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Development of an Engine Block Polishing Machine Using Locally Sourced Material

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Abstract—*The design of a cylinder bore-type polishing machine from a locally sourced material is presented in this paper work. Polishing of an engine block cylinder is necessary after undergoing boring operation to eliminate uneven surface of the cylinder wall. The polishing machine is powered by an electric motor of 1 H.P, the motor transfers torque to the pulley with the aid of a belt drive. A pair of polishing stone is provided with a movable base coupled to the rotating shaft which has a stopper that determines the vertical length at which it travels. The threaded adjuster was incorporated to determine the width of the polishing stone. An inclined iron bar feeds the shaft into the cylinder bore. Thus, the polishing cylinders are moved along with the base and rotated by the actuation of the rotary drive motor for smoothing the engine cylinder with the aid of abrasives. The application of this machine will eliminate manual methods, reduces the operation time, human effort and enhances smooth polishing accuracy.*

Keywords— *Abrasive, Block, Cylinder, Design, Engine, Motor, Polishing and Stone.*

I. INTRODUCTION

A cylinder is the central working part of a reciprocating engine or pump, space in which a piston travels. Multiple cylinders are commonly arranged side by side in an engine block (Raja *et al*., 2017). A cylinder or block is an integrated structure comprising the cylinder(s), and often some or all of their associated surrounding structures that comprises of the coolant passages, intake and exhaust passages, ports, and crankcase. Polishing is an abrasive machining process that produces a precision surface on a metal work piece (cylinder) by scrubbing an abrasive stone against it along a controlled path. Polishing is primarily used to improve the geometric form of a surface, but may also improve the surface texture.

After tens of thousands of miles, the cylinder bores can become worn, tapered or scratched (Rands, 2018). An engine which has developed cylinder wear will find lubrication oils and exhaust gases passing the rings, when this occurs, a reduction in power output and increased oil consumption in the engine will be experienced. It is required to bore or sleeve the cylinder, that's why boring a cylinder to reclaim the already worn out portion of the cylinder through inserting sleeves into the cylinder bore. The cylinders which require sleeves have to be re-bored, to make room for the cylinder sleeve. The cylinders are then inserted using a hydraulic press; thereafter the sleeve is polished to ensure a smooth surface inside the cylinder (Pravalika *et al*., 2016). Polishing is to make the wall as smooth as possible without tapering, the bores as round as possible (minimal distortion, which is especially important with low tension rings), to have the rings amount of crosshatch for good oil retention and ring support, and to produce a surface finish that meets the requirement of the rings (Carley, 2000). .

A lot of experimental works had been done on engine block polishing including; that of Hosnedl, (2018): which defined bore polish as being evidence by clearly defined areas of bright mirror finish. It is a machining activity after engine block sleeving and boring process. They went on further to define the visual rating of bore polishing as either light, medium, or heavy polish. Wilson and Callow (1976) stated that bore polishing is characterized by a bright smooth (mirror) finish of less than 0.125μm in C.L.A. value, with a total absence of cross hatch pattern. Different intensities of polishing can occur and a broad scale of reference has been agreed as follows: Light Polish, Medium Polish, and Heavy Polish. As the surface progresses through the various degrees of polish, the overall roughness decreases. This can be explained by the fact that rotating motion of the abrasive polishing stone removes the majority of the roughness on the cylinder liner surface. Yang *et al.,* (1999) analyzed the stability of the cutting system with an oscillating cutter which is used to suppress chatter in a cutting process and also it enhances the stability of the cutting system by properly increasing time varying magnitude and frequency of the oscillating cutter. Taylor and Eyre, (1979) explored experimentally about the mechanics of boring process on Cast Iron automotive Engine cylinders and concluded that by selecting proper cutting conditions, cutting forces can be controlled below a threshold value, tool life and part quality can be increased. Vignesh *et al.,* (2017) studied the improvement of damping capability of boring tools and suppression of chatter vibration using impact dampers and also conducted experimental test by varying the method of applying an impact damper to a boring tool they also investigated about the effects of amount of free mass and clearance, the overhang length of the boring tools and the cutting conditions. In this work of an engine block cylinder polishing machine has been developed. The polishing machine of the cylinder is achieved by a pair of polishing device known as abrasive stone.

