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DEVELOPMENT OF A LABORATORY PIN ON DISC WEAR TEST MACHINE

Aliemeke B.N.G., Ososomi, A. S., Oshawo, E. I. and Ehibor O.G.

Department of Mechanical Engineering, Auchi Polytechnic, Nigeria

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ABSTRACT

A Pin on disc wear rate testing machine has been successfully developed. This is a pointer that local content can be built within our research space and institutions. The development became necessary as it serves as a boost in the utilization of locally made materials for the production of laboratory equipment. The development of the laboratory machine was carried out by designing for the various machine components using mathematical formulae and graphical modeling. The designed laboratory equipment developed a turning torque of 9.55Nm which produced a centrifugal force of 318.3N. The diameter of the solid shaft and power transmitted by belt and belt weight were calculated to be 27mm, 1758.23watt and weight of 15.4N respectively. The developed machine in capable of competing with imported Wear test laboratory equipment.

1. Introduction

The importance of metallic materials in our society cannot be over emphasized. Various physical and mechanical properties are essentially required to be acquainted with before being put into use. Some ferrous and nonferrous materials exhibit plethora of mechanical properties such as hardness, wear resistance, tensile strength, fatigue strength and impact strength [1]. These properties are essential as it goes a long way to determine the nature of work and environment suitable for material application.

One important property that demands utmost attention is the wear rate of ferrous and non ferrous metallic materials. It portrays the rate at which metallic particles get detached from the parent material. It shows the workability of the material during service [2]. So many materials when subjected to undue force will wear off with ease thereby causing misalignment or unnecessary clearance within an engine system. Practically, it has been observed that rough surfaces wear faster and quickly than smooth surfaces this may not be unconnected with the practical difference of the microstructure, surface roughness, residual stress and material composition of the metallic structure [3].

*Corresponding author: *Aliemeke B.N.G.*

E-mail address: aliemeka@yahoo.com, Tel: +2348030648051

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The Pin on disc wear test machine is highly necessary to help ascertain the rate of wear reduction and tool friction which in turn increase life and performance of tools and materials. This is often important in aerospace, automotive, construction and tooling industries were any failure as a result of wear could be disastrous[4].
Pin on disc wear test machine has found utmost expression in the field of material engineering and science as it has been used in the determination of abrasive, sliding and friction wear of various materials. In ensuring its availability, the machine was developed by [5] to carry out sliding wear in some selected metallic materials. The machine has frame, disc, specimen pin, electric motor, pin holder, rim and weights. The developed machine was used to carry out sliding wear operation on an aluminium alloy AA6061. In another vein, Finite Element Analysis was used to determine the stress and strain present in a fabricated pin on disc wear machine [6]. It was noticed that the calculated wear values depended on the state of stress and strain of the machine components . Also, a developed Pin on disc wear machine by [7] was used to study the effects of friction on a copper and aluminium specimen pin on a plain steel disc. In determining the effect of the metallic pin on the steel disc, various parameters such as sliding speed, torque, moments, time of rotation, revolution per minute of the disc and force applied. The work showed that aluminum and copper had a wear rate of 0.19mm/s and 0,.05mm/s respectively which concludes that aluminium wears faster than copper. In another development, a Dual condition wear test machine for computing the dry and lubricated surface of an aluminium alloy AA6061 was developed by [8]. The study examined parameters such as pin on disc specific wear rate and wear resistance of the alloy. It showed that lubricated surfaces reduce wear by 54%.
The pin on disc wear test laboratory machine consist mainly of frame, rotating disc, electric motor, specimen pin, shaft, pulleys, belt, bearing, rim, weights, specimen holder and weight holder. The pin is held by a specified weight (1N, 2N, 3N etc) from a considerable distance to the rotating disc which rotates under the influence of a constant velocity. The specimen pin is designed according to ASTM G-99(05) standard which portrays that the pin may have any shape to induce contact with the rotating disc [9]. Conventionally, spherical pin is used because of the tendency to impact normal load transfer to the disc and to initiate point contact. In experimenting this process it is pertinent to note that the two specimens (pin and disc) have to come into contact when the electric motor is energized. The flat circular disc rotates about the fixed pin making a sliding circular path on the disc surface. The specimen pin is pressed against the circular disc by means of an arm or lever bearing attached specified load or weight. The wear rate values are calculated as the ratio of the weight or volume loss to the time taken. The experiment is always conducted for a specified sliding distance, speed and selected values of load.
This study is focused on building local content in the development of a locally made Pin on Disc wear test machine.

