Fabrication of Erosion Corrosion Equipment and Testing of Al 6063 Alloy

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***Abstract*—In general sense the term wear has been known to man since the earlier days, only in mechanical age it has been specially studied with a view to minimize the effect of wear and to enhance the properties of materials subjected for respective studies carried out. This study focus upon investigation on erosion and corrosion behavior of aluminium 6063 alloy under varied material condition, environmental concentration and angle of impingement and process parameters. Experiments were carried out on 6063 Al alloy by considering various impingement angles such as 0◦ and 90◦. The specimens were tested under normal conditions. The slurry media contains the abrasive particles with the same size and shape and 2% NaCl solution. Results show Al 6063 alloy has high resistance to wear and hence the experiments conducted on these hardened materials shows less wear. Rotation speed showed much influence on the wear loss.**

Keywords—Aluminium 6063 alloy, corrosion, erosion, wear, weight loss

I. INTRODUCTION

Wear is a phenomenon observed whenever there is a relative motion between two surfaces. In any machine part or mechanical equipment there will be a relative motion either in the form of sliding, rotating, reciprocating, impact and so on. It is related to surface interactions and more specifically the removal of material from a surface as a result of mechanical action. The need for mechanical action in the form of contact due to relative motion is an important distinction between mechanical wear and other processes with similar outcomes. Wear of materials result in loss of material, production, power, time, money etc. In the worst situation it also results in failure of component. The number of variables involved during wear of materials cannot be controlled precisely. The variables involved are speed, time/distance, angle of impingement, height, size, shape, contents of micro constituents and atmospheric conditions like humidity, temperature, surface condition, interference of outside materials etc., influence the wear behavior of materials. Here the specified material is Aluminium. Since aluminum is durable and lightweight. In today's energy-conscious society, these two basic properties combine to make the metal the preferred material. The weight saving achieved depends on the approach to design which varies with different applications where weight reduction to reduce fuel consumption, to increase the load carrying capacity and in many types of marine vessels to increase payload to expand capacity for equipment to decrease the power required. The use of aluminum normally results in initial cost premiums that are justified over the life of the application by the low maintenance cost and construction for transport applications. Products like motorcars, aircraft, ships, Lorries, trains and conductors are all obvious examples. The 5000 and 6000 series Aluminium alloys are commonly used in applications like marine, commercial etc., where low density materials, good mechanical properties and better resistance to corrosion are desired. Therefore here the selected material is 6000 series of Aluminium and investigation on erosion corrosion behavior of Al 6063 alloy

II. FUNDAMENTALS OF WEAR

Wear is a phenomenon observed whenever there is relative motion between two surfaces. Wear situation exists whenever there is relative motion between two mating parts. Broadly speaking the motion can be unidirectional or reciprocating, either sliding or rolling. There may be combination of rolling and sliding wear may occur due to oscillating movements at small amplitudes".

CLASSIFICATION OF WEAR

Depending on the nature of the movements or the media involved in an interaction under load, wear can be classified as:

- Abrasive Wear
- Adhesive Wear
- Corrosive Wear
- Fatigue Wear
- Erosive Wear
- Diffusion Wear

This study concentrates on erosive and corrosive wear behavior. Hence, parameters influencing these properties on aluminum 6063 alloy were studied.

Corrosive Wear: Wear is primarily a removal of material by mechanical action which would tend to discount any contribution from corrosion. In many instances however

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chemical action upon a material surface can affect the process of mechanical wears. This is known as corrosive wear. Corrosive wear involves the interaction of the wear surfaces and a corrosive environment. Under such conditions it may be the corrosion product which is being removed more easily and preference to the base material. This exposes the material to further corrosive attack. And for example the metal corrosion is shown in Fig 2.1

Fig 2.1 Metal Corrosion

Erosive Wear: Erosive wear is caused by the impact of particles of solid or liquid against the surface of an object. The impacting particles gradually remove material from the surface through repeated deformations and cutting actions. It is a widely encountered mechanism in industry. A common example is the erosive wear associated with the movement of slurries through piping and pumping equipment.

