

Investigate the  
erosive  
characteristics of  
targets using a  
centrifugal  
accelerato...



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## ABSTRACT

Erosive wear is the phenomenon of removal of the surface of any component basing on different conditions due to high-speed impact of solid, liquid or gaseous particles. It is a common occurrence on most plant and machineries and manufacturing industries. The phenomenon of erosive wear has been studied for many years, and still research is going on the material-related aspects of particle impact erosion. Different laboratory testing methods were used to determine the erosion resistance of all eroded materials. In order to predict the erosive wear rate during the erosion test, some major properties such as effect of erosion parameters, effect of abrasive particle characteristics were investigated.

The Aim of the project was to continue the work done by scholars and to investigate erosive characteristics of targets by using a small centrifugal accelerator erosion tester. The present project focuses on the erosion of ductile materials particularly mild steels as these are used in pneumatic conveyor plants where some of the most severe erosion problem occurs. An experimental process was conducted with olivine sand, mild steel as hitting and target specimens to calculate the erosion rate. During the experimental process a study was made to calculate the specific wear rate and analyse the wear properties under different testing conditions.

The report presented gives the detailed description of experimental process along with description of materials and tools used. Also report gives detailed analysis of relations of wear properties and rates of relations. Finally future works which could be possible are discussed in the report.

## **Chapter 1: Introduction**

### **1. 1 Overview:**

Wear is a progressive loss of substance resulting from mechanical interaction between two contacting surfaces, it is a common occurrence on most plant and machineries and manufacturing industries. In 1997, a survey of wear problems and costs in UK industry indicated that a typical average cost due to wear was about 0. 25 percent of company turnover [4] [5]. Wear can be abrasion, erosion, corrosion or other chemical reaction, appearance of failed surfaces (e. g. cracking, melting, phase transformation) etc... But processes involving erosive wears where there is an involvement of particle size, particle velocity, angle of incidence, and particle distribution are more effective than others.

### **1. 2 Erosive wear of pneumatic conveying systems**

Erosion involves the mass removed from the surface of any component at different conditions due to high-speed impact of solid particle or a liquid particle. Generally the erosive wear sizes between 5 and 500 microns by causing the particles. (W-1) [3]. Today, many engineering industrial plants are facing the situation of the erosion wear.

Phenomenon of erosive wear has been studied for many years, and still research is going on the material-related aspects of particle impact erosion. There is a certain need for the analysis of wear process, before defining the exact problem. As stated earlier wear can be abrasion, erosion, corrosion or other chemical reaction, appearance of failed surfaces (e. g. cracking, melting, phase transformation etc.). The types of wear process will be able to tell what kind of testing is needed to find the wear problem. Sliding friction,

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erosion testing processes which involve surface fatigue can be modelled at a reduced scale. But processes involving abrasive wears, erosive wear where there is an involvement of particle size, particle velocity, angle of incidence, and particle distribution should be modelled at full scale. This can only happen with an appropriately designed test, and it will be carried out in specially designed erosion testers which involve impact of a stream of particles against a test sample. In order to predict the erosive wear rate during the erosion test, some following major aspects have been investigated (3 progress) [6].

Size and shape of particle

Material Properties of the target

Impact conditions (Impact angle, impact velocity)

Particle concentration on the target.

Now a day's Different laboratory testing methods are used to determine the erosion resistance of all eroded materials. But the main challenge lies in the prediction of correct test conditions which should be adopted during the test. Current project study will involve calibration of test conditions such as particle velocities and impact angles to the targets. The work was mostly concentrated on erosive characteristics of ductile materials used in pneumatic conveyor plants where erosive problems occur most often. As mild steel is a commonly used ductile material in conveyor plants it was chosen as the target material and centrifugal accelerator type erosion tester was used to find the wear characteristics.

### **1. 3 Project Aim and Objectives**

Aim:

The Aim of the project is to continue the work done by those scholars and to investigate erosive characteristics determination of mild steel targets by using a small centrifugal erosion tester. The present project focuses on the erosion of ductile materials particularly mild steels as these are used in pneumatic conveyor plant where some of the most severe erosion problem occurs. The experiment will be carried out with some of effective erosive wear factors.

Objectives:

The project has been divided into several objectives. The main objectives of this project are listed below

- Calibration of impact conditions on a centrifugal erosion tester
- Controlling the impact characteristics for pre-set test condition
- Determination of erosive wear for mild steel targets
- Relationship between erosion rates for different impact conditions.

### **1. 4 Project and its scope**

The main purpose of the project was to determine the erosive wear which is a serious problem in the pneumatic conveyors. Here in this project an attempt was made to calculate erosive wear rate in the mild steel target material using the olivine sand as the eroded material. The results obtained from the experiment can be used for minimising the erosion rate in the mild

steel made pneumatic conveyors. Also the work done can be taken as a guideline for several future works in the field of erosive wear.

## **CHAPTER 2 LITERATURE REVIEW**

### **2. 1 Overview**

Ample of research has been carried out in the area of erosive wear impact on plant and machineries and manufacturing industries. The theoretical concepts obtained from different references such as journals, websites, papers and books which are directly or indirectly related to the project are presented in this chapter.

### **2. 2 History of wear concept**

Erosive Wear is the concept which is not new to the manufacturing industry, it was first proposed in 17th century. Till 18th century until Osborne Reynolds paper on hydrodynamic lubrication it was not well known in manufacturing industry. In the paper author explained the causes of wear and need for lubrication for the first time. Gradual progress was made from 18th century and now days it has emerged as important factor in any manufacturing industry.

### **2. 3 Basic concepts of erosive wear**

Removal of material from the surface of the solid body is known as wear. Wear may combine effects of various physical and chemical processing preceding the friction between two contracting materials. obtained result was micro-cutting, micro-ploughing, Plastic deformation, cracking, fracture, welding, melting, chemical interaction(w-2)[11]. Before the start of project it is necessary to know the all basic concepts of wear.