II. METHODOLOGY

This aspect of the work is committed to the assumptions made for the various design parameters, design consideration for the function ability of the polishing machine and the design calculation of the parts of the machine. In machine design and construction, there are numerous considerations that are being made as well as assumptions. These considerations are in area of the choice of design, material selection with respect to its properties, load to be overcome by the machine, safety of operation, cost of construction friction resistance and lubrication, etc. However, in this design, the machine fabrication, its operation, material selection were carefully done bearing in mind the operation of the machine. Also, the condition considered in this regards were the tendency of the chosen material to fracture under fatigue, resistance to wear during operation, corrosion when in contact with moisture. Three design factors of the machine was selected for development in this project, they are; the speed of the polishing operation, weight of the machine and power transmission

2.1 Material Selection

Material selection plays an important role in the construction and performance of any equipment or design work. The selection of materials for this project was on the design consideration parameters cost, capacity, weight and availability. Choice of materials used for the machine part depend on the following consideration; general function that is for structural, bearing, sealing, heat-conducting and space filling secondly, environment which involve loading, temperature and temperature range, exposure to corrosive condition or to abrasive, wear-life and expectancy. Thirdly are space and weight limitations, fourthly is the cost of the part, maintenance and its replacement and lastly is a special consideration that deals with appearance and painting colour. Material whose essential function is to carry relatively high stresses will here be classed as structural i.e. casing, shaft and stone hanger. The heavily stressed materials include those that carry and transmit the forces and torques developed by the belt used powered by electric motor. The success of the structural materials is measured by their resistance to structural failure. The machine components and their relative function are listed and explained accordingly, which includes; firstly, bearing, this is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The bearing used in this project is the plain bearing which consists of a hole in which the shaft rotates. The shafts to transfer radial load from the pulley which has its source of rotating motion from the electric motor with the aid belt drive. When the shaft rotates it should be mounted in bearings which allow rotation, reduce friction to a low level and educe wear of both shaft and bearings to an acceptable level. Secondly is the electric motor, it is an electrical machine used to convert electrical energy to mechanical energy. As regard this work, an electric motor capacity between 0.75 – 1.0 Horse Power is suitable for use. The 1 H.P was selected for high speed, high voltage and efficiency of the machine. Thirdly, the frame or casing, material selected for the casing of this project is the metal plate (Mild Steel) of suitable thickness to accommodate the weight of electric motor and capacitor. It is also selected to ensure the stability, easy welding process and efficiency of the polishing machine. Fourthly, the spring adjuster, this is a device used in coil springs to operate as spring lifter, to eliminate sag by restoring spring function and resist compression of the coil spring. It is made welded metal with hollow center of diameter 5mm. Fifthly, the stone hanger is a fabricated metal which exist in the form on of a fork with two gong each at the center of the gongs has a cutting stone fastened with bolt and nuts. The coarseness of the cutting stone depends on the expected surface finish of the cylinder during polishing operation. Sixthly, the belt, it is a loop of flexible material used to link two or more rotating shafts or pulley mechanically, most often parallel. The V belt is selected for power transmission in the design of this project because; its ability to transmit power efficiently, improved torque transmission, provide solution to slippage and alignment problems and provide the best combination of traction, speed of movement, load of the bearings, and long service life. Seventhly, the capacitor, it is used temporarily to store electrical energy in an electric field widely used as part of electric circuits in many electrical device. It is a passive two terminal electric component separated by a dielectric insulator that can store electrical energy by becoming polarized. The capacitor used in this project acts to influence the biasing voltage transistor’s base; the resistance values the voltage-divider resistors and the capacitance value of the capacitor together control the oscillatory frequency of the electric motor. Ninthly, is the speed regulator, it is the switch that allow user to select the output by controlling the speed of an electric motor by placing a potentiometer or rheostat between the motor and the power source. Adjusting the potentiometer or rheostat changes its resistance value and alters the voltage. Hence, rotating speed of the polishing stone hanger is regulated. Tenthly, the pulley, is a wheel on an axle or shaft that is designed to support movement and change direction of a cable rope or belt along its circumference. Pulley are used in a variety of ways to loads apply forces, and to transmit power. The drive element of the pulley used in the design of this project work is the belt that runs over two pulleys, one which is fixed on the electric motor with the aid of the key, and the other fixed on the rotating shaft in such a way that it has free vertical movement along the shaft during the machine operation. Lastly is the stopper, this component is fixed on the shaft with the aid of the bolt to limit or control the downward traveling of the shaft during machine operation. The stopper is set variably on the rotating shaft according to the length of the cylinder bore. It prevent the polishing stone from traveling beyond the length of the bore being polished hence preventing the damaging of the polishing stone.