2. Material and Methods.

The materials and methods employed in this work are presented in this section,

2.1 Materials

The materials used in this study are welding machine, fabrication tools, drilling machine, marking tools, mild steel sheets, angle steel, electrodes ,electric motor, variable speed digital meter, digital counter, digital timer, digital weighing balance, variable weights, lever, pin holder, disc and specimen pin [10].

2.1.1 Description Machine components

The various machine components used in this study are Frame, pulleys, belts, electric motor, lever, speed variable device, digital timer and digital weighing balance.

2.1.1.1 Frame

The frame is mainly responsible for the structural support of the machine. It was constructed to have a length, width and height of 1000mm, 900mm and 500mm respectively. The frame was constructed with angle bar mild steel and metal sheets. The frame was designed to accommodate the disc, weighing balance, digital counter and digital variable meter.

2.1.1.2 Electric motor

The electric motor is the prime mover for the machine. It converts the electrical power to mechanical power which brings about the rotation of the pulleys and the belts that in turn rotates the disc and ensures the wear of the specimen pin.

2.1.1.3 Lever

The lever bears and moves the specimen pin holder that accommodates the pin. It has a pivot that responds to the variable weight or load attachment.

***2.1.1.4** Speed variable device*

The speed variable device ensures the selection of rotational speed of the disc. The effective speed of rotation takes effect from 1000rpm. It is made up of sensors installed between the disc and the belt. The signals of the rotating motion are sent from the rotating disc.

***2.1.1.5** Digital counter*

The digital counter records the number of cycles attained in specific time for wear to occur on a material. It is controlled by sensor attached to the disc. Signals are received from the sensor and transmitted to the counter.

***2.1.1.6** Digital Timer*

The digital timer records the time taken for the experimental engagement between the specimen pin and the disc. It is measured in seconds and minutes. For this study , the device was built into the machine.

***2.1.1.7** Digital weighing balance*

The digital weighing balance was built into the machine. The weighing balance weighs the specimen pin before and after each experiment.

***2.1.1.8** Specimen Pin*

The specimen pin is made up of aluminium and steel constructed according the ASME standard code of ASME G 99 (05). It measured a height and diameter of 600mm and 80mm respectively.

2.2 Design considerations

Machine parameters applied in this study are power required, belt speed, belt length, belt tensions and shaft diameter.

***2.2.1** Design specifications*

The design specifications adopted in this study are shown on Table 1.

Table 1: Design specifications

N	rameter	ecification
	dius of small pulley	mm
	dius of large pulley	mm
	ntre to centre distance	0mm
	ngth of shaft	0mm
	ea of belt	mm^2
	odulus of rigidity	.5N/m^2
	near speed	00m/s
	ea of belt	mm^2
	lt width	nm
	lt thickness	nm
	nsity of shaft	50kg/m^3

2.2.2 Design for belt length

The belt length was calculated by applying equation (1) obtained from [11]

$$L_b = \pi(R + r) + 2x + \frac{(R - r)^2}{x} \quad (1)$$

Where L_b =belt length

R=radius of large pulley

r= radius of small pulley

x =centre to centre distance

The length of belt was determined to be 0.89m. A belt of length of 1m was used in this study.

2.2.3 *Determination of the speed of pulley and velocity of belt*

The speed of the pulley and velocity of the belt was calculated using equations (2) and (3) respectively from [11]

$$\frac{n}{N} = \frac{D}{d} \quad (2)$$

$$V = \frac{2\pi NR}{60} \quad (3)$$

Where V=velocity of belt

N=speed of large pulley

n =speed of small pulley

D=diameter of large pulley

d =diameter of small pulley

The angular velocity was determined to be 157.1rad/s, while the velocity of belt was 9.426m/s.