Definition of wear coefficient K. (Lb-2) [12] $K =$

Where V= volume worn away

L= total sliding distance

W= applied load

Erosive wear occur due to the impact of number of small particles on the surface of the any mechanical object. Generally erosive wear is caused by the particles of sizes between 5 and 500 microns. Surfaces are impacted by continuous stream of hard particles which is known as particle erosion (11) [3]. One of such major place where erosion occurs is pneumatic conveyors, which may result in punctuation of conveyor bends or dust problem if the bends are penetrated. The main effects of the erosive wear are (2) [13].

Dimensional changes

Leakage

Lower efficiency

Generated particles contribute more wear

Erosive wear resistance cannot be estimated only by hardness and characterizing resistance to penetration. The wear resistance of hard material with equal hardness level can be attributed to their resistance fracture (8) [14]. There are two types of wear which are main reasons for erosion. The first one is due to the repeated deformation during the collision and the other one is due to the cutting action of the free moving particles. The rate of erosion depends on the particle velocity which results in the plastically formed concavity of similar radius of curvature to that of the particle (2)[13].  
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Repeated deformation during the collision: This type of erosion occurs in the systems in which particles move at high speeds for example pneumatic fluid bed systems, air mills etc. where the particles move free at high speed and impact on the solid which results in the wear (2)[13]. The formula for deformation wear is

Where

$W_d$  = Units volume loss

$M$  = Total mass of impinging particles

$V$  = Particle velocity

$\theta$  = Impact angle

$K$  = Maximum particle velocity at which the collision still is purely elastic and

$E$  = the energy needed to remove a unit volume of material from the body by deformation wear.

Cutting action of the free moving particles: This type of wear is occurred due to the particle that impinges the component at an acute angle and due to this there is scratching of material from the surface of the component. This scratching of the material is highly influenced by the velocity and the impact angle of the particle (2)[13].

## **2. 4 Mechanisms of wear test**

Wear is occurred by mechanical or chemical reactions generally accelerated by friction heating. There are six main wear phenomena which explain only



removal of material from the solid surfaces (16) [15]. In many cases, wear is initiated by one of these mechanisms and it may proceed by other wear mechanism, there by complicating failure analysis. Particle contamination can damage systems by causing a variety of types of wear (15) [12]. The following table shows the primary cause of wear for each mechanism (1) [16].

Type of mechanism	Primary cause
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Abrasive wear	Particle between adjacent moving surface
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Adhesive wear	Particle and high fluid velocity
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Fatigue wear	Surface to surface contact (loss of oil film)
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Corrosive wear	Particle damaged surface subjected to repeated stress
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Erosive wear	Water or chemical
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Table 2. 1: Different types of wear mechanisms. (1)[16]

Finnie in his work Observations of the erosion of ductile metals has made an attempt to clearly discuss the factors affecting the erosion in ductile metals. Also Gwidon W. Stachowiak, Andrew W. Batchelor, Grazyna Stachowiak (2004) in their journal Experimental methods in Tribology discussed the mechanism of erosion of ductile metals analytically and experimentally. The analysis was carried out by writing the equation of motion of a single particle impaction on the surfaces, volume for the same was then calculated using the trajectory of particles [18]. Such type of approaches was obviously unsuitable for brittle materials. In the experiment the particle velocity on the surface of the ductile metals were obtained by using high speed double flash light source. The authors mainly concentrated on the calculation of single

particle of different sizes and at different angles with which he then calculated for whole of the volume of particles. The authors also explained about the drawbacks that they came across during the experiment and mentioned about the most unsatisfactory feature of his analysis. It underestimates the weight loss at large angles and, in particular, predicts no erosion at  $90^\circ$ , and explained the three effects which cause the relative erosion at high angles to be greater than that predicted by the sample theory (9)[17].

## **2. 5 Factors effecting the erosive wear**

The numbers of factors which significantly affect the rate of erosive wear were discussed by Dr. Dmitri Kopeliovich in his work Mechanisms of wear in 2009. According to him the factors are (12)[11]

Impingement angle: the angle at which a particle hits the surface is very important to erosive wear rate. By the experience it was found that the wear rate was high at an angle of  $30^\circ$  for ductile material and  $90^\circ$  angle for brittle materials.

Impact speed: high speed particles impacts cause more damage than low speed collisions.

Particle properties: particle properties were more important in erosive wear phenomenon, sharp and hard particles causes more wear rate.

Temperature: High temperatures cause high erosive wear because increase in softness of material in high temperatures

Particle flux rate: Particle flux rate is the mass of particles hitting an area of surface per unit of time, which can vary greatly from 100 kg/m<sup>2</sup>/s to 10,000 kg/m<sup>2</sup>/s.

## **2. 6 Test facilities and conditions**

### **2. 6. 1 Wear Test facilities**

The national laboratory in the UK identified over 400 wear testing standards all over the world and American society of lubrication engineers identified 300 tests that were used in various test laboratories in year of 1973. From these tests some type of tests have slight variation on others, less than 100 number of tests are useful to find out the wear problems (15)[12]. As early as Mr. Neale was carried out a survey on wear in 1997 as the result in his survey seven types of wear mechanism were identified, most significant wears were abrasive, erosive and adhesive wear. More than one test method is justified for a particular wear type and more than ten test methods are justified to meet industrial need for seven types of methods (14)[5]. There are three major types of erosion testing devices that are used throughout the world for quantifying particle impact erosion against a solid surface (10) [18].

### **2. 6. 2 Test condition for erosive wear impact**

One of the important tasks of the project was to identify the ideal testing conditions. A journal by B. G Mellor in Surface coatings for protection against wear gives the brief idea of various testing standards. According to Mellor the main equipment that is required to find the erosive wear of the pneumatic bed is the centrifugal accelerator erosion tester. Here in the <https://assignbuster.com/investigate-the-erosive-characteristics-of-targets-using-a-centrifugal-accelerator-erosion-tester/>

experiment the different test conditions like using different velocities at different impinging angles are used to find the erosive wear of the component. The investigation is mainly focused on the effect of the particle concentration, effect of progression of wear and the effect of bend radius (3) [19].

