Development of the Design and Manufacturing of a Pin-on-Disc Wear Machine

Huda Jassim Mohammed*, Khansaa Dawaod Salman Abed, and Ahmed Hameed Reja

Electromechanical Engineering, University of Technology, Baghdad, Iraq
Email: Hudaaljumaili7680@gmail.com (H.J.M.); 50123@uotechnology.edu.iq (K.D.S.A.); 50073@uotechnology.edu.iq (A.H.R.)
*Corresponding author

Abstract*—The main goal of this work is to develop the design and manufacturing of a Pin-on-Disc wear machine using a Programmable Logic Controller (PLC), a new method of changing sliding distance to find out the influence of changing the sliding distance on the wear rate, also adding a unit to collect the debris resulting from the wear process, as well as isolate the machine with a material that reduces the noise caused by the sample friction with the disc. A Human-Machine Interface (HMI) that communicates with input/output sensors and a PLC to control and monitor multiple elements, including temperature, rotational speed, and friction force, was used to design and implement the control system. The Coefficient of Friction (COF), wear rate, temperature, and noise level were among the computed variables. Variations in wear parameters, such as rotating speed (300–900 rpm) and sliding distance (3–9 cm), were used to conduct wear tests. Wear test results revealed that a rise in sliding distance decreases the wear rate for AA6061 alloy is 3.2887×10^{-5} gm/cm and decreases with increased sliding distance to 2.8977×10^{-5} gm/cm, for CK45 steel alloy the wear rate value is 1.4094×10^{-5} gm/cm and decreased with increased sliding distance to 1.1938×10^{-5} gm/cm, but increases in the COF and temperature for AA6061 alloy are 0.6867, 67 °C, respectively, to 0.7946 and 163 °C, for CK45 0.5493, 58 °C to 0.6003, 142 °C respectively. An increasing rotating speed reduces the wear rate but increases the COF, and the temperature for AA6061 alloy is 3.2887×10^{-5} gm/cm to 2.7979×10^{-5} gm/cm , for CK45 steel alloy the wear rate value is 1.4094×10^{-5} gm/cm to 0.8678×10^{-5} gm/cm, but increases in the COF and temperature for AA6061 alloy are 0.6867, 67 °C respectively, to 0.7848 and 175 °C, for CK45 0.5493, 58 °C to0.5984, 115 °C, respectively.

***Keywords*—wear rate, coefficient of friction, noise reduction, Programmable Logic Controller (PLC), sliding distance**

I. Introduction

Many abrasion testing techniques have been developed and implemented in mechanical engineering to predict the wear of different parts under various circumstances. The American Society for Testing and Materials (ASTM) Standards list four common abrasion test configurations. According to these methods, the reference material and test specimen should be processed without flexure or failure [1]. Wear was a dynamic and intricate process that considered the material and surface qualities and the operating environment. The corrosion that occurs in underground or buried pipelines can cause wear and tear. This makes it crucial to create a device that can assess the surface abrasion of engineered materials [2]. The pin-on-disc wear test method was a laboratory technique that used a pin moving on a rotating disc to measure material wear during sliding. As the name suggests, this type of apparatus consists of a pin in contact with a rotating disc. The pin was the test piece in this work, and it was made of various metal types. Any practical geometry, including the actual wear components, such as spherical or flat, can be used for the pin's contact surface [3, 4]. Friction defined as the resistance encountered when one body moves tangentially over another at which it was in contact, was the main cause of wear and energy dissipation. It was controlled by processes that mostly take place in the contacting bodies' thin surface layers. As a result, it was regarded as a tribological system characteristic rather than a characteristic of basic materials [5]. The wear machine that was used in this work contains several types of sensors to get the best performance and a Programmable Logic Controller (PLC) system was used for its programming, Human Machine Interface (HMI) was also used as the communication instrument between the machine and the user.

II. Literature Review

Several studies dealt with the issue of designing and manufacturing the pin-on-disc wear machine such as Federici *et al.* [6] present a model of the surface contact temperature in this sliding system to highlight the role of the different surface conditions, i.e., coated and uncoated, on the evolution of the pin and disc temperatures during sliding. In addition, propose a simplified analytical equation for estimating the average temperature rise in the contact region during sliding, by extending the Kennedy approach to be able to provide a quick evaluation of the contact temperature for this kind of coupling, which is very helpful when characterizing a large number of systems in

Manuscript received October 8, 2024; revised November 4, 2024; accepted December 10, 2024; published April 14, 2025.

doi: 10.18178/ijmerr.14.2.191-199

different contact conditions. Also, Sobarad *et al.* [7] designed and fabricated a pin-on-disc wear testing machine which is used for determining the wear of a given sample and is capable of determining the wear rate of materials. Copper, brass, and aluminum. The machine is developed as per the American Society for Testing and Materials (ASTM G99) standard. The machine's outcomes are compared in terms of the standard wear rate available for copper, aluminum, and brass. The machine showed results which were very close to the standard wear rates. Further, the machine can handle different load and speed levels.