2.2.4 *Determination of Transmitted Torque and Centrifugal force*

The turning torque of the shaft and centrifugal force were determined by the application of equations (4) and (5) obtained from [12]

$$T = \frac{P \times 60}{2\pi N} \quad (4)$$

The turning torque of the shaft was determined to be 9.55Nm for a motor power of 1.5Kw.

$$F = \frac{T}{r} = \sigma_{b\times}A_b \quad (5)$$

Where T= Torque transmitted in Nm

P=Power transmitted in kW

F=Centrifugal force

A_b=area of belt

σ_b =Stress

The centrifugal force was determined to be 318.33N, while the stress on the belt was calculated to be 3.93N/mm^2.

2.2.5 *Determination of Belt tensions*

The belt tensions were calculated by the application of equations (6), (7) and (8)

$$T = \sigma_b \times b \times t \quad (6)$$

$$T_1 = T - T_c \quad (7)$$

$$\frac{T_1}{T_2} = \ell^{\mu\theta} \quad (8)$$

Where T= maximum tension on the belt

b =belt width

t =belt thickness
T_1=Tension on tight side
T_2=Tension on slack side
T_c=Centrifugal tensions
μ=coefficient of friction
θ= Angle of contact in radians

The angle of contact was determined by using equation (9)

$$\theta = 180 - 2sin^{-1}\left(\frac{R-r}{x}\right) \quad (9)$$

The maximum tension on the belt was determined to be 318.33N. The centrifugal tension was considered to be negligible and as such the maximum tension was made to be equal to the tension on the tight side. The angle of contact in radians is calculated to be 2.94. Applying equation (7) the tension on slack side was determined to be 131.8N.

2.2.6 *Determination of Power transmitted by belt*

Power transmitted belt as calculated by applying equation (10)

$$P = (T_1 - T_2)v \quad (10)$$

The power transmitted by belt was determined to be 1758.23Watt by substituting for the values of the tensions and the velocity of belt in equation (10).

2.2.7 Design of shaft diameter

The shaft diameter was determined by using equations (11) and (12)

$$\frac{T}{J} = \frac{C\theta_t}{L} \quad (11)$$

$$J = \frac{\pi d^4}{32} \quad (12)$$

Where d_s = diameter of shaft
J= Polar moment
L= Length of shaft
C=Modulus of rigidity for mild steel was taken to be 80GN/mm^2.
θ_t= angle of twist

The polar moment of the shaft, J was determined to be 0.05m^4 using a shaft length of 300mm.

$$J = \frac{9.55 \times 0.3}{80 \times 10^9 \times \frac{0.05 \times \pi}{180}} = 0.05m^4$$

By the application of equation (12), the diameter of shaft as calculated to be 27.02mm from a polar moment of 0.05m^4.

Also, the volume of the shaft was determined by equation (13)

$$V = \frac{\pi \times L \times d^2}{4} \quad (13)$$

Where V=volume of shaft

The volume of shaft, V was determined to be 200013mm^3. Consequently the weight of the shaft was determined by equation (14)

$$W = \rho_s \times g \times V \quad (14)$$

Where W=weight of shaft
ρ_s =density of the mild steel shaft taken to be 7850kg/m^3.
g =acceleration due to gravity taken to be 9.81m/s^2.

By substitution of values into equation (14), the weight of shaft as determined to be 15.4N

$$W = 7850 \times 9.81 \times 0.00002 = 15.4N$$

3. Results and Discussions

The summary of the calculated parameters of the wear rate testing machine are presented in the section. Also, presented are the various graphical modeling of the machine.

3.1 Summary of the calculated parameters of the wear rate machine

The designed parameters of the wear rate testing machine are shown in Table 2.

Table 2: Designed parameters of wear test machine

S/N	Parameters	Calculated value
1	Length of belt	0.89m
2	velocity of belt	9.426m/s
3	turning torque	9.55Nm
4	centrifugal force	318.33N
5	stress on the belt	3.93N/mm^2
6	maximum tension on the belt	318.33N
7	tension on slack side	131.8N
8	power transmitted by belt	1758.23Watt
9	diameter of shaft	27.02mm
10	volume of shaft	200013mm^3
11	weight of shaft	15.4N

The designed parameters were similar to the designed values used in [13].

3.2 Graphical Modeling of Wear rate Testing machine

The graphical modeling of the developed wear rate testing machine showing the third angle orthographic projection and components drawing is presented in Figures 1 and 2.