The pneumatic conveyor test rig should also be inspected prior to the experiment. The equipment should be set to the conditions that would exactly suit the experiment. Hence, the rotational speed of the screw feeder, the blow tank pressure and the mass flow rate of the air supplied to the conveying pipe all should be adjusted to give a positive experimental result (4)[20]. As mentioned the test rig material is the mild steel on which the experiment is to be performed.

The material that is to be used in the experiment which is to be impinged on the mild steel component is the olivine sand abrasives. Olivine sand consists of 98. 5%  $(\text{Mg, Fe})_2\text{SiO}_4$ , with the balance being made up of traces of metallic oxides. The particles density of the abrasive material should be found out prior to the experiment. The grain size should also be measured and found before the experiment (3)[19].

### 2. 6. 3 Centrifugal accelerator erosive tester

The test equipment that is to be used for the determination of the erosive wear for mild steel impacted by olivine sand is the centrifugal accelerator erosion tester. The schematic figure of the centrifugal accelerator erosion tester is shown below (4)[20].

Figure 2. 1: Schematic of the centrifugal accelerator type erosion tester (4) [20].

The centrifugal accelerator erosion tester is the testing equipment that is to be used in the experiment in the laboratory. The main parts of the centrifugal erosion tester are feeder, an accelerating rotating disc and a target holding system. The abrasive olivine sand is fed into the central hole of the rotating disc and is accelerated through the several radial ceramic tubes by the centrifugal force and ejected from the end of the tubes. The specimen targets are set for the reorientation relative to the direction of parallel flow by the disc on holders. The edges and back face of the specimens are protected from particle impact to prevent unwanted erosion. The target holder is the main equipment that is used for the change of angle for the particles that to be feed into the system.

There are many experiments performed using the same equipment by many researchers which would help the present work with their papers. They clearly explained about the working procedure of the experiment and the methodology and also the result which would be a great reference for the present piece of work (5)[21].

#### 2. 6. 4 Glass-blast erosive wear test

This test used for determined the wear factors . the glass blast test is consist of carbide nozzle 90mm in length with inter diameter 3mm and it having air injection for particle acceleration. A screw feeder mounted to form a loss in weight, this feeder fed the abrasive into the injector housing. And the object was placed on the adjustable table to control impact angles on the object.  
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The author T. Deng was compared the wear factors using the two wear test and compared the results (6) [22]. The figure 2. 2 show below was glass-blast erosive wear test.

Figure 2. 2: Glass blast erosive wear test (6)[22]

#### 2. 6. 5 Measurement of wear

The measurement of wear is partly determined by the change of mass occurred in the object. A journal by Gwidon W. Stachowiak, Andrew W. Batchelor, Grazyna Stachowiak in Experimental methods gave the brief idea about measurement of wear. Another problem in the experiment of wear is loss of data when wear is measured over a series of intervals as opposed to continuous monitoring and this monitor shows all worn loss on the object figure 2. 3.

Figure2. 3: Loss of information when continues wear recording is substituted by periodic measurement (17)[23].

At present there are methods of measuring wear:

Detection of change in mass.

Measurement of reduction in dimension of a worn specimen.

Profilometry of the worn specimen.

#### 2. 6. 6 Measurement of solid particle velocity in erosive wear

Authors A. W. Ruff and L. K. Ives in their paper explained about measurement of solid particle velocity in erosive wear that is being performed in their experiment in the laboratory. Measuring of solid particle

velocity is mostly depends on the best erosive testing equipments. Here they have performed the experiment using three different erosion testing apparatus, and explained the working procedure of each of the three different apparatus used. The motion of velocity of particles was determined by high speedphotographics methods. Also they have shown methods of increasing and decreasing the velocity of particles through motors and transmitted them on transducer output which can be viewed directly on an oscilloscope. As the project is based on experiment the paper would be of great use because the experimental procedure can be useful in many ways (7)[9].

## **2. 7 Summary**

The chapter gave detailed literature review of the concept of erosion and its developments over the years. Literature review was very much useful for the proper understanding of the topic and gaps in research. Based on these gaps in research the author proceeded further in project work and the next chapter gives detailed methodologies, equipments and tools used during project work.

# **CHAPTER 3 METHODOLOGY**

## **3. 1 Overview**

This chapter explains about the different testing methods and tools used during the experimental process. Also a brief description of materials and material handling equipment is given.

## **3. 2 Experimental requirements**

olivine sand was prepared to required sizes:

Due to vast availability of olivine sand in the nature it is been preferred in the present project. With the use of sieving machine olivine sand was prepared to required sizes ranging from 45-425 $\mu$ m.

impact velocity and angle were calibrated by double disc velocity meter:

The double disc velocity meter was used for calibration of impact angles and impact velocities. The calibration results were used for calculating the erosion rate of the mild steel target at proposed conditions.

Setting up of right test conditions:

To satisfy the proposed test conditions the correct setup of the experiment was required. The setup process would include setting up the position of the target angle, rotating speed of the accelerating rotating disc and feeding rate of the olivine sand.

The erosion characteristics of mild steel were determined at certain conditions:

Most of the pneumatic conveyers are designed by specific characteristics conditions , based on this characteristics condition have been choose some specific conditions such as an impact angles 20°, 30°, 45° and 90°and velocity 20, 30 and 40 m/sec during this experiment . The main intention was to finding impact angles, impact velocities and size of the material were to determine the erosion rate.

Determination of specific erosion rate on mild steel:



The specific erosion rates of mild steel target were calculated at different conditions by changing the impact angles and impact velocities, the results were analysed. The highest erosion rate and the least erosion rate of the target were calculated. These results were useful for the predicted models.

### **3. 3 Test facilities**

There were number of tools used for analysing the test during the experiment which was described below.