In addition, Aparecido Carlos Gonçalves et al. presented the design and fabrication of a pin/ball on disk type tribometer, which seeks to determine using experimental tests and analysis of material properties, the coefficients of friction as well as the wear volume of certain pairs of engineering materials. The project aims to meet the needs of users, researchers, or technicians, whether for studies of science and research or industrial purposes of development or quality control. The tribometer was effective and the experiments performed showed satisfactory results [8]. as well as Hussein Mohammed Ali also gave information about the design steps and manufacturing procedure for the pin-on-disc apparatus and discussed the problems following the design and manufacturing process. It also gives information about the wear testing process. Different types of experiments were done with several different test specimens to be able to make a comparison between the wear test results of this work and that of another experiment found in the literature. It was concluded that a pin-on-disc wear testing apparatus that is working properly is successfully designed and manufactured. The results of the wear testing obtained by the apparatus that has been designed and manufactured show that the wear of the test sample increases as the speed (rpm) of the motor increases. Also, as the sliding distance increases, the wear decreases at constant load and speed [3].

Through previous studies, no new techniques were used to change the sliding distance from the pin center and disc center when designing and manufacturing the pin-on-disc machine. The use of new technological methods was taken into consideration. The difference between this work and previous works is the new method was used to change the sliding distance, so that the disc that moves changes the sliding distance instead of the sample, by the PLC system without interfering with the person performing the examination process Also, adding a unit to collect the debris resulting from the wear process, as well as isolate the machine with a material that reduces the noise caused by the sample friction with the disc.

III. Materials and Methods

This design can determine the coefficient of friction COF, the specific wear rate, and the temperature. the weight loss method was used to calculate the wear rate by calculating the weight of the sample before and after the testing device and then applying Archard's wear Eqs. (1)–(3).

$$WR = \Delta w/SD \quad (1)$$

$$SD = 2\pi rnt \quad (2)$$

$$\Delta w = w1 - w2 \quad (3)$$

where; WR is the wear rate (g/cm), Δw is the weight change w1is the weight of the sample before testing (g), $w2$ is the weight of the sample after testing (g), SD is the sliding distance (cm), r is the distance between the sample center and the disc center (cm), n is the number of rotating disc (rpm) and t is the rotating time (min) [9].

The force opposing the motion of the friction force (F_f) divided by the applied normal force (F_n) is known as the coefficient of friction. as shown in Eq. (4) [10]. It is a dimensionless parameter which means that the physical matter does not change by the direction of the force [11].

$$\mu = \frac{F_f}{F_n} \quad (4)$$

In the design analysis part, the following components of the pin-on-disc wear machine were designed for the best and safest operation. All parts of the pin-on-disc wear machine and its specifications are illustrated in Fig. 1 and Table I. The pin-on-disc wear machine is made up of the following components: electric motors, disc, pin (sample), pin Holder, shafts, base support and frame, pulley, bearing, conveyor belt, toothed pulleys, transducers, sensors, control unit (speed or voltage controller that includes (PLC, rotary encoder, inverter, power supply, and HMI), and silencer (noise reduction part).

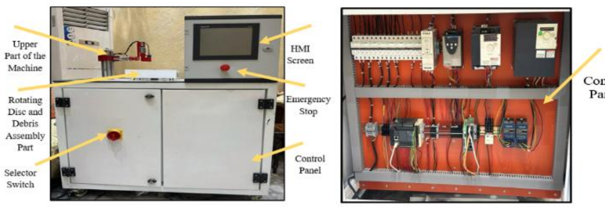

Fig. 1. Pin-on-disc wear machine.

TABLE I. Specification of Pin-On-Disc Wear Machine

No.	Parameter	Value
1	Wear disc diameter	25 cm
2	Wear track diameter	17 cm
3	Disc thickness	10 cm
4	Disc hardness	60 HRC
5	Pin diameter	1 cm
6	Pin length	4.6 cm
7	Power supply	220V/50Hz
8	Max. power consumption	3 kw
9	Type of movement	sliding
10	Max sliding velocity	1420 rpm
11	Max normal load	25 N
12	Tribotester dimensions	100×80×140 cm^3

1) Induction motor

The AC 3 ph induction motor 220/380 V, 0.12 kW, 20.76 A, 50 Hz, 1420 rpm, as shown in Fig. 2 with a gearbox has a capacity of 0.12 kW and a change ratio of 30/1, this type was responsible for changing the location of the rotating disc to change the sliding distance. This process was done by installing the plate that fixed the rotating disc motor on the aluminum rail a slide-moving part as shown in Fig. 3, where this motor moves the slide using a toothed shaft linked to the motor's gearbox to change the distance between the center of the sample and the center of the rotating disc by the PLC control system without interfering with the person performing the examination process to obtain different values for the sliding distance and calculated the wear rate at each value, this method was considered a development in the design process so that the disc was the one that moves to change the sliding distance instead of the sample change that used in the previous studied. An AC induction motor in this work requires many electronic components such as the AC power supply and AC inverter.

Fig. 2. AC induction motor for changing the sliding distance.