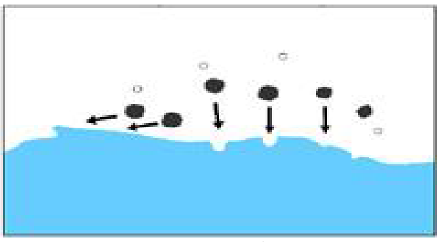

Fig 2.2 Principle of Erosion

The rate of erosive wear is dependent upon a number of factors. The material characteristics of the particles, such as their shape, hardness, and impact velocity and impingement angle are primary factors along with the properties of the surface being eroded. The impingement angle is one of the most important factors and is widely recognized in literature. For ductile materials the maximum wear rate is found when the impingement angle is approximately 30° whilst for non-ductile materials the maximum wear rate occurs when the impingement angle is 90° to the surface.

WEAR MEASUREMENT METHODS

The most common way of measuring wear consists of examination of sliding materials before and after wear and difference in weight of the material being attributed as wear. The common methods used to determine wear rates of material are given below:

- Loss of dimension method
- Displacement method
- Optical method
- Loss of weight method

This study focused on loss of weight method of wear measurement because of very easier and simplest method of finding wear rate of any type of material.

Loss of Weight Method The pin specimen is cleaned with acetone or alcohol and weighed initially (W1) in the electronic balance before conducting the test. After conducting the wear test, the pin specimen is cleaned with alcohol and it is weighed in the electronic balance to get the weight (W2). Thus the difference between the initial weight (W1) and final weight (W2) gives the loss of weight of the pin specimen in the form of percentage (%).

III. PROBLEM FORMULATION

The piping design used in the aerospace and off-shore structure is one of the most critical challenges which an engineer will face. The components will be exposed to different acidic environments and are highly susceptible to erosion and corrosion. At the same time depending on the type of fluid flow in a pipe line and an open exposure of the off-shore structure to the acidic water environment makes the material to erode. The concentration of acidic environment is one of the most significant factors which influences on the erosion corrosion wear. For these extreme engineering components the 6000 series aluminium is widely used. It has been well documented in past literature that 6063 aluminium is a most common and a prominent piece of material used for such applications. It has also been revealed from the literature that the combined effect of corrosion and erosion plays a vital role on the performance of the component. In practical cases the angle of impingement of the abrasives on the material will vary. It has also been identified from the literature that the angle of impingement abrasives has a significant effect on the corrosion erosion wear characteristics.

Hence there is a scope, to carry out the experimental analysis on 6063 series Aluminium under varied material condition, environmental concentration and angle of impingement. In the present study efforts are made to determine the wear behavior of the 6063 series Aluminium, under varied process parameters and material conditions.

IV. EXPERIMENTAL SET UP

- Fabricate the different parts of the erosion-corrosion equipment such as frame, container, acrylic shaft and acrylic disc.
- Preparing the aluminium 6063 specimen as per the dimensions.
- Conducting the experiment for different parameters such as linear speed and linear distance.
- Developing bridge rectifier to convert the A.C. current to D.C. current.

FABRICATION OF EQUIPMENT

The machine is fabricated to assemble the parts. Sleeve is to connect the motor shaft and disk shaft. Bearing and clamp helps in dampening the vibration and make the axis of motor shaft and disk shaft coincident each other. In this equipment the frame which is the major fabricating component is made of stainless steel. It is constructed by the sequence of operations like shearing and filing. The next step is to prepare the frame by joining the columns by welding process. Then the required size of holes is drilled on the plate, one for the foundation and other for mounting the motor by drilling machine. The holes are drilled on the base into which foundation bolts are inserted and on another plate, the holes are drilled into which the motor shaft is inserted and finally all other components are assembled and inspected