#### **3. 3. 1 Centrifugal accelerator tester**

Erosion wear test apparatus built by T. deng at the wolfson centre was available for this wear test. Centrifugal accelerator tester which is illustrated in figure 3. 1 below consists of a feeder, an accelerator rotation disc and target holding systems. There were two types of feeders to feed the materials into the rotating disc which were vibratory feeder and conical feeder. Conical feeder was used for this present project. The target particles continuously fed to the centre hole of the accelerator rotating disc through special type of funnel, and then from the feeder they travel outwards along the radial tubes in the rotating disk. Material leaves disc at the periphery with tangential velocity equal to disc velocity. Targets are mounted at the points surrounding the periphery of the disc and the specimens are exposed to a series of eroded streams particles from the radial tubes of the rotating disc.

Figure 3. 2 schematical diagram of centrifugal accelerator tester:

Figure 3. 1: Centrifugal accelerator type erosion tester

This method is more advantageous over the gas jet method and well suited to perform the screening tests on many different materials. The specimens were mounted on the holding system which rotates slowly around the accelerator rotating disc but it rotates only in one direction, to eliminate any possible bias associated with specific specimen locations. The maximum numbers of specimens per test have ranged to 30 in different design of rigs. [25]

Accelerator rotating disc is one of the most important parts of the centrifugal accelerator tester. Usually the rotating disc diameter varies between 200 and 600 mm. The apparatus shown in figure 3. 1 has a disc of 240 mm in diameter and it contains six radial alumina ceramic tubes with an internal bore diameter of 2. 6 mm. The erosion centre was placed on rotating disc of 0. 24m diameter [25]. The disc was attached to an infinitely variable inverter controlled motor that was driven by V- shape belt drive. The motor requires 220-240 voltage and which has maximum of 2850 revolution per minute.

### 3. 3. 2 Description of tabular feeder system

In order to obtain a constant mass flow rate of the abrasive particle, a tabular feeder is used to feed the abrasive material into conveyers or into the erosion test rig and serves as an auxiliary machine in coal washing, electric power, sintering plant and building industries [24]. Tabular feeder consist two main parts.

1) Hopper

2) Rotating control disc

Hopper acts as storage for olivine sand before feeding into the accelerator disc, rotating control disc controls flow rate of material is required. The speed of the rotating disc can be altered using this speed control unit as a result the material flow will change according to the speed of the rotating disc. Figure 3. 2 shows the laboratory tabular feeder used for the project work. Calibration of the tabular feeder was achieved by measuring the flow rate of mass of materials.

Figure 3. 2: Tabular feeder [U1]

### 3. 3. 3 Description of Double Disc Velocity meter

There are two types of instruments which were used to measure the particle velocity vector in an erosion tester, they are optoelectric velocity meter and laser Doppler anemometer (k89) [10]. The accuracy of the particle velocity measure was low while using optoelectric velocity meter in centrifugal erosion tester. Therefore, a static form of the double-disc velocity meter and displaced wear scar method (R75)[9] were used for calibration test of the particle velocity vector. Static form of double disc velocity meter is used to measure the particle velocity vector and direction of particle travel. The slot on the double disc velocity meter from which continuous flow of eroded particle travels and hits the surface of the target forms a scar on target material. The exit angle of the actual particle jet can be calculated by the following equation. A schematic diagram of double disc velocity meter is shown in figure 3. 3.

Figure 3. 3: Double disc velocity meter

### 3. 3. 4 Tachometer

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Tachometer is a mechanical instrument used to measure the speed of rotating devices. Here in the present experiment it is used for measuring the speed of the accelerating rotating disc. It has the digital display which when placed against the rotating device shows the speed in rpm. The figure of tachometer is shown below.

Figure 3. 4: Tachometer

### 3. 3. 5 Mechanical sieves

Sieving is one of the oldest and well-known methods for particle size measurement. Sieve test is a procedure to differentiate the fine material from the coarse material with the help of a nested column of sieves with wire mesh cloth. Required material is poured into the top sieve which has largest screen openings, each sieve openings in the column are arranged in order of decreasing size, from top to bottom, where it is collected at the base, which is called receiver. The sieve shakes the column, for fixed amount of time, depending on amount of material poured. After the material is finished amount of sand on each sieve is weighed. The weight of sample of each sieve is then divided by the total weight to give a percentage retained in each sieves. Figure 3. 5 shows BS Sieves with sieve shaker machine.

$$\% \text{ Retained} = \frac{W}{W_{\text{total}}} \times 100 \%$$

Where  $W$  sieve is mass of retained in sieve

$W_{\text{total}}$  is the total mass retained in all sieves.

Figure 3. 5: Mechanical sieves on sieve shaker

### 3. 3. 6 Ultrasonic bath for clean the targets

An ultrasonic machine is cleaning equipment used for delicate items which uses ultrasound (usually from 20-400 kHz) and the appropriate cleaning solvent (sometimes ordinary tap water). This machine can only be used with water but solvent which gives a better cleaning option is always advised to clean the object. These machines are mostly used for cleaning jewellery, lenses and other optical parts, surgical instruments. Ultrasonic machine uses high frequency sound waves to agitate in an aqueous or organic compound. Water is used for normal cleaning of the object where as the solvent is used for more effective cleaning.

Figure 3. 6: Ultrasonic Targets Cleaner

## 3. 4 Description of test materials

### 3. 4. 1 Specimen (Mild steel)

Mild steel typically means soft, unhardened steel with low carbon content. Mild steel is the type of steel that contains iron as well as little amount of other elements i. e. 0. 18-0. 23% Carbon, 0. 30-0. 60% Manganese, 0. 30% Silicon, 0. 040% Phosphorous and 0. 50% Sulphur. Cheap availability, high stiffness and magnetic property are some of the user friendly characteristics for the vast application of mild steel. Other specifications of mild steel are:

Density of mild steel = 7. 85 g/cm<sup>3</sup> (0. 284 lb/in<sup>3</sup>)

Young's modulus = 210, 000 Mpa (30, 000, 000 psi)

Mild steel was taken in 2. 5? 25? 26 mm square specimens and mass of each specimen was measured as approximately 13. 34 to 14. 90 grams.