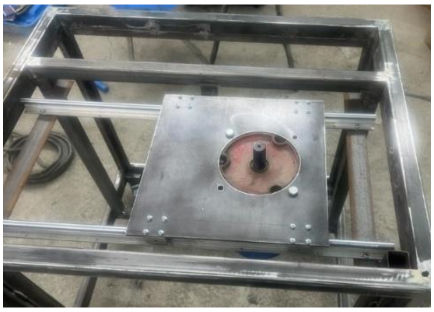

Fig. 3. AC induction motor and Aluminum rail.

a) Variable speed drive (AC Drive)

The variable speed drive type used in this work can convert the supply voltage from (220 V single phase to 220 V three phases) and can control the motor speed variation (speed controlled by voltage and frequency variation). The variable speed drive used in manufacturing the wear machine was the inverter of the motor responsible for changing the position of the rotating disc. It has been programmed to work at one constant speed and in two different directions (forward and reverse) to ensure that different values of the sliding distance are obtained to know the effect of changing the sliding distance on the wear rate.

b) Shaft and coupling shaft

The toothed type for moving the part (slide) is responsible for changing the sliding distance as shown in Fig. 4.

To transfer power from a drive shaft to a driven shaft, shaft couplings join two shafts and absorb some degree of misalignment and mounting error between the two shafts. The aluminum jaw coupling with polyurethane elastic element was the motor's first component to transmit torque. Two couplings were used in manufacturing the machine. The first coupling transmits movement from the shaft of the motor gearbox to the slide that was responsible for changing the sliding distance, which changes the location of the disc to obtain a different sliding distance value. The second coupling is used for connecting the encoder and the second shift of the motor gearbox that was responsible for changing the sliding distance. Another type of bearing for fixing the toothed shaft of the moving part changes the position of the rotating disc to ensure obtaining different values of the sliding distance. Two bearings are used for this purpose.

Fig. 4. Tooth shaft for changing the sliding distance.

c) Bearing

The type of bearings that were used in this work for installing the fixed part for changing the sliding distance values during the samples test (the plate on which the motor for changing the location of the rotating disc is installed), this type illustrated in Fig. 5.

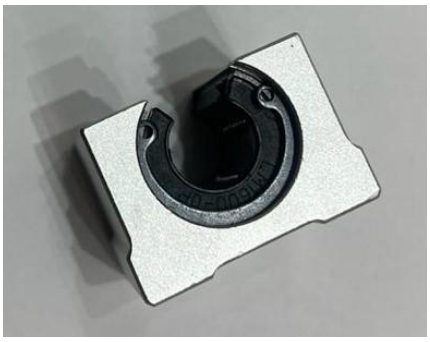

Fig. 5. Bearing for fixing the fixed part of the sliding distance.

d) Debris assembly part

The other development in the design process of the pin-on-disc wear machine is adding a part to collect the debris resulting from the wear process so that we can study the effect of wear on alloys. Fig. 6 illustrates this part, which contains four holes with φ10 mm for fixing, a hole with φ22 mm for clearing the debris resulting from the wear process, and a hole with φ22 mm for fixing the disc.

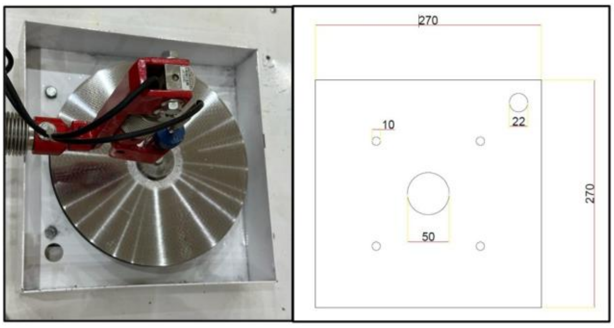

Fig. 6. Debris assembly part.

2) Measurement system

After the disc movement and force application are designed, the wear machine performs controlled experiments. The measurement of physical quantities during the experiment is an essential subsystem of the pin-on-disc wear machine. The key variables that are needed to understand any test are the friction force between a pin and a disc, sliding time, sliding distance, rotating speed, and contact temperature.

a) Thermocouple

Heat is generated at the contact point between a pin and a disc due to friction, and some of that heat is transferred by conduction through the pin and disc. The thermocouple type (pt 100) that was used in manufacturing the wear machine, was installed inside the tested sample as shown in Fig. 7 to measure the temperature between the sample and the disc.

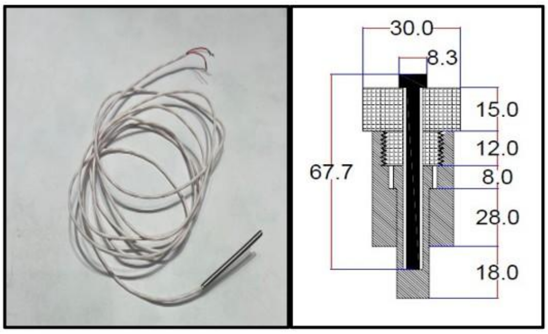

Fig. 7. Thermocouple (pt 100) and install it inside the sample.

b) Temperature transducer

The PLC program does not understand the sent signal from the thermocouple, so the temperature transducer must be used as shown in Fig. 8, it connects with the thermocouple to convert the value of the thermocouple signal from an impedance value to an analog signal with a value of (4–20 mA) and it is sent to the PLC unit and temperature measuring range (−200 ℃… 850 ℃).