2.2 Design Calculation

The polishing machine as discussed comprises of the shaft, electric motor, casing, spring adjuster, stone hanger, belt, capacitor, speed regulator, pulley and stopper as shown in Fig. 1. The figure presents the design working diagram of the machine.

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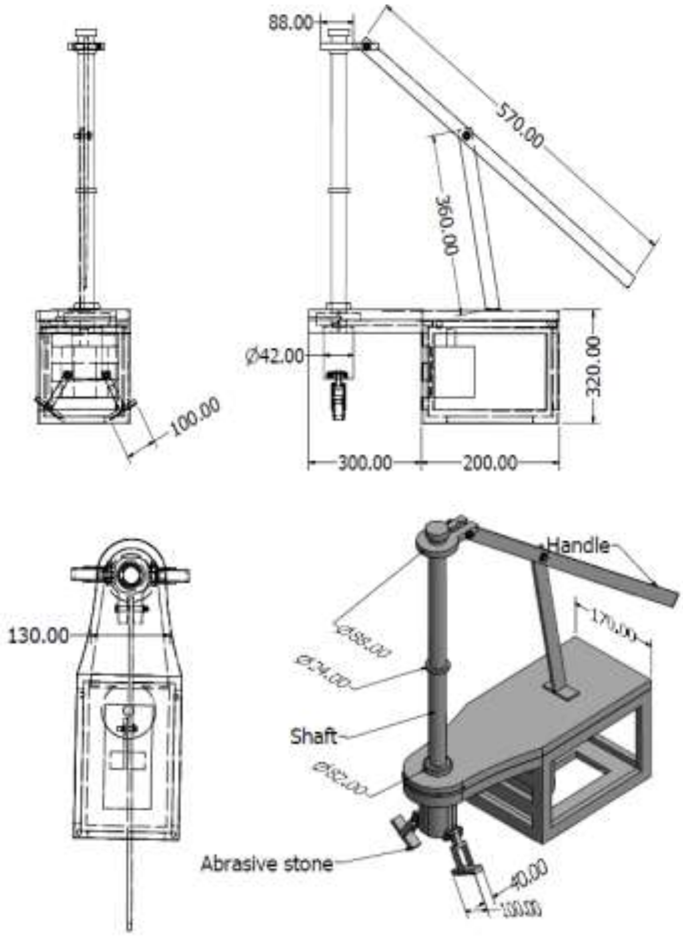

Fig. 1. Polishing machine design diagram.

