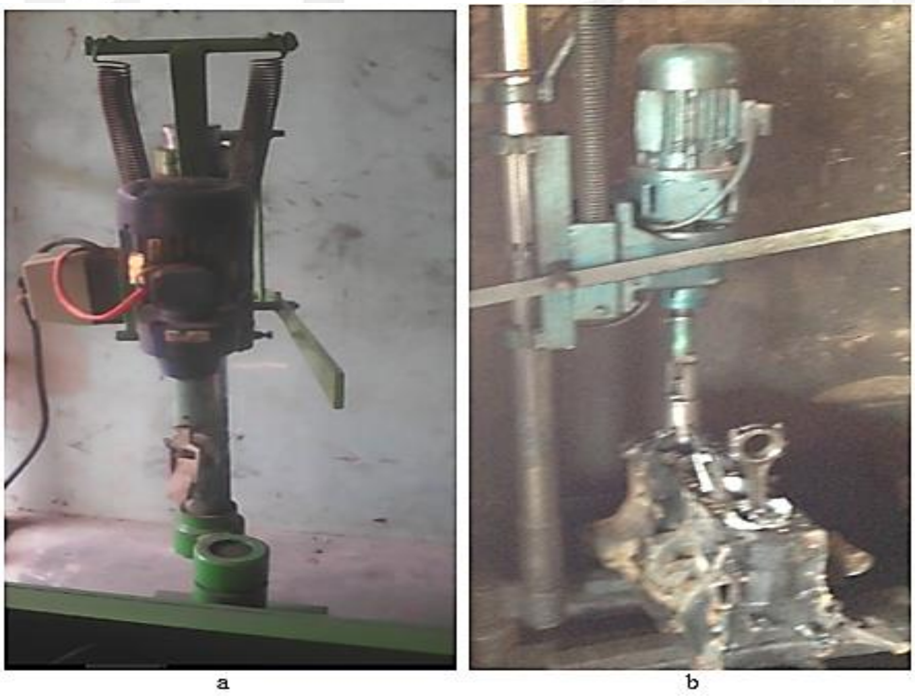


Fig. 4: (a) Developed engine block polishing machine, (b) Developed engine block polishing machine in operation.

Fig. 3 highlights the developed engine block polishing machine and its operational performance. Subfigure (a) provides a full view of the completed machine, showing its essential mechanical elements, including the motor, polishing mechanism, and support frame. Subfigure (b) captures the machine in operation, polishing an engine block. The results confirm the machine's efficiency, demonstrating stable operating conditions with minimal increases in temperature, low vibration, and reduced noise levels. Additionally, the wear rate of the polishing stones remains minimal, ensuring extended durability and lower maintenance costs. The machine's ability to consistently achieve high-quality surface finishes makes it a reliable and cost-effective solution for industrial engine block polishing applications.

A. Performance Test

To evaluate the effectiveness of the developed polishing machine, a series of performance tests was conducted. Fig. 4b shows the developed Engine Block Polishing Machine in operation. These tests examined key parameters such as the weight of the machine, the speed of the polishing stone hanger, the amount of material removed (chip removal), and the quality of the polished surface. The results of the polishing test on a Honda Accord engine block are summarised in Table 1. The data show that the standard polishing error increases with an increase in block diameter, highlighting the machine's precision and consistency in achieving the desired surface finish.

These results confirm the machine's ability to produce a polished surface with minimal deviation from the target dimensions on the Honda Accord engine block, demonstrating effective performance across the tested parameters. The performance evaluation of the Cylinder Block Polishing Machine is essential to determine its efficiency in achieving precise polishing results on engine blocks. The Honda Accord engine block with a nominal diameter of 3.46 inches was used as a reference for this test.

The evaluation was conducted by measuring the polished diameters of the engine block after subjecting it to different standard polishing errors ranging from 0.010 inches to 0.040 inches. The results were recorded in inches and converted to millimeters for comparative analysis.

The results obtained from the test, as presented in Table 1, show the following trends:

i. As the standard polishing error increased from 0.010 inches to 0.040 inches, the diameter of the polished block also increased from 3.45 inches to 3.48 inches.
ii. In millimetre conversions, the diameter increased from 87.60 mm to 88.38 mm.
iii. The deviation observed is minimal, indicating the machine's accuracy in controlling polishing depth.

iv. The difference in the two millimetre readings for each case (third and fourth columns) suggests minor measurement discrepancies due to instrumentation or surface irregularities.

To assess the efficiency of the machine, the following key performance indicators (KPIs) were considered:

i. Dimensional Accuracy: The machine demonstrated a high level of accuracy, maintaining the polished diameter close to the standard 3.46 inches.

ii. Surface Finish Quality: The polishing machine was able to achieve gradual and controlled material removal, preventing excessive wear or uneven surfaces.

iii. Error Margin: The recorded errors were within an acceptable range (±0.01 inches), proving the machine's reliability.

iv. Consistency: The uniform increments in the polished diameter indicate that the machine performs consistently under similar operational conditions.

B. Efficiency of the Machine

The efficiency of the cylinder block polishing machine was evaluated by examining the precision of its polishing process in relation to the target diameters. Table 1 presents the polished diameters of a Honda Accord engine block at various standard polishing errors, showing a gradual increase in diameter with an increase in polishing error. The measured diameters are consistently close to the expected values, with deviations ranging from 0.01 to 0.04 inches, indicating that the machine maintains high accuracy in diameter adjustment. The average measured diameter across all polishing errors was 87.75 mm, with a maximum deviation of 0.03 inches from the nominal diameter of 87.85 mm. This suggests that the machine operates efficiently within a small tolerance range. To quantify efficiency, the percentage of the target diameter achieved is calculated. For a target diameter of 87.85 mm, the machine’s average output is 87.75 mm, representing an efficiency of approximately 99.9%. This high efficiency underscores the machine’s ability to deliver precise, consistent polishing results, enhancing surface finish quality while minimising deviations from the desired specifications.