Fig. 8. Temperature transducer.

c) Rotary encoder

To control the change of the motor position, a rotary encoder was used as shown in Fig. 9, consisting of two parts, mechanical and electrical. The mechanical part is a shaft that is linked to the gearbox of the motor that is responsible for changing the location of the disc to change the sliding distance. The electrical part is a wire connected to a PLC unit to program the required sliding distance values and make the motor move based on these distances.

Fig. 9. Rotary encoder.

3) Design the control system of the pin-on-disc wear machine

The controller is a crucial component of the system; specifically, a PLC controller is used, which is designed to regulate machine operations for the pin-on-disc wear machine to maintain the necessary applied load, sliding time, sliding distance, and rotating speed throughout the test, a controller design that manages both the pin and disc actuators is necessary. The ladder diagram design on the installed computer software is part of the control system as shown in Figs. 10 and 11. It is connected to the PLC through the communication interface after being downloaded. It also covers how different hardware devices are interfaced. The main components of the system are the emergency switches, sensors, and proximity switches. They send a signal to the PLC, which then generates the proper output to the pulley, coupling, and direct motor based on these input signals and the code that is implemented in it.

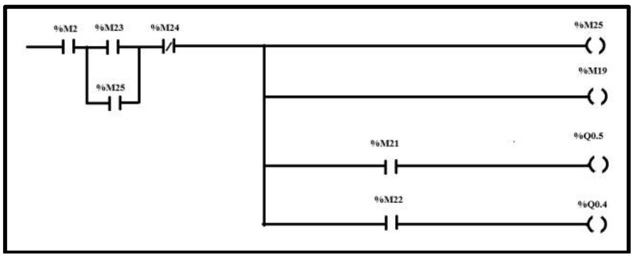

Fig. 10. The ladder diagram for sliding distance control.

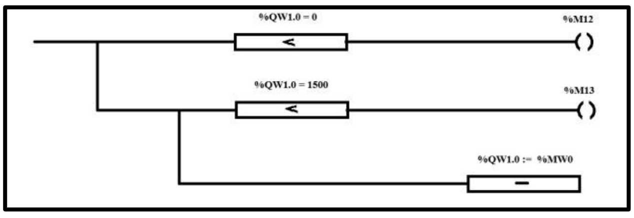

Fig. 11. The ladder diagram for the rotating speed control.

a) Hardware design

In the hardware design, each component was selected carefully to fit the project requirements and limitations. This model consists of Schneider PLC, expansion analog, network switches, and an HMI screen as shown in Fig. 12. Each part of the control system mentioned above is discussed below:

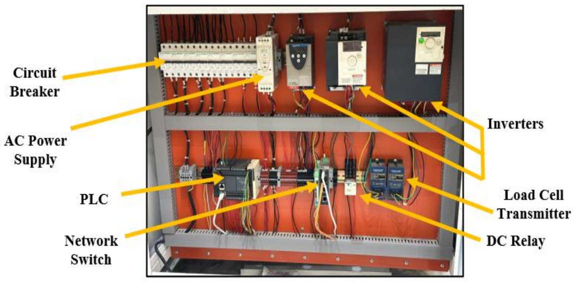

Fig. 12. Hardware of the control system.

b) Software design

Software design is an important part of the design of the PLC control system for pin-on-disc wear machines. When designing software, all kinds of situations in machines are considered. Four programs were installed on the personal computer for programming and controlling the device, these programs were issued by Schneider and Phoenix Company. It includes So Move AC Drive Software used to program the variable speed drive, EcoStruxure machine expert-basic V1.2 VP1 Software is considered the basic software in programming the machine because it is related to PLC programming through the inputs (digital and analog) and the outputs (digital and analog), Vijeo designer 6.2 Software is for programming the HMI touchscreen, Ifs—Conf RTD Software is for programming the temperature transducer to measure the temperature in each wear test parameter.

4) Noise reduction part (Silencer)

Over the past few years, noise reduction has drawn more attention because it can lead to symptoms like sleep disorders and hearing loss. The character of the noise and its average levels are often linked to people's annoyance when exposed to different types of noise. Humans have a maximum sensitivity for sound frequencies of 1000 Hz, but low-frequency noise which is louder than 200 Hz was the most irritating [12, 13]. When traditional wall materials are replaced with glass windows, the wall's ability to insulate against sound usually deteriorates. Glass manual handbooks may give different Sound Transmission Classes (STCs) depending on how the glass is installed. STC can be readily reduced by using the wrong supporting materials, such as frames and sealing materials, and improperly installing glass [14]. Doubling the thickness of the glass should result in a 6 dB increase in sound insulation, according to theoretical Mass Law considerations. Resonances, however, obstruct this trend, in actuality the incremental increase is only about 4 dB. These data reveal a notable resonance known as Coincidence Resonance, which was a "dip" in the sound insulation whose frequency, measured in Hertz (Hz), was inversely related to the thickness of the glass [15]. This Critical Frequency (f_c) is determined from the formula:

$$f_c = 12000\ \text{Hz}/d \tag{5}$$

where d is the glass thickness, in millimeters.