Shaft Design A shaft is a rotating member, usually of circular cross section, used to transmit power or motion. It provides the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and controls the geometry of their motion. The equation used to determine the shaft diameter is written in is given in equation 1 by Bhandari, (2010); Khurmi and Gupta, (2005) and Ejiko *et al.*, (2009).

$$d^3 = \frac{16}{\pi \times S_u}\left(\sqrt{(K_t M_t)^2 + (K_b M_b)^2}\right) \quad (1)$$

where,
d= shaft diameter
K_t= stress combine shock and fatigue factor for torsion
K_b = stress combine shock and fatigue factor for bending
M_b = maximum bending moment (16.5 Nm)
M_t = maximum twisting moment (193.6 Nm)
S_u = Ultimate tensile strength of steel is 56MPa
K_b = 1.5, K_t = 1.0 as given by Hall *et al.,* (1983) in ASME design shaft code

$$d^3 = \frac{16}{\pi \times 56 \times 10^6}\left(\sqrt{(1.5\times 193.6)^2 + (1.0\times 16.5)^2}\right)$$

d = 30 mm
Hence 30mm diameter shaft was selected.

Power Required To Drive Shaft

The power required in driving the rotating shaft subjected to a torque T of 10.92 Nm and rotating at 394 rpm with the aid of a belt drive was calculated using equation 2 as given by Khurmi and Gupta (2005); Afuye and Ejiko (2017) and Akerele and Ejiko, (2015)

$$P = TV \quad (2)$$

Where
T = torque
V = velocity of the shaft

$$10.92 \times \frac{2\pi(394)}{60} = 450.49W$$

Applying a factor of safety of 1.5 it gives an horse power of 0.89
0.89hp is approximately 1hp, this implies selecting a motor of 1 hp.

Belt Design Calculation

The length of belt used was calculated using the formula in equation 3 as given by Khurmi and Gupta, (2005) and Ejiko *et. al.,* (2015)

$$L = \pi(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x} \quad (3)$$

where,
d_1= diameter of drive pulley
d_2 = diameter of driven pulley
X = distance between the center of the two pulley
Given, d_1 = 77mm, d_2 = 65mm, x=200mm (from measurement)
L = 437.9 mm

This implies the length of the belt used in the development is 437.9mm

The angle of wrap was established with the relationship between the tensions T_1 and T_2 in the belt is given in equation 4 by Khurmi and Gupta, (2005)

$$2.3\log\frac{T_1}{T_2} = \mu\theta \quad (4)$$

where, θ = angle of wrap of a belt
μ = co-efficient of friction
T_1 = Tension in the tight side of the belt
T_2 = Tension in the slack side of the belt
x = distance between the pulleys for open belt, angle of contact is given by

$$\sin = \frac{r_1 - r_2}{x}$$

The angle of contact,α for the belt around auger and fan is given in equation 5 by Hall *et al.,* (1983) and Akerele and Ejiko, (2015)

$$\alpha = 180 \pm 2\sin^{-1}\left(\frac{R - r}{x}\right) \quad (5)$$

R= radius of big pulley, r = radius of small pulley, x= distance between the two pulley.

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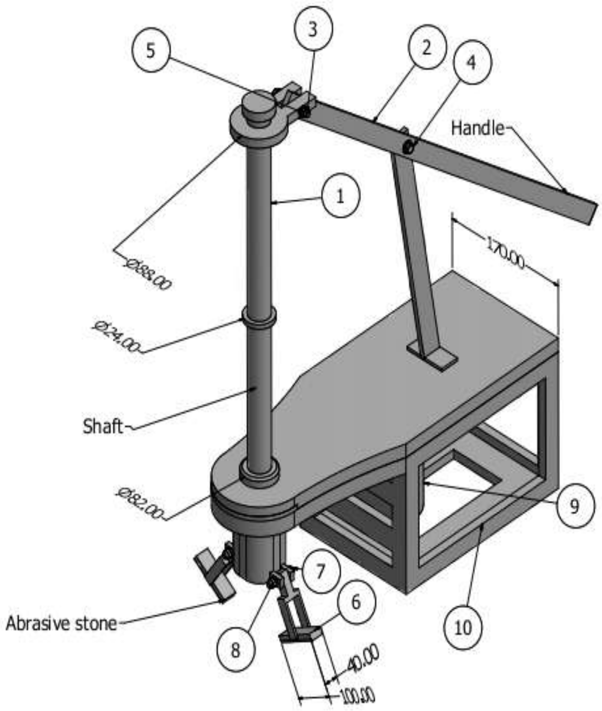

