PROJECT REPORT ON

EROSION WEAR OF MATERIALS

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF

Bachelor of Technology
In
METALLURGICAL AND MATERIALS ENGINEERING

By

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&
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NATIONAL INSTITUTE OF TECHNOLOGY
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CERTIFICATE

This is to certify that the thesis entitled "*EROSION WEAR OF MATERIALS*" submitted by Sri Balaram Bijayakumar Behera & Neeraj Vimal Prasad Roll No. 10304004 & 10304010, in partial fulfillment of the requirement for the award of Bachelor of Technology Degree in Metallurgical and Materials Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Wear is damage to a surface as a result of relative motion with respect to another substance. One key point is that wear is damage and it is not limited to loss of material from the surface. However, loss of material is definitely one way in which a part can experience wear.

Another way included in this definition is by movement of material without loss of mass. An example of this would be the change of geometry or dimension of a part as a result of plastic deformation (e.g., from repeated hammering).

There is also a third mode implied, which is damage to a surface that does not result in mass loss or dimensional changes. An example of this third mode might be development of network of cracks in a surface. This might be of significance in applications where maintaining optical transparency is a prime engineering concern. Lens and aircraft windows are examples where this is an appropriate definition of wear.

In the older definitions of wear there used to be a greater stress on the "**loss of material**" , however now-a-days the newer and more general definitions of wear is very natural to the design or device engineer , who thinks of wear in terms of a change to a part that effects its performance. The focus is on the change which may be translated to damage. The implication of this generalization will be further explored in the discussion of wear measures.

Previously wear was defined as damaged to a surface. The most common form of that damage is loss or displacement of material and volume can be used as a measure of wear—volume of material removed or volume of material displaced. For scientific purposes this is frequently the measure used to quantify wear. In many studies, particularly material investigations, mass loss is frequently the measure used instead of volume. This is done because of the relative ease of performing a weight loss measurement. However there are some problems in using mass as primary measure of wear.

Direct comparison of materials can only be done if their densities are same. For bulk material this is not a major obstacle, since the density is either known or easily determined. In the case of coatings however, this can be a major problem. The other problems are more intrinsic ones.

A mass measurement does not measure displaced materials. In addition it is sensitive to wear debris and transferred material that becomes attached to the surface and can not be removed. This material does not necessarily have to be from the same surface; it can from the counter face as well.

From the above it can be seen that volume is the fundamental measure for wear when wear is calculated with loss or displacement of material. However, in engineering applications, is generally with the loss of a dimension, the increase in clearance or change in contour not the volume loss.

Volume, mass loss and a dimension are not the only measures for wear that are used in engineering. Life, vibration level, roughness, appearance, friction level, and degree of surface crack or crazing are some of the operational measures that are encountered.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

What is Wear?

There are several precise definitions for wear. However, for engineering purposes the following definitions contains the essential elements.

- Wear is damage to a surface as a result of relative motion with respect to another substance. One key point is that wear is damage and it is not limited to loss of material from the surface. However, loss of material is definitely one way in which a part can experience wear.
- Another way included in this definition is by movement of material without loss of mass. An example of this would be the change of geometry or dimension of a part as a result of plastic deformation (e.g., from repeated hammering).
- There is also a third mode implied, which is damage to a surface that does not result in mass loss or dimensional changes. An example of this third mode might be development of network of cracks in a surface. This might be of significance in applications where maintaining optical transparency is a prime engineering concern. Lens and aircraft windows are examples where this is an appropriate definition of wear.

In the older definitions of wear there used to be a greater stress on the "**loss of material**" , however now-a