When the pin-on-disc wear machine is running, a loud noise is produced due to the friction of the metal of the sample with the metal of the rotating disc. This noise increases with the increase in the friction of the sample metal. Therefore, a special part was designed and manufactured to reduce the noise using two layers of 6 mm tempered glass with an air gap of 12 mm separated (6×12×6) to ensure better sound insulation. An aluminum frame and a slide door were used as shown in Fig. 13. To measure the noise level before and after using the silencer, a PROSKIT digital sound level meter was used, as shown in Fig. 14.

Fig. 13. Silencer

Fig. 14. Digital sound level meter

IV. Result and Discussion

The results include calculating the COF, the wear rate, and the amount of temperature change using the thermocouple in each wear parameter, including the applied load to the sample, the speed of the rotation disc, the sliding distance, and the sliding time. These calculations are for two types of metal alloys, AA6061 alloy and CK45 steel alloy.

A. *Effect of Sliding Distance on the Wear Rate and Temperature of AA6061 Alloy and CK45 Steel Alloy*

The proposed algorithm and the parameters affected in this case are shown in Fig. 15. Increasing the sliding distance ranging from (3–9 cm) leads to minimizing the wear rate owing to an increase in the resistance for the pin surface as a result of increasing the friction between the pin and rotating disc which in turn leads to an increase in the bonding at the contact surfaces [5, 16]. Fig. 16 describes the relationship between sliding distance and temperature value. Fig. 17 describes the relationship between sliding distance and wear rate value, this test was done at a constant rotating speed of about 300 rpm, sliding time at 5 min, and applied load at 5 N.

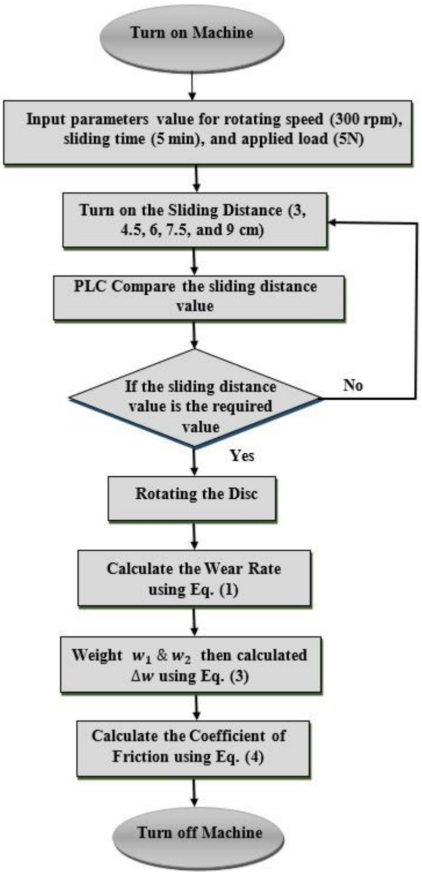

Fig. 15. The flow chart represents the effect of the sliding distance on the wear rate of AA6061alloy and CK45 steel alloys.

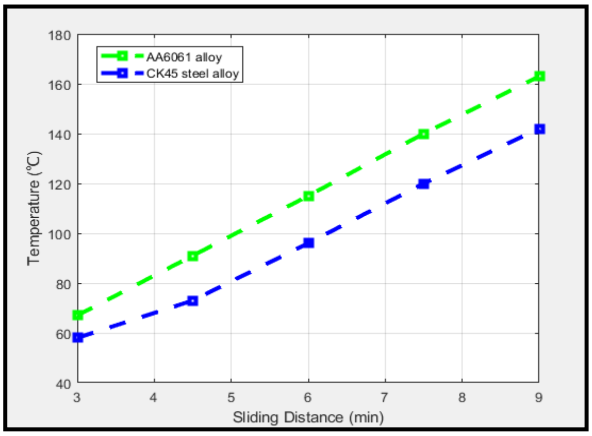

Fig. 16. The sliding distance and temperature for AA 6061 alloy and CK45 steel alloy.

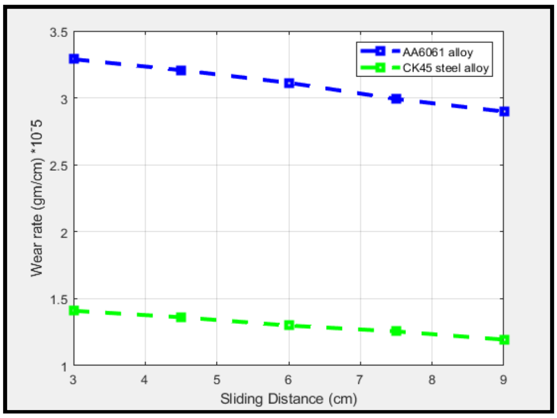

Fig. 17. The sliding distance and wear rate for AA 6061 alloy and CK45 steel alloy.

B. Influence of the Sliding Distance on the COF of AA 6061 Alloy and CK45 Steel Alloy

With an increase in sliding distance as shown in Fig. 18, there is a correspondent increase in the coefficient of friction, which is justified where the hard nature of reinforcement impeded through the matrix alloy delivers some reluctance to motion during the friction process leading to an increase in coefficient of friction [17, 18].