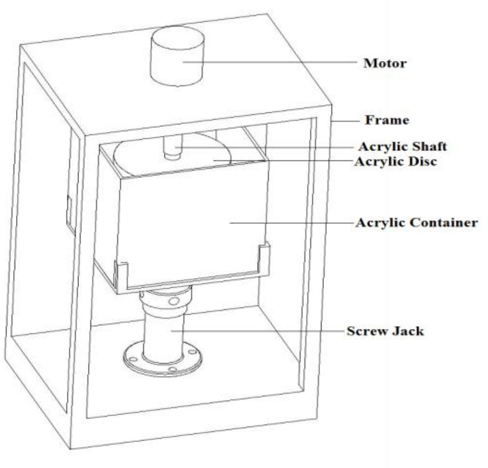

Fig 4.1 Schematic View

Fig 4.2 Designed and fabricated experimental set-up

COMPONENTS OF EQUIPMENT'S

Frame: The main supporting member of the test set-up which is made of stainless steel. It has a rectangular shape and all parts of the test set-up such as motor, mechanical lifter, etc., are supported by the frame. Frame is built of four long square tubes of length 750mm provided. The base of the frame has a length of 500mm and width of 400mm. The frame consist of a hole of diameter 40mm at the top column at exactly centre from all corners into which the motor is placed on the rubber bushes

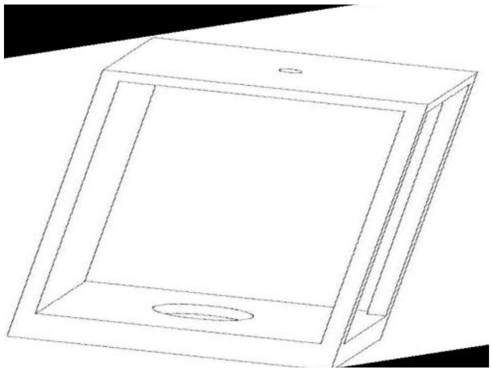

Fig 4.3 Structure of frame

DC Motor with Control Unit

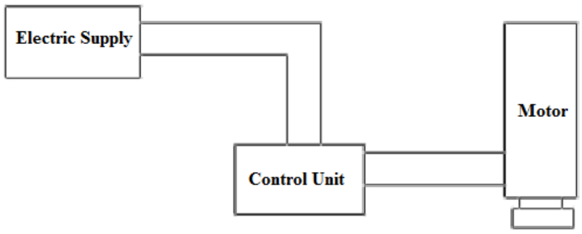

Fig 4.4 Control Unit of Motor

DC motor rotates the acrylic shaft. This is coupled to the motor shaft by means of scrub screws. The outer diameter of motor shaft is 12mm.The motor has to obtain the desired speed. The specifications of the motor are as follows: Frequency = 50Hz Power = 0.25HP Speed = 4000rpm Voltage = 90V. The control unit converts alternating current into direct current. The analogue speed controller obtains the different speed, varying from 0 to 4000 rpm. The circuit for control unit is shown in fig 4.4.

Mechanical Lifter (Screw Jack)

Fig 4.4 Screw Jack

Mechanical lifter raises the tank for complete immersion of the test pieces in the acid or in the slurry which is filled in the tank. The screw jack is a vendor product barrowed from outside. It has an initial height of 210 mm and maximum lift up to 350 mm (height and lift). This jack is able to take the load up to 50,000kg.

Acrylic Shaft

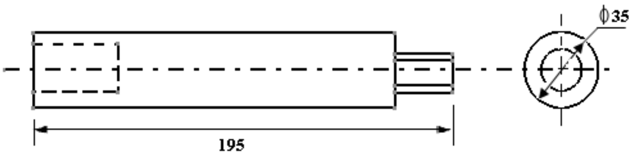

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Fig 4.5 Acrylic Shaft

Acrylic shaft is a non-metal. The purpose of an acrylic shaft in the erosion test set-up is to hold the acrylic disc. The reason behind the selection of acrylic material is to handle and avoid reactions with the acids. The shaft is driven by the motor. The motor shaft and acrylic shaft are coupled by a key. Motor rotates the shaft, which in turn rotates the disc to conduct a test. The outer diameter of the shaft is 35 mm, and its length is 195 mm as shown in Fig 4.5. Disc is fitted to the lower end of the shaft