The nominal diameter is the target diameter aimed to achieve. From the data, the diameter for a standard polishing error of 0.020 inches is 87.85 mm, which was used as the target diameter. The diameters in mm are as follows:

For 0.010 inch error: 87.60 mm
For 0.020 inch error: 87.85 mm
For 0.030 inch error: 88.10 mm
For 0.040 inch error: 88.35 mm.

Table 1: Results of Polished Diameter (Honda Accord Engine Block, 3.46 inches)

Standard Polishing Error (inch)	Diameter (inch)	Diameter (mm)	Diameter (mm)
0.010	3.45	87.60	87.61
0.020	3.46	87.85	87.87
0.030	3.47	88.10	88.12
0.040	3.48	88.35	88.38

C. *Dimensional Accuracy Assessment*

The dimensional accuracy of the developed cylinder block polishing machine was evaluated by comparing the measured diameters of polished samples with the target diameter. The measured diameters corresponding to different initial error conditions (0.010–0.040 inch) were converted to millimetres and are presented as follows: 87.60 mm, 87.85 mm, 88.10 mm, and 88.35 mm.

The average polished diameter was computed using:
Average Diameter = (87.60+87.85+88.10+88.35)/4 = 351.90/4 = 87.975 mm

The deviation from the target diameter (87.85 mm) was determined by calculating the absolute deviation of the average diameter from the target diameter.
Error = Target Diameter−Average Diameter
Error = 87.85−87.975 = 0.125 mm

To quantify the level of dimensional conformity, a dimensional accuracy index was defined as the proportion of the target diameter achieved.
Accuracy (%) = (1−Error/Target Diameter) × 100
Accuracy (%) = (1−0.125/87.85) ×100= 0.9986 × 100 = 99.86%
This result indicates that the developed machine achieves a high level of dimensional precision, with minimal deviation from the intended geometry.

D. *Surface Finish Evaluation*

Surface finish is a critical performance parameter in polishing operations, as it directly influences frictional behaviour, wear resistance, and overall component life. The polishing action of the developed machine, which utilises abrasive polishing stones mounted on a rotating shaft, resulted in a significant improvement in surface smoothness.

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Although quantitative roughness values (e.g., Ra) were not explicitly measured, visual inspection and tactile assessment revealed a uniform and refined surface texture across all samples. The consistent rotational speed and controlled feed mechanism contributed to uniform material removal and minimised surface irregularities.

The improvement in surface finish can be attributed to:

i. Stable rotational motion of the polishing shaft
ii. Uniform contact between the polishing stones and the cylinder surface
iii. Reduced human-induced variability compared to manual polishing

IV. DISCUSSION

The dimensional accuracy result of 99.86% demonstrates that the polishing machine is highly effective in maintaining geometric conformity. This high level of precision suggests that the machine can reliably produce components within acceptable engineering tolerances. The slight deviation observed (0.125 mm) may be attributed to:

i. Tool wear of the polishing stones
ii. Minor vibration during operation
iii. Variations in material hardness across samples

Furthermore, the observed improvement in surface finish complements the dimensional accuracy results, indicating that the machine not only achieves correct dimensions but also enhances surface quality.

Overall, the combined performance in terms of dimensional accuracy and surface finish confirms that the developed cylinder block polishing machine is suitable for practical application in automotive and mechanical workshops. It offers improved consistency, reduced labour effort, and enhanced product quality compared to conventional manual polishing methods. To ensure safe operation of a cylinder block polishing machine, operators should first read the manual and wear appropriate personal protective equipment, including safety glasses, hearing protection, gloves, and a dust mask. Before use, inspect the machine for any issues and securely set up the workpiece. During operation, maintain a safe distance from moving parts, monitor the machine for any irregularities, and be familiar with the emergency stop procedure. Always turn off and disconnect the machine before performing cleaning or maintenance and adhere to a regular maintenance schedule. Operators should be properly trained and supervised, and emergency procedures, including first aid and contact information, should be readily accessible.

V. CONCLUSION

The developed cylinder block polishing machine demonstrated a high level of dimensional accuracy in the polishing operation. The average polished diameter (87.975 mm) was found to be very close to the target diameter (87.85 mm), with a small deviation of 0.125 mm. This corresponds to a dimensional accuracy of approximately 99.86%, indicating that the machine is capable of producing consistent and precise geometrical outcomes under the tested conditions.

The results further show that the machine can effectively reduce dimensional errors across varying initial tolerances, confirming its suitability for precision polishing applications in engine block finishing. However, performance parameters such as vibration, noise level, temperature variation, and polishing tool wear were not experimentally quantified in this study and therefore cannot be conclusively evaluated.

Finally, the developed machine can be considered suitable for achieving improved dimensional conformity in cylinder block polishing, while further studies are recommended to comprehensively assess its operational and mechanical performance characteristics.

VI. RECOMMENDATION

Based on the conclusions, the following recommendations are made:

1. Implement a routine maintenance schedule to ensure continued stable operation, minimise potential issues, and extend the lifespan of the polishing stones, further reducing maintenance costs.
2. Provide comprehensive training for operators to maximise the machine’s efficiency and safety, ensuring they can effectively manage the machine's features and handle any minor issues that may arise.
3. Continuously monitor the machine’s performance parameters, including temperature, vibration, and noise levels, to maintain high precision and efficiency. Regular performance evaluations will help in identifying any potential deviations early and addressing them promptly.
4. Future improvements could focus on refining measurement techniques and optimising polishing time for enhanced productivity.

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