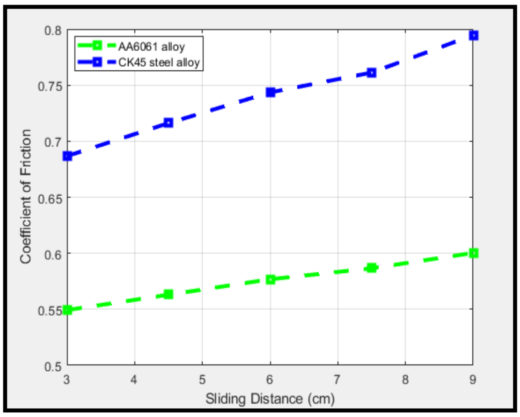

Fig. 18. The sliding distance vs COF for AA 6061 alloy and CK45 steel alloy.

C. Effect of Rotating Speed on the Wear Rate of AA6061 Alloy and CK45 Steel Alloys

The proposed algorithm and the parameters affected by this case are shown in Fig. 19. Increasing the rotating speed leads to minimizing wear rate owing to increasing the temperature at the surface where the pin and rotating disc make contact, as seen in Fig. 20. As a result of the increasing friction between them. Increasing the temperature between two contact surfaces will lead to the transmission of the material from one of them to another and create an oxidation layer which minimizes the wear rate. The heat dissipation for higher rotating speed is lower than for lower rotating speed and in turn leads to the softening of asperities and minimizes the loads required to shear the welded points, hence the wear rate will be reduced [16, 19]. Fig. 21 shows the relationship between rotating speed and wear rate. In this instance, the sliding distance is 3 cm, the applied load is 5 N, the rotation speed ranges from (300–900 rpm), and the sliding time is 5 min.

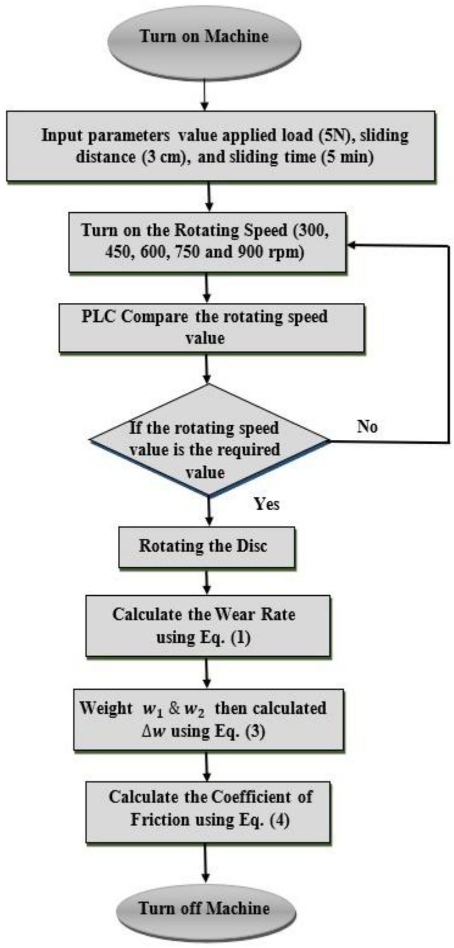

Fig. 19. The flow chart represents the effect of the rotating speed on the wear rate of AA6061 alloy and CK45 steel alloys.

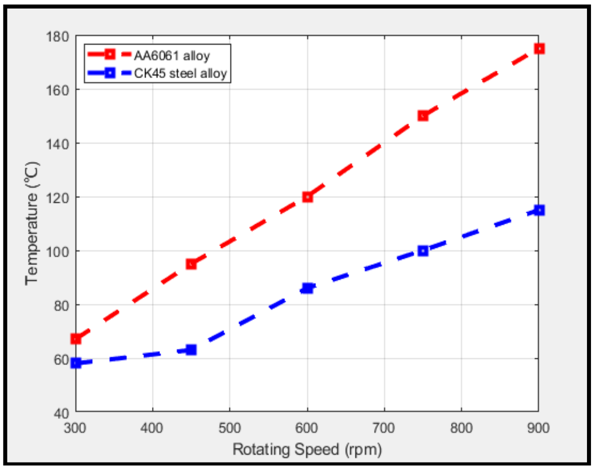

Fig. 20. The rotating speed and temperature for AA 6061 alloy and CK45 steel alloy.

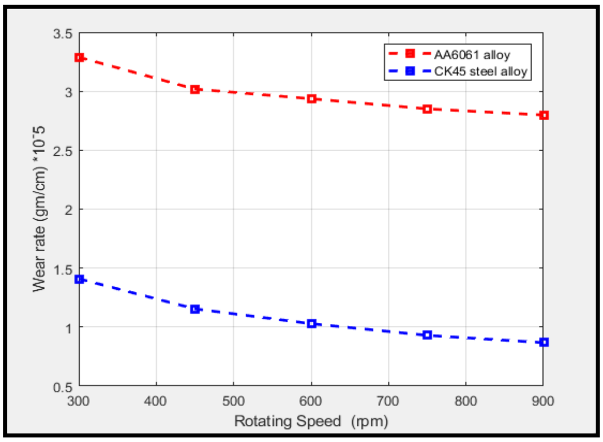

Fig. 21. The rotating speed and wear rate for AA 6061 alloy and CK45 steel alloy.