Acrylic Disc

Fig 4.6 Acrylic Disc

Acrylic disc is a non-metal and its purpose is to rotate the specimen (Al 6063 alloy). The disc has a central hole with internal threads through which the shaft is fastened. The locking nut is made up of acrylic material, which is to lock the disc at its position. The disc having drilled holes of 8mm on it proportionately at 0° and 90° into which specimens are fastened. The disc rotates as the shaft rotates. The diameter of the disc is 225 mm and the thickness is 18 mm as shown in fig.4.6

Acrylic Container

The container is cubical in shape, made up of plates of 300 mm square cross section. The thickness of the plates is 6 mm and joined together by chloroform adhesive and seal is provided for leak proof. The top plate is equally divided into two pieces on which 65 mm hole is drilled, through which the acrylic shaft is passed. Provision is made to open and close the tank. This tank is mounted on a metallic frame, which is screwed to the jack.

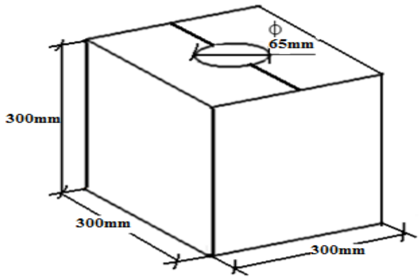


Fig 4.7 Acrylic Container

V. EXPERIMENTAL PROCEDURE

The specimen preparation and experimental procedures have been enumerated and the experimentation has been carried out on Al 6063 alloy. The strength property of this material has been identified.

Material Selection

The 6063 series Aluminium was used for the experimental analysis. The mechanical properties and the chemical composition of the materials used in the investigation are as shown in the table 1 and 2 respectively

Sl no	Element	%Present
01	Si	0.2-0.6
02	Fe	0.35
03	Cu	0.1
04	Mn	0.1
05	Mg	0.45-0.9
06	Zn	0.1
07	Ti	0.1max
08	Cr	0.1max
09	Al	Balance

Table 1 Chemical composition of 6063 Aluminium

Sl no	Property	Value
01	Minimum Proof Stress 0.2% (MPa)	0.2-0.6
02	Minimum Tensile Strength (MPa)	0.35
03	Shear Strength (MPa)	0.1
04	Elongation A5 (%)	0.1
05	Hardness Vickers (HV)	0.45-0.9

Table 2 Mechanical properties of Al 6063 alloy

Sl no	Property	Value
01	Density	2.70 g/cm3
02	Melting Point	600°C
03	Modulus of Elasticity	69.5 GPa
04	Electrical Resistivity	0.035x10-Ohm
05	Thermal Conductivity	200 W/m.K
06	Thermal Expansion	23.5 x 10-6 /K
07	Density	2.70 g/cm3

Table 3 Physical properties of Al 6063 alloy

Specimen Preparation

Specimens are prepared from the standard rod of 8 mm diameter. Initially the rod is ground to 32 mm length by fixing the specimens in Machine vice. Then the specimens are faced to 1 mm at both the ends and one end of the specimen is threaded to a length of 10 mm. The experiments were carried out on the Erosive-Corrosive wear set-up.

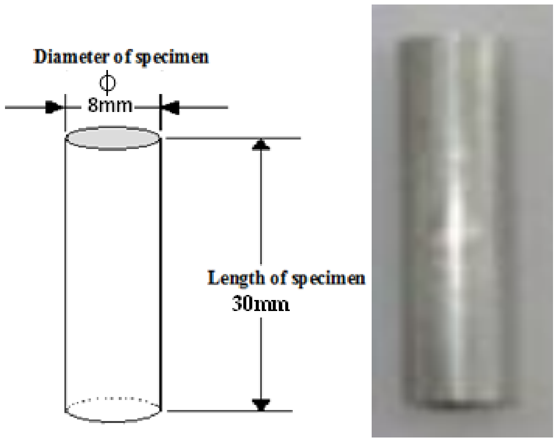
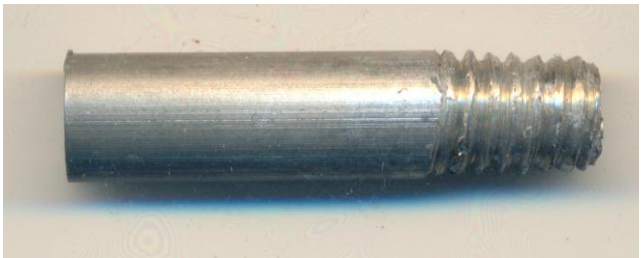