Figure 3. 7: Mild steel target

### 3. 4. 2 Olivine sand

Olivine sand is one of the most common and easily available minerals in the earth, It has less amount of thermal dilation and is composition of magnesium and iron ortho silicate with chemical formula  $(\text{Mg, Fe})_2\text{SiO}_4$ . The density of olivine sand is 3. 28 gm/cm<sup>3</sup>, melting point up to ~1760 deg. C and the crystals present are angular with sharp edges [29] and the product is hard, dense and heavy in nature. It is an abrasive media for sand blasting and water jet cutting services. The main uses of olivine sand are iron ore processing, foundry sands, abrasives, agriculture etc.

Chemical Specification of olivine sand [30]:

Products Specification

MgO 42-47 %

SiO<sub>2</sub> 35-42%

Fe<sub>2</sub>O<sub>3</sub> 10-13%

CaO 2-2. 5 %

LOI 1. 5% Max

Figure 3. 8: various size of olivine sand (45~425 μm)

### 3. 5 Test conditions for impacting erosion wear

The prominent parameters and their effect on erosion are as follows:

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### 1) Impact angle

Impact angle is defined as the angle between the target surface and the direction of striking the solid particle. The variation of erosion wear with the impact angle depends on the characteristics of the target surface material namely brittle or ductile type.

### 2) Velocity of solid particles

Velocity of solid particle strongly impacts the erosive wear. As particle velocity increases there is significant increase in erosion rate. The erosion rate is generally related to the particle velocity using power law relationship in which the power index for velocity varies in the range of 2-4.

### 3) Particle size and shape of test materials

Particle size and shape is also one of the prominent parameter, which impact erosion wear. Many investigators have considered solid particle size important to erosion. The erosive wear increases with increase in particle size according to power law relationship. The effect of particle shape on the erosion is not very well established due to difficulties in defining the different shape features. Generally roundness factor is taken into consideration. If roundness factor is one then the particles are perfectly spheres and a lower values show the particle angularity.

### Analysis of hitting particle (Olivine Sand)

Pneumatic conveyors are mainly used to transport the powdered materials with high speed and various angles. Project work was mainly based on wear

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erosion of ductile materials in pneumatic conveyors which is caused by powdered particles, hence Olivine sand was chosen as hitting material. Olivine sand is Magnesium Iron silicate which is one of the most common materials found on the earth, Because of its availability and low cost it was chosen in the work, a detailed description of olivine sand was given in section 3. 2.

One of the important factors in erosion rate of the target material is size of the particle. Hence measuring of size of the olivine sand was the first experimental work which has been carried out. The size of the sand was measured by using BS Sieves; the description of BS sieves was given earlier in the chapter. Steps involved in analysis of sand are as follows:

300 grams of olivine sand was taken and dried before use.

The sand was poured through different sizes of BS Sieves which vary from 45  $\mu\text{m}$  to 425  $\mu\text{m}$ .

Ten minutes of vibration with amplitude of 7 Hertz were taken as the standard measurements for the apparatus.

The vibrator which was connected to sieves vibrates whole apparatus then sand follows downward path on the apparatus leaving behind different sizes of grains in each sieve.

Amount of Different sizes of sand left behind in each sieve was measured using electronic weighing machine.

Calculations related to Olivine sand are as follows:

Percentage of weight retained in each sieve is given by dividing the weight of sand in each sieve by total weight of sand.

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$$\% \text{ retained} = (W_{\text{sieves}} / W_{\text{total}}) \times 100 \%$$

Where  $W_{\text{sieve}}$  is mass of sand retained in sieve

$W_{\text{total}}$  is the total mass retained in all sieves.

Amount of sand left behind in each sieve and percentages of remaining amount of sand were calculated and tabulated. Tabular column was given in appendix 3. 1

A graph was plotted with cumulative percentage of total mass of sand retained on Y axis and sieves size on X axis. This graph gives the average size of particle which was to hit the target.

Figure 4. 1: Cumulative graph for percentage mass of sand and sieve size

It can be seen from the graph that a centre line is cutting the cumulative percentage weights of the sand. The point where the line cuts the graph is the average weight of the particle. The average size of the particle was calculated as  $\approx 144\mu\text{m}$  from the above graph and shape of olivine sand was angular.

After size analysis of material, the next stage of the experimental procedure was calibration of impact velocity and angle of the particle . In case of the centrifugal accelerator, the particle velocity is dependent on the rotation velocity of the rotating disc. The range of particle impingement over the surface of a target varies due to the geometry of this type of erosion tester and need to be accounted for. Therefore, some calibrations are necessary to

be carried out before the test work starts which include measurement of particle velocity and calibration of the abrasive feeders.

#### 4) Particle concentration for erosive tests

Concentration is amount of solid particles by weight or by volume in the fluid. As concentration of particle increases more particles strike the surface of impeller which increase the erosion rate, the concentration of slurries can vary from 2% to 50% depending upon the type of slurry. However, at very high concentrations particle interaction increases and this decreases the striking velocity of particle on the surface.

### 3. 7 Summary

This chapter can be considered as the backbone of project work as all the methodologies, description of working equipment, testing conditions and analysis of testing materials were discussed in the chapter. The following chapter discusses about the calibrations of impact angles which is most important in finding the exact test conditions.

## CHAPTER 4 Calibrations of Impact Conditions

### 4. 1 Overview

This chapter gives detailed description of work done during the project work. All the experimental works, results obtained from those experiments, analysis of the results have been discussed the chapter.

## **4. 2 Calibration of exit angle of particle jet, particle velocity and speed of the rotating disc:[S2]**

The second and most important phase of the experimental work was the calibration of exit angle of the particle, velocity of particle and speed of the accelerator rotating disc.

Before calculating erosion rate of target material it is necessary to know the speed of accelerator rotating disc and exit angle of hitting particle at given testing conditions.

These can be calculated by calibrating the results obtained after carrying out the experiment with different standard speeds of accelerator rotating disc and various impact angles of hitting particles of the target material.