D. *Influence of the Rotating Speed on the Coefficient of Friction*

The highest rotating speed values were found to have the highest friction coefficient. As seen in Fig. 22, the differences in friction coefficient levels under dry sliding conditions can be understood as a temperature rise in the steel surface brought on by frictional power. This leads to the weakening of the bond and loosening of the alloy atomic chains. Consequently, the bonds break into pieces and create debris, increasing the coefficient of friction [20].

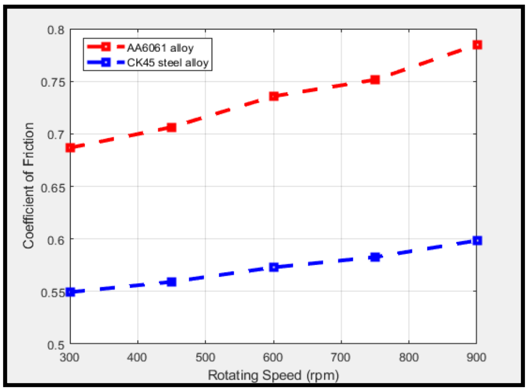

Fig. 22. The rotating speed vs COF for AA6061 alloy and CK45 steel alloy.

E. *Effect of the Silencer on the Noise Degree*

While testing the wear of metals using the pin-on-disc wear machine, a continuous and increasing noise is produced based on changing the values of the wear parameters as illustrated in Table II. The PROSKIT digital sound level meter recorded this noise, resulting in 138 dB. After using the silencer and operating the machine under the same conditions and variables, the noise value became 85 db this means that noise has been reduced by 61.6% as shown in Table III.

TABLE II. NOISE DEGREE BEFORE THE SILENCER

Wear parameters	Noise degree before silencer (DB)
Sliding distance (3, 4.5, 6, 7.5, and 9 cm)	(110–138)
Rotating speed (300, 450, 600, 750, and 900 rpm)	(110–130)

TABLE III. NOISE DEGREE AFTER THE SILENCER

Wear parameters	Noise degree after silencer (DB)
Sliding distance (3, 4.5, 6, 7.5, and 9 cm)	(50–85)
Rotating speed (300, 450, 600, 750, and 900 rpm)	(50–75)

V. CONCLUSION

Depending on the results obtained through the pin-on-disc wear machine for AA6061 and CK45 steel alloys for each of the wear parameters, it is possible to draw the following conclusions:

(1) The pin-on-disc wear machine's design and manufacturing and the addition of a developmental component made it easier to adjust the wear parameters and produced more accurate results.

(2) The PLC programming system successfully controlled the three motors' operations in terms of disc rotation speed, sample load, and varying the distance between the disc center and sample center to obtain various sliding distances as well as sliding time.

(3) Using the HMI screen and programming it with a PLC system led to the machine being programmed so that the user was able to enter the required data through the touch screen, as well as obtain the outputs and monitor the device's performance continuously through the graphics that appear on the screen.

(4) That used two layers of 6 mm tempered glass with an air gap of 12 mm separated (6×12×6) were used to reduce the noise resulting from the friction process between the sample and the disc by 61.6%.

(5) The wear rate is proportionately inversed to the change of sliding distance, the wear rate value for AA6061 alloy is 3.2887×10^{-5} gm/cm and decreased with increased sliding distance to 2.8977×10^{-5} gm/cm, for CK45 steel alloy the wear rate value, is 1.4094×10^{-5} gm/cm and decreased with increased sliding distance to 1.1938×10^{-5}gm/cm, so that the wear rate in the AA6061 alloy tests is greater than in the CK45 steel alloy. For AA6061 and CK45 alloy, the C.O.F increased with increased sliding distance, the AA6061 alloy coefficient of friction was more than the CK45 steel alloy coefficient of friction.

(6) The wear rate is proportionately inversed to the change of rotating speed, the wear rate value for AA6061 alloy is 3.2887×10^{-5} gm/cm and decreased with increased rotating speed to 2.7979×10^{-5} gm/cm, for CK45 steel alloy the wear rate value is 1.4094×10^{-5} gm/cm and decreased with increased rotating speed to 0.8678×10^{-5} gm/cm, so the wear rate in the AA6061 alloy tests is greater than in the CK45 steel alloy. For AA6061 and CK45 alloy the COF value is increased with increased rotating speed, the AA6061 alloy coefficient of friction is more than the CK45 steel alloy coefficient of friction.

(7) When the wear rate decreases, the value of the coefficient of friction increases due to the increase in the frictional force between the sample and the disc. Since the relationship is directly proportional between the frictional force and the coefficient of friction, the value of the coefficient of friction will increase.

VI. RECOMMENDATIONS

By designing and manufacturing a pin-on-disc wear machine, conducting metal tests, and obtaining results in several variables of wear parameters that affect the temperature, (C.O.F), the wear rate, and noise, the following are considered as areas of concentration for further study:

(1) Changing the motor to rotate the disc from a three-phase induction motor to a stepper motor to obtain a higher speed in the wear test.

(2) Increasing the hardness of aluminum metal using the surface coating method to lower the wear rate.