Fig 5.1 Standard Specimen



Preparation of Slurry

The slurry was prepared for an environment by using purified water, silica carbide particles (600 microns) and NaCl. The tank is filled with 80% of purified water, 20% weight of Sic particles and 2% of NaCl.

Table 4 Test Matrix

Environment	Material Conditions	No. of Specimens
Normal water+ 2% wt. of NaCl+20% wt. of Sic	Normal	48

Experimental Parameters

Specimen angle in degrees, linear distance in mm, angular speed in rpm or linear speed in m/s, initial and final weight in grams, experimental time in seconds

Experimental Steps

The test is carried out by using erosive-corrosive wear tester. The specimens were cleaned in tissue paper and weighed using an electronic balance before each test. Weighed specimens were fixed on the rotatable disc attached with an electric motor. The samples were tested under normal conditions. The speed of the slurry was maintained at 250, 500 and 750 rpm. The distance was varied in the range of 1000, 2000, 3000 and 4000 metres with the height of 130mm. The weight loss method was used to compute the wear rate. The working procedure of Erosive-Corrosive wear test is as follows:

- Clean the specimen with tissue paper and this is done even before weighing it. Care must be taken to remove any dust and foreign particles from the surface
- Weigh the specimen on electronic balance and note down the initial weight (w1) of the specimen.
- Insert the specimen securely in its holder and adjust the specimen with respect to their angles.
- Set the stop watch to the desired time.
- Start the motor and adjust the speed to the desired value.
- The test is stopped when the desired time is achieved.
- Remove the specimen and clean with tissue paper and weigh on electronic balance and note down the value of final weight (W2); then calculate weight loss by loss of weight method
- Percentage of wear (%) = (W1-W2)/ (W1*100).
- Repeat the test for various parameters to obtain sufficient data for analysis.

VI. RESULTS AND DISCUSSION

The experiments have been conducted on 6063 Al alloy by considering various impingement angles such as 0◦ and 90◦. The specimens were tested under normal conditions. The slurry media contains the abrasive particles with the same size and shape and 2% NaCl. The effect of various parameters on wear loss were discussed

Conventional Method of Wear: This study suggests significant influence of material and experimental parameters on the wear behaviour of the specimens. The experimental variables include slurry composition that is the nature of the slurry environment, the shape, size and volume fraction of the suspended solid particles, the speed of rotation, the angle of impingement and the time variation.

Effect of Process Parameter on Erosive-Corrosive Wear Sample rotation method was used for testing the specimens. The ductile properties of Al 6063 alloy causes considerably more wear loss by varying parameters like speed, distance and time. Fig. shows variation of wear loss with respect to varied distance in the range of 1000 to 4000 m with step of 1000 m keeping linear speed constant.

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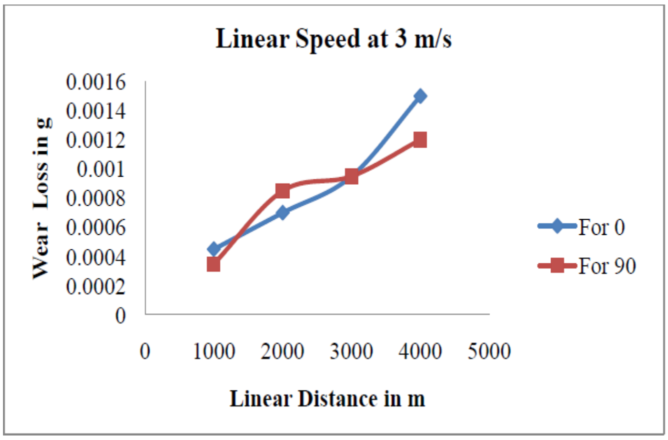