Certain testing conditions were suggested for the experiment which are:

Impact angles of the hitting particles at 20°, 30°, 45°, 90° of the target material

Impact Velocities of hitting particle: 20m/s, 30m/s, 40m/s

This stage of experiment was sub divided in different stages:

### **4. 2. 1 Calculation of exit angles and particle velocity**

The exit angle and velocity of the particle was calculated by hitting the target surface with olivine sand. An electric circuit board was taken as target material for this calibration test. The exposed surface of the target was coated blue colour for a better view of particle impact and then it was placed in double disc velocity meter. A detailed description of double disc velocity

meter was given in chapter 3. A total of six double disc velocity meters were used for three different angles for more accurate calibrations. The double disc velocity meters were placed in a work holding system where the normal target holders are placed and with desired angles which are 30, 45, 60 degrees respectively. The figure 4. 2 shows the work holding system with double disc velocity meters.

Figure4. 2: Double disc velocity meter on target holding system

Figure 4. 5: detailed schematic figure of double disk velocity meter with target

Different stages of the experimental procedure are described below.

Velocity of accelerator rotating disc was fixed to 1500 rpm with the help of tachometer. There was a speed controller for increasing and decreasing the rotating disc speed to obtain desired speed.

The double disc velocity meter was located at the position where the normal specimen target holders stand and rotated to a given angle Or, with respect to the centre of the rotating disc.

500gms of olivine sand was manually fed into the centre of accelerator rotating disc with the help of conical feeder. From the centre of rotating disc the eroded particles (olivine sand) was equally distributed into the six ceramic tubes. By centrifugal force Olivine sand is forced towards target specimens through alumina ceramic tubes.

The continuous flow of sand hits the targets with certain angle which is the exit angle of particle (K) forming the impact on surface of the target.

The specimen was then removed and cleaned and then photo scanned for <https://assignbuster.com/investigate-the-erosive-characteristics-of-targets-using-a-centrifugal-accelerator-erosion-tester/>

further calculations of exit angle and particle velocity.

Figures 4. 3 show the scanned photo of two test specimen for 30 degrees impact angle on target surface.

Figure 4. 3: The scan photo of two test specimen for 30 degrees impact angle on target surface.

Figures related to other angles and other rotating speeds are shown in appendix 4. 1.

Exit angle of the particle was calculated by using the following figure.

Figure 4. 4 geometry of the double disc velocity meter for measuring the particle velocity vector and particle exit angle at the time of testing

4. 2. 2 Calculations of impact conditions of centrifugal erosion tester:

Using photo scanner which can improve the accuracy of measurement from 0. 5mm up to 0. 01mm, the exit angle of the actual particle jet can be calculated by the following equations,

$$K = \cos^{-1} [\sin (60^\circ - \theta) / r \cdot (r + s)] \text{ —————for } 30^\circ \text{ angle}$$

$$K = \cos^{-1} [\sin (45^\circ + \theta) / r \cdot (r + s)] \text{ —————for } 45^\circ \text{ angle}$$

$$K = \cos^{-1} [\sin (30^\circ + \theta) / r \cdot (r + s)] \text{ —————for } 60^\circ \text{ angle}$$

Where, K= exit angle, r= radius of the rotating disc, s= distance between slot and edge of accelerator disc,  $\theta$ = angle between target centre and particle jet.

1)1500 rpm -30°- 1 target

From the formula stated above  $K = \cos^{-1} [\sin (60^\circ - \theta) / r \cdot (r+s)]$

From the reference of figure 4. 4 the following values were obtained

$x = 3.98$ ,  $y = 11.55$ ,  $r = 120\text{mm}$ ,  $s = 18.65$ ,  $\theta = 19.01^\circ$

$k = \cos^{-1} 0.723$

$K = 40.73^\circ$

Where

$X$  = distance from impact centre to target centre

$Y$  = distance from slot to target

$r$  = rotating disc radius

$s$  = distance from rotating disc to slot centre

$\theta$  = angle of target holder

2)1500 rpm -30°- 2 target

From the formula stated above  $K = \cos^{-1} [\sin (60^\circ - \theta) / r \cdot (r+s)]$

From the figure the values were obtained  $x = 4.15$ ,  $y = 11.95$ ,  $r = 120\text{mm}$ ,  
 $s = 18.65$ ,  $\theta = 19.15^\circ$

$\cos k = 0.730$

$K = 40.91^\circ$

The calculations for the exit angles of the particle jet at 45, 60 degrees at a speed of 1500 rpm are shown in appendix 4. 2.

The experiment was repeated with different speeds of accelerator disc which are 2000 and 2500 rpm respectively. The calculations are shown in appendix 4. 2.

The quantity of sand was decreased with increasing speeds of accelerator disc, for accurate impact on the surface.

Exit angle for each speed of rotation disc was calculated by the formula

Exit angle  $K =$

Where  $k_1, k_2, k_3, k_4, k_5, k_6$  are exit angles of particle jet.

And all the exit angles were tabulated below

Position of the Target angle (deg)	Exit angles of Particle jet (deg)	Accelerator disc speed (rpm)
1500	2000	2500
30°		
Target 1 ( $k_1$ )	40.73°	
	40.68°	
	42.68°	
Target 2 ( $k_2$ )	40.91°	

41. 23°

41. 29°

45°

Target3 (k3)32. 43°

32. 50°

39. 42°

Target4 (k4)33. 55°

32. 81°

40. 39°

60°

Target5 (k5)37. 79°

37. 69°

38. 53°

Target6 (k6)35. 78°

36. 43°

37. 01°

Exit angle (K)



36. 86°

36. 905°

39. 88°

Table 4. 2: Exit angles for various double-disc velocity meters at different angles and speeds

The next step was to calculate the particle velocity which was calculated by using the following methodology:

Figure 4. 5: calibration of the particle velocity

For 1500RPM

Exit angle  $K = 36.865^\circ$  from above tabular column.