(3) Increasing the disc's rotation speed allows the pin-on-disc wear machine to examine ceramic materials with a high degree of hardness and need high rotation speeds to measure wear rate.

(4) Changing the chassis metal from iron to stainless steel, will reduce the machine weight and thus make it easier to move the wear machine from one place to another.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, K. Salman and A. Reja; data curation, H. Mohammed; formal analysis, H. Mohammed, K. Salman and A. Reja; investigation, H. Mohammed; methodology, H. Mohammed; project administration, H. Mohammed; resources, H. Mohammed; software, H. Mohammed; supervision, K. Salman and A. Reja; validation, K. Salman and A. Reja; visualization, K. Salman and A. Reja; writing—original draft preparation, H. Mohammed; writing—review and editing, K. Salman and A. Reja. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENT

I would like to express my deep thanks and appreciation to Prof. Dr. Khansaa Dawaod Salman and Ass. Prof. Dr. Ahmed Hameed Reja for their kind advice, valuable guidance, and encouragement during the supervision of this work. My sincere appreciation also extends to all my colleagues and others who have assisted on various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

REFERENCES

[1] D. J Kim, H. Kang, C. H. Song *et al.*, "Design of pin-on-disk type abrasion testing machine for durability assessment of rock cutting tools," *International Journal of Precision Engineering and Manufacturing*, vol. 40, pp. 749–755, 2021.

[2] Abdulwahab, "Development of dual condition pin-on-disc wear testing machine," *Federal University of Technology*, Ph.D. thesis, 2021.

[3] H. M. Ali, "Design and manufacturing of a pin-on-disc wear testing apparatus," *Kirkuk University Journal /Scientific Studies (KUJSS)*, vol.12, pp. 65–97, 2017.

[4] Y. Yao and Y. Zhou, "Effects of deep cryogenic treatment on wear resistance and structure of GB 35CrMoV steel," *Metals Journal*, vol. 8, pp. 502–513, 2018.

[5] A. Rudnytskyj, "Simulations of contact mechanics and wear of linearly reciprocating block-on-flat sliding test," Master thesis, University of Technology Department of Engineering Sciences and Mathematics, 2018.

[6] S. K. Yadav, "Classification for sensors in automotive cyber-physical systems," Master thesis, Faculty of Informatics, Masaryk University, 2018.

[7] B. C. Patel, G. R. Sinha, and N. Goel, *Advances in Modern Sensors*, IOP Publishing, 2020.

[8] S. Adhikari, "Operator machine control using siemens PLC and HMI," Master thesis, University of Toledo, 2018.

[9] C. F. Galvão, G. A. Slavec, P. L. D. Menardi *et al.*, "Design and construction of a pin-on-disc experimental bench to determine the friction coefficients," in *Proc. 25th ABCM International Congress of Mechanical Engineering*, 2021.

[10] M. Federici, G. Straffelini, and S. Gialanella, "Pin-on-disc testing of low-metallic friction material sliding against hvof coated cast iron: modelling of the contact temperature evolution," *Tribol. Lett. Journal*, vol. 4, pp. 65–121, 2017.

[11] S. Martin, "Study of the wear behavior of SS16L + WC composites: Role of the counter," Master thesis, de Liège University, 2020.

[12] R. Bliudžius, K. Miškinis, V. Buhagiar *et al.*, "Sound insulation of façade element with triple IGU," *MDPI Journal*, vol. 12, pp. 1208–1239, 2022.

[13] D. Chen, S. Zheng, M. Jing *et al.*, "Enhancing sound insulation of glass interlayer films by introducing piezoelectric fibers," *Royal Society of Chemistry*, vol. 4, pp. 2466–2473, 2023.

[14] W. Larbi, C. Soussi, J. F. Deü *et al.*, "Sound transmission loss through double glazing windows in low-frequency range," *HAL Open Science Journal*, 2020.

[15] T. Sharpe, "Building mounted wind turbines on existing multi-storey housing," *Open House International Journal*, vol. 33, pp. 60–69, 2008.

[16] N. Radhika and R. Raghu, "Influence of parameters on sliding wear of titanium nitride coated 6061 aluminum alloy," *Tribology in Industry*, vol. 40, pp. 203–212, 2018.

[17] A. A. G. El-Mawla, S. Z. El-Abden, and A. H. Badran, "Wear behavior of Al6061/TiO_2 composites synthesized by stir casting process," *Journal of Advanced Engineering Trends*, vol. 41, pp. 113–125, 2022.

[18] Y. P. Chang, Z. W. Huang, and H. M. Chou, "Effects of doping elements on the friction and wear of SUJ2 steel sliding against aluminum alloys," *Micromachines Journal*, vol. 8, pp. 96–107, 2017.

[19] J. Y. Byun, N. N. Okechukwu, E. Lee *et al*, "Friction characteristics of aluminized polyester fabric under dry and water- lubricated conditions," *Tribology and Lubricants Journal*, vol. 35, pp. 396–402, 2019.

[20] M. Hoić, A. Miklik, M. Kostelac *et al.*, "Analysis of the accuracy of mass difference-based measurement of dry clutch friction material wear," *Materials Journal*, vol. 14, pp. 5356–5373, 2021.