Fig. 6.1 Speed Versus Linear Distance

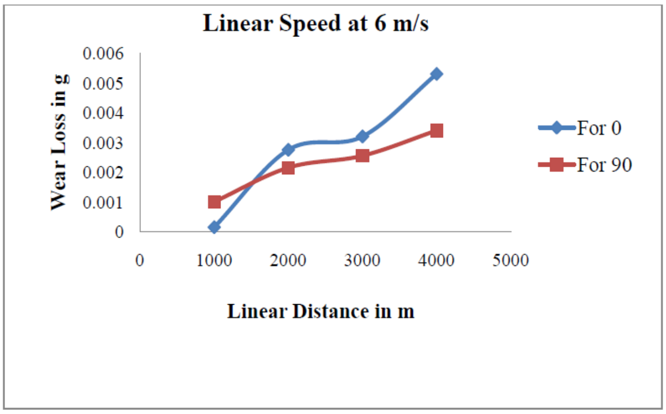

Fig.6.2 Effect of distance variation on wear loss

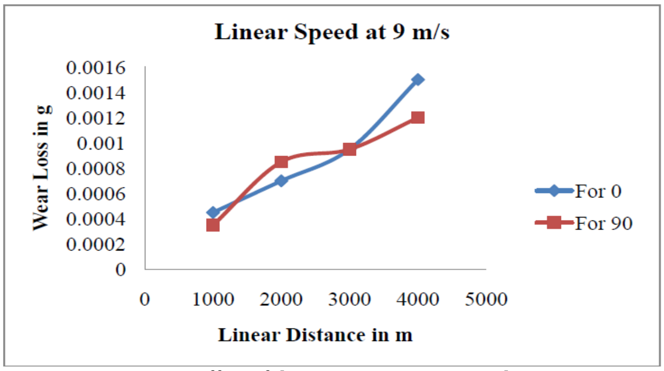

Fig 6.3 Effect of distance variation on wear loss

During experiment the constant speed and varied distance like 1000, 2000, 3000, 4000m were used. From the graphs it was observed that the rate of wear is maximum at the distance of 4000 m and minimum at the distance of 1000 m. At the distance of 1000 m and at a speed of 3 m/s wear values are 0.00045, 0.00035 gms and similarly at 6 m/s the wear values are 0.00045, 0.0004 gms and other values are shown in graphs. It is found that the increased speed of disc, increases impingement attack of Sic particles on the material because of kinetic energy phenomena. Due to this whirling effect, hitting action of abrasive particles on the material causes higher wear. The same concept is reverse on results of lower speeds. Also the acidic media plays a vital role on the wear behaviour. Based on experiment result it is stated that wear going to increase by increasing the time because of the action of particles and attack of acid on the material. The concept of value of wear varied due to time variation because of impingement action increases. Hence due to chemical action on material results corrode the material which in turn increases the erosion.

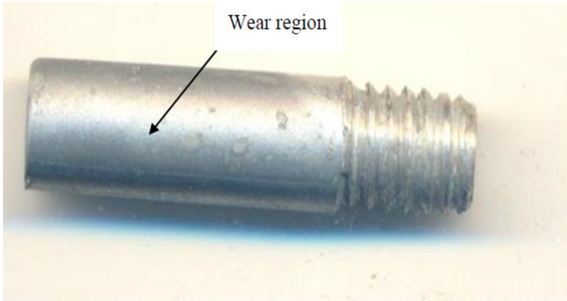

Fig 6.7 Specimen after Wear

The plot indicates that when the metal is submitted to hard particles impact with different angles and each erosive event causes removal of protective oxide film from the surface, when the metallic surface exposed to the solution under 0°, the particles hits the surface in tangential direction and causes the less wear .Similarly the wear under 90° is slightly more in compare to an angle of 0° and the reason of behind is particles hit the metallic surface in vertical direction. The tested specimen shown in the fig. indicates corrosion region on the surface which mainly affected by chloride content present in the water.