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Shaft	Mild steel
2	1	LINNKAGE	Mild steel
3	1	JIS B 1189 - M12 x 1.25 x 85	Hexagon Flange Bolt
4	1	JIS B 1189 - M12 x 1.25 x 45	Hexagon Flange Bolt
5	2	ANSI B18.2.4.4M - M10 x 1.5	Metric Hex Flange Nuts
6	2	POLISHING STONES	Abrasive material
7	2	AS 1427 - M10 x 60	ISO metric machine screws
8	2	AS 1285 - M10	Prevailing torque steel hexagon locknuts (ISO metric series)
9	1	Electric motor	
10	1	Polishing Stand	Mild steel

Fig. 2. Isometric working diagram with part list table.

III. Result and Discussion

The fabricated engine block polishing machine as shown in Plate 1 was tested for efficiency. It was connected to a power source and an engine block whose cylinder is to be polished was polished, confirming that the developed machine is working as expected. It was operated for some time to inspect its operational conditions such as temperature, vibration, noise, and polishing stone wear.

Plate 1. Developed polishing machine.

3.1 Performance Test

The following tests were carried out on the developed polishing machine to examined the weight of the machine, the speed of the polishing stone hanger, the quantity of chip removed and the quality of the surface been polished. The result of the polishing test carried out on the engine block of Mazda 626 is shown in Table 2. The standard polishing error is proportional to the increase in block diameter.

TABLE 2. Result of polished diameter (Mazda 626 Engine block 3.46inch).

Standard Polishing Error	Diameter (inch)	Diameter (mm)	Diameter (mm)
0.010	3.47	86.75	86.76
0.020	3.48	87.00	87.02
0.030	3.49	87.25	87.28
0.040	3.500	87.50	87.54

3.2 Efficiency of the Machine

Efficiency is the percentage ratio of mechanical advantage to the velocity ratio

Velocity Ratio; the velocity ratio can be determined using equation 6 as given by Oigbochie and Ejiko, (2015)

$$\frac{N_2}{N_1} = \frac{D_2}{D_1} \quad (6)$$

Where

D_1 = 77 mm and D_2 = 65 mm

V.R. = 0.84

Mechanical Advantage; is given as the ratio of T_B to T_A, that is the force about the motor shaft and the abrasive shaft, which are 20 N and 30 N respectively. The efficiency is therefore estimated to be 79%.

3.3 Machine Operation Safety Precautions

1. The machine must be properly mounted to avoid unnecessary vibration.
2. The appropriate abrasive must be selected for a particular operation (Honing, Boring, Lapping and Polishing)

3. Personal Protective Equipment such as Eye goggle and Hand glove, must adequately use to prevent accident.
4. Electrical cable and connections must be properly insulated to prevent shock.
5. The cylinder bore to be polished must free from dirt and all forms of fluid.

IV. CONCLUSION

Conclusively, based on the knowledge gathered on the use of hand drilling machine incorporated with stone grit brush and also the use of Emery paper, the design of a machine that is portable and can be operated by feeding the shaft into the surface of the cylinder bore thereby improving its safety of operation as well as reducing the time and effort taken to polish the cylinder bore of an engine block.

V. RECOMMENDATION

During the analysis and construction process we were face with some challenges that require future research and development so as to further improve on the efficiency of the polishing operation.

The following are hereby recommended for subsequent work on this project to improve on the working condition of the machine as well as its parts;

It is recommended that a carrier with adjusting screw be used. This will enhance a firm placement of engine block and direct polishing operation.

The calibration of the adjuster should be considered for study to eliminate the manual process used to determine degree of polishing accuracy.

The evaluation of the surface roughness and cutting stone size analysis will be an area for future reference.

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