Tangent angle  $(V?) = ? r$

Where  $?$  is speed of the accelerator rotating disc

$r$  is radius of radius of accelerator rotating disc

$V? = 18.84\text{m/sec}$

From the Figure 3. 4  $\cos(K) = V?/VP$

Where  $VP$  is Particle Velocity

$\cos(36.865^\circ) = 18.84/VP$

$VP = 23.55\text{m/sec}$

In the similar way particle velocity at different rpm was calculated . the calculation part are shown in appendix 4. 3 and the velocities are:

Particle velocity for 2000 RPM is 31.43 m/sec

Particle velocity for 2500 RPM is 40.94 m/sec.

4. 2. 3 Calibration of exit angles of particles, particle velocity, speeds of rotating disc.[S3]

The next and most important stage of the experiment was calibration of Exit angles of particles, particle velocity, and speed of the rotation disc. A graph was plotted with the help of obtained exit angles; particle velocity for standard conditions (disc velocity 1500, 2000, 2500 rpms, and target angles 30 45 60 degrees) is shown in figure 4. 6.

Figure 4. 6: Calibration of exit angles of particles, particle velocity, speeds of rotating disc.[S4]

Calculation of speed of rotating discs, exit angle from the calibration, at proposed impact velocities.

With the help of graph, the values of rotating disc speed, exit angles of the particles were found for the given testing conditions. The values of particle exit angle (K) and rotating disc speed are given in the tabular column below.

Proposed impact velocities (m/sec)

Particle exit angle K (degree)

Rotating disc speed (rpm)

20

36. 5

1280

30

36. 9

1909

40

39. 9

2442

Table4. 3: values of exit angle and rotating disc speed at impact velocities 20, 30, 40 m/sec.

#### **4. 3 Design of target holders for mild steel**

Target holder is an important device in the experiment which was used to place the target in different required positions. Hence designing of target holders was an important task for any erosive experiment. These target holders contain screws for tightening the specimen in correct position to avoid slips when the test was running. As discussed earlier in chapter 3 mild steel material was used as a target with 25mm square in size and approximately each target was 14. 34grams mass. The target was held in a jig which protects the edges and back face of the test specimen. The jig with test specimen was fitted in to a target holder which would be capable of

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supporting the velocities of hitting particle jets, and can be tilted to different angles required for the test. Generally, there were three types of target holders used to find out the erosion rate of the target, but in the present project the horizontal target holders are used to hold the target specimen to find out the erosion rate. Here the suggested four different impact angle targets such as 20°, 30°, 45° and 90° were taken. For each angle two target holders are taken and the totals of 8 target holders were located on the target holding system for this experiment. The figure 4. 1 shows the target in the target holder. As the experiment was conducted at four different impact angles which are 20°, 30°, 45° and 90° which are shown in the figure 4. 2, 4. 3, 4. 4, 4. 5 schematically.

Figure 4. 1: target holder

### Summary

In the chapter discussed the calibrations working procedure for find out the exit angles and velocities by related formulas and calculation which is most important in finding the exact test conditions.

## Chapter 5: Experimental procedure

### Overview:

The chapter discusses about the experimental procedures which were carried out during the project work. A flow chart is also presented in the chapter which shows the detailed working procedure. Typical photographs of the target surface eroded at different test condition were shown in this chapter.

**Procedure:**

Finally the main part of project work was carried out, calculation of erosive wear under specified conditions. From above section, with the help of graph and tabular column it was found that for given testing conditions of particle velocity 20 m/s, 30 m/s and 40 m/s the accelerator speeds are 1280 rpm, 1909 rpm and 2442 rpm, similarly the exit angles are 36. 5, 36. 9 and 39. 9 degrees respectively. The first stage of experiment was carried out for 20 m/s particle velocity and later it is repeated for other particle velocities. But Different quantity of sand was taken when increasing speeds of accelerator disc.

Steps involved in the experiment are followed:

The apparatus was setup before the experiment.

The targets were arranged on target holding system in horizontal position with the impact angle of 20°, 30°, 45°, and 90°.

For more accurate values a total of eight targets were used two for each impact angle position.

Target specimens were punched with numbers A1 to A8 for clear identification after the experiment.

Before fixing the target materials on holding system they were cleaned with ultrasonic bath using isopropyl alcohol. A detailed description of Ultra sonic bath was given in section 3. 3. 6.

Once the targets cleaned they were weighed using electronic weighing machine which has an accuracy of about 0. 1mg. For more accuracy three readings were noted and an average of three was taken as the original

weight of target specimen.

In the next step the target was arranged at an exit angle of 36. 50 and with a centrifugal accelerator disc speed fixed to 1280 rpm and at a particle speed of 20 m/s.

The apparatus was all set for carrying out the experiment.

Once the apparatus was set up the olivine sand was poured through the tabular feeder for experiment. But at this instance the issue was how much sand per specific time the feeder should pour. The calibration of tabular feeder gives the rate of feeding for sand. After the calibration was completed the rate of feed should be set for this particular testing condition.

This completes all the required set up and requirements for the experiment.

After all setup was completed experimental process was started by pouring the sand at a rate of 66. 6 g/min. The feeder continuously poured the sand which was approximately 2 Kg in to rotating disc centre for about 30 minutes and the accelerator disc dispatched the sand on to targets. Sand particles which were in line with target materials hit the target and eroded the material from the target. After finish the test, target materials were removed from the target holders. They were again cleaned with ultrasonic bath using isopropyl alcohol also dried and weighed using the electronic balance. The experiment was repeated six times for more accurate results and results were tabulated. Results obtained during the experimental procedure are discussed in the next chapter.

A flow chart of experimental procedure is given below:

Figure: flow chart describing the experimental procedure

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The above experimental procedure of the flow chart was used for the other impact condition. The figure 5. 2 shows target specimen for 20 m/sec velocity after the test. 30 and 40 m/sec. Velocities figures was shown in the appendix 5. 1

Figure5. 2: Above figures shows the mild steel specimen after the impact of particles on it at 20o, 30o, 45o and 90o angles and impact velocity 20 m/sec.

## Summary

Chapter provided the detailed description of experiment procedure for erosive wear test using centrifugal accelerator tester. And also the working procedure flow chart.

## Chapter 6 Experimental Results

### 5. 1 overview:

This chapter gives the results obtained during the experimental procedure. Detailed tabular columns of results, graphical representations are presented in the report.

### 5. 2 Experimental results

Table4. 2 gives the detailed weights of target material before and after the experiment.

After measuring target material weights it was time to calculate the amount of eroded material. The amount of eroded material is calculated by deducting the weight of test specimen after the impact of olivine sand from the weight before impact. The specific erosion rate which is amount of

material eroded per kilogram of sand was found using a software program designed to calculate the specific erosion rate.

The tabular column 4. 3 gives the detailed results of amount of eroded material for different angles and weights.

Target's Angle of Targetssand used

No. Impact	2 kg	4kg	6kg	8kg	10kg	12kg	remove material (g/kg)	specific E(g/kg)
A120	0.00030	0.00080	0.00120	0.00180	0.00230	0.00280	0.002330	0.005720°
0057								
A220	0.00040	0.00110	0.00160	0.00230	0.00270	0.00370	0.003080	0.007520°
0075								
A330	0.00050	0.00090	0.00140	0.00220	0.00270	0.00340	0.002830	0.006930°
0069								
A430	0.00040	0.00060	0.00120	0.00200	0.00260	0.00320	0.002670	0.006530°
0065								
A545	0.00020	0.00030	0.00110	0.00190	0.00220	0.00300	0.002500	0.006145°
0061								
A645	0.00040	0.00070	0.00090	0.00140	0.00180	0.00270	0.002250	0.005545°
0055								
A790	0.00040	0.00050	0.00060	0.00080	0.00090	0.00130	0.001080	0.002690°
0026								
A890	0.00040	0.00050	0.00060	0.00070	0.00080	0.00120	0.001000	0.002490°
0024								



A graph was plotted between the amount of material eroded on Y- axis and amount of sand used on X axis which shows a gradual increase in the material eroded with the increase in amount of sand.

Figure :

This ends the experimental process which was carried out for the given testing conditions.

After the experimental procedure the following values of erosion rate were obtained.

Impact angle	Specific erosion rate
--------------	-----------------------

200.	0057
------	------

200.	0075
------	------

300.	0069
------	------

300.	0065
------	------

450.	0061
------	------

450.	0055
------	------

900.	0026
------	------

900.	0024
------	------

The experiment was again repeated for other testing conditions, the amount of sand used will vary with respect to testing conditions.

For Impact velocity 30m/s

Accelerator disc speed 1909 rpm

Exit angle 36. 90

The results were found as

Impact AngleMaterial RemovedSpecific Erosion Rate

200. 0009220. 0225

200. 0010110. 0246

300. 0010890. 0265

300. 0011220. 0274

450. 0010220. 0249

450. 0010220. 0249

900. 0005000. 0122

900. 0005330. 0130

For Impact velocity of 40m/s

Accelerometer speed of 2442 rpm

Exit angle of 39. 9 degrees

the results were found as

remove material (g/kg)Specific E (g/kg)

0. 0019000. 048320

0. 0018670. 047420

0. 0019830. 050430

0. 0021330. 054230

0. 0020170. 051345

0. 0020670. 052545

0. 0011330. 028890

0. 0011330. 028890

## **Chapter 7 Discussion of Results:**

### **6. 1 Overview:**

This chapter gives the detailed discussion of results obtained during the experimental process. Variation of erosive rate with respect to various characteristics is discussed in the chapter.

From the experiments it was found that erosion rate of the material from test specimen is mainly dependent on two factors;

Impact angle of the particle

Velocity of the particle

### **6. 2 Erosion rate with respect to Impact angles:**

A Graph was plotted between impact angles on X axis and Specific erosion rate on Y axis which was shown in figure 5. 4. 2. This graph has an increase in erosion rate from 20 degrees to 30 degrees of impact angle of target material. This increase was because decline in erosion rate along with increase in impact angle. It can be understood from the graph that as the impact angle of particle increases the erosion rate gradually decreases. This decline in erosion rate is because the number of sand particles hitting target decreases with increase in angle.

Figure :

### **6. 3 Erosion rate with respect to velocity of the particle:**

From the tabular columns 3. 4 and 3. 5 and 3. 6 it can be noted that as the velocity of particle increases the rate of erosion increases. The reason behind this graph is high velocities particles erodes more material.

### **6. 4 Conclusions**

## **CHAPTER 7 CONCLUSIONS**

The project had four objectives to be delivered and which were successfully achieved. The main objective of the project was to investigate the rate of erosion for mild steel targets under specific testing conditions. After conducting series of experiments with olivine sand and mild steel targets, erosion rate for particle speed of 20 m/s, 30 m/s and 40 m/s was calculated. From all the results obtained graphs were plotted to understand the nature of rate of erosion of particles. The graph suggests that rate of erosion increases with increase of particle speed on the target material. Also other graphs plotted between the rates of erosion and impact angle of target suggested that rate of erosion decreases with increase of impact angle of target specimen. Hence the main objectives of the experiment were achieved.

## **CHAPTER 8 Future work**

The project discusses conditions to avoid erosive wear for mild steel impacted by olivine sand. The vast nature of subject gives the opportunity to carry out the experiment by changing various properties of impact materials and target materials and testing conditions. Some of the experimental works which were not possible to carry out during the present work and would be possible in future are suggested. The next work can be carried out by <https://assignbuster.com/investigate-the-erosive-characteristics-of-targets-using-a-centrifugal-accelerator-erosion-tester/>

applying electro static charge to the olivine sand using electrostatic ring sensor equipment. The aim of using electro static ring sensor equipment is to find out charge to mass ratio. Another work that can be suggestible is combination of powder with sand. This is because every powder has its own properties, but when they mix with other materials they lose original properties and adopt new properties. This can be helpful to find out the new test procedure to avoid erosive wear for materials that can be impacted by olivine sand and other material mixture. The other important future work could be comparing of the present project result with the gas blaster erosion tester. From the result of this work, it can be observed that the accuracy of the tester would result in accurate results, so it is suggested that, to improve the accuracy of the centrifugal accelerator tester.

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