EXPERIMENTAL RESULTS

SPECIMEN ANGLE AT 0°

Sl no.	Linear speed in m/s	Linear distance in m	Time in sec	Initial weight in gms	Final weight in gms	Difference in gms	Average
1	3	1000	330	3.5109	3.5105	0.0004	0.00045
2				3.5020	3.5015	0.0005	
3		2000	660	3.5378	3.5373	0.0005	0.0007
4				3.6189	3.6180	0.0009	
5		3000	990	3.5278	3.5267	0.0011	0.00095
6				3.5559	3.5551	0.0008	
7		4000	1320	3.5834	3.5822	0.0012	0.0015
8				3.6303	3.6294	0.0009	
9	6	1000	165	3.7206	3.7203	0.0003	0.0004
10				3.5915	3.5910	0.0005	
11		2000	330	3.6680	3.6674	0.0006	0.00045
12				3.5201	3.5198	0.0003	
13		3000	495	3.6325	3.6317	0.0008	0.00085
14				3.5009	3.5000	0.0009	
15		4000	660	3.6387	3.6366	0.0021	0.0020
16				3.5687	3.5668	0.0019	
17	9	1000	110	3.5564	3.5551	0.0013	0.00015
18				3.4835	3.4825	0.0010	
19		2000	220	3.5778	3.5740	0.0038	0.00275
20				3.5266	3.5249	0.0017	
21		3000	330	3.5735	3.5704	0.0031	0.0032
22				3.6399	3.6366	0.0033	
23		4000	440	3.6039	3.5997	0.0058	0.0053
24				3.5988	3.5940	0.0048	

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SPECIMEN ANGLE AT 90°

Sl no.	Linear speed in m/s	Linear distance in m	Time in sec	Initial weight in gms	Final weight in gms	Difference in gms	Average
1	3	1000	330	3.6570	3.6567	0.0003	0.00035
2				3.6099	3.6095	0.0004	
3		2000	660	3.5737	3.5728	0.0009	0.00085
4				3.6256	3.6248	0.0008	
5		3000	990	3.5510	3.5499	0.0011	0.00095
6				3.6485	3.6478	0.0007	
7		4000	1320	3.5687	3.5676	0.0011	0.0012
8				3.5546	3.5533	0.0013	
9	6	1000	165	3.5784	3.5780	0.0004	0.00045
10				3.5527	3.5522	0.0005	
11		2000	330	3.5336	3.5329	0.0007	0.00065
12				3.5575	3.5569	0.0006	
13		3000	495	3.6044	3.6037	0.0007	0.0007
14				3.6867	3.6860	0.0007	
15		4000	660	3.6358	3.6348	0.0001	0.00085
16				3.6523	3.6516	0.0007	
17	9	1000	110	3.7561	3.7552	0.0009	0.0010
18				3.6701	3.6690	0.00011	
19		2000	220	3.6201	3.6180	0.00021	0.00215
20				3.6679	3.6657	0.0022	
21		3000	330	3.6318	3.6291	0.0027	0.00255
22				3.6179	3.6155	0.0024	
23		4000	440	3.6117	3.6082	0.0035	0.0034
24				3.5633	3.5600	0.0033	

VII. CONCLUSION

From the experimental analysis carried out on 6063 Aluminium under normal material condition and the process parameters, the following conclusions were given

- The material condition has shown maximum influence on the wear, irrespective of the environmental concentration and the process parameters. Al 6063 alloy has high resistance to wear and hence the experiments conducted on these hardened materials shows less wear.
- The wear loss has shown deepest dependency on the angle of impingement. When the angle of impingement 0◦ wear rate is high, and the wear rate has shown drastic decrement with angle of impingement of 90◦.
- The speed of rotation of the specimens has also shown much influence on the wear loss. As the speed increases the wear rate will also increase. This is mainly because of the high velocity impingement of the abrasive at high speeds.
- The results obtained from the experimental analysis have good agreement with those reported in the previous literature. Hence the designed and the fabricated Erosion-Corrosion wear set-up are up to the mark and can be used for such experimentations on any other materials with different environments and abrasive particles.

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