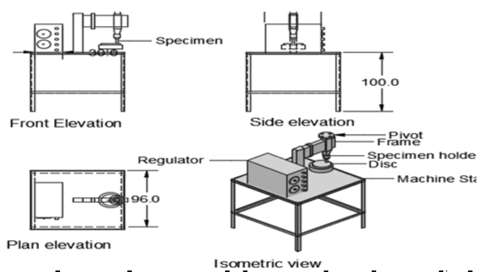

Figure 1: Third angle orthographic projection of the Pin on disc machine

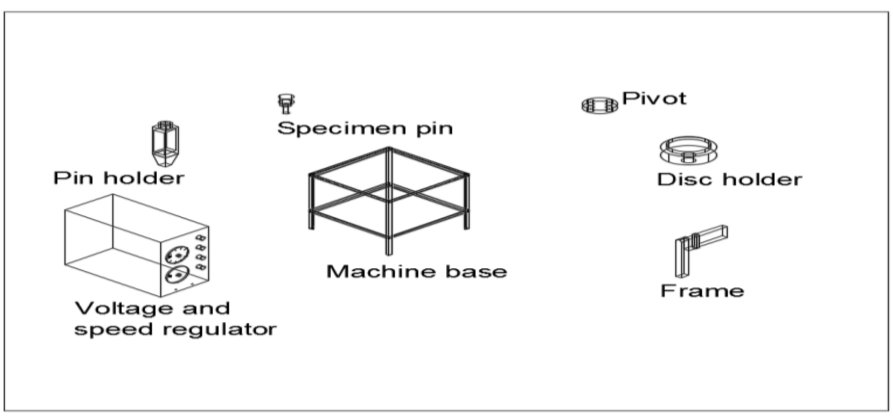

Figure 2: Components of the Pin on disc machine

3.3 Construction of the Wear test Machine

The wear test machine was constructed by the application of joining processes such as welding and riveting. The angle bar mild steel and sheets were marked out and consequently joined to fabricate the machine frame. The frame served as a structural base for the components such as electric motor, digital counter, digital variable speed meter, lever, pin holder, disc, belt and pulleys [14]. Also, rivet pins, bolts and nuts were used for temporary joining process. The finishing of the machine was done using filing and polishing machine. The constructed Pin on disc wear test machine is shown in Figure 3.

Figure 3: The Constructed Pin on disc wear test machine

3.4 Wear Experimentation

An experiment was carried out using the Pin on disc wear test machine. An aluminium silicon alloy and mild steel specimen pins were used for the experimentation. Table 3 shows the results of the wear experiment.

Table 3: Wear rate experiment

Material	Load	peed (rp	Veight of pin in grai (before experiment	Veight of pin in gra (after experiment	Difference i weight (gram	Time (minutes)	Vear rate in g/
Aluminium all (AA 6061)	1	90	90	85	5	5	0.016
	2	70	85	74	11	4	0.046
	3	50	74	60	14	3	0.078
Mild steel	1	90	102	100	2	5	0.007
	2	70	100	95	5	4	0.021
	3	50	95	84	11	3	0.061

It is shown that aluminium wear faster than mild steel. Also, noteworthy is the decrease in speed for increased load consequently leading to an increase of wear rate as evident in [15]. The experimental comparative analysis shows that the aluminium alloy wears faster than the mild steel. This comparative analysis is similar to the result obtained in [16].

4. Conclusion

Africa has cultivated the habit of developing local content in the production of machines and laboratory equipment. Research is progressively laudable when necessary equipment is made available in various studies. Laboratory equipment is essential in the development of any nation. This study have successfully brought to bear the development of an important laboratory machine relevant to material and manufacturing engineering. In the recent past, some appreciable works have been done by researchers in the development of machines and laboratory equipment. There is still some visible gap to be filled in machine development. This study placed much emphasis on the complete digitization of the Pin on disc wear test machine. It has a digital counter, variable speed selection sensor controlled device, digital weighing balance and timer. The development of the Pin on disc wear test machine was carried out by putting up design calculation for the various machine components and the graphical modeling of the machine. The designed laboratory equipment had a turning torque of 9.55Nm produced by a centrifugal force of 318.3N. The designed solid shaft diameter of 27mm had the capacity to withstand a power transmitted by belt of 1758.23watt and weight of 15.4N. The developed machine in capable of competing with imported Wear test laboratory equipment. It is safe to say that this study has successfully developed a locally made Pin on disc wear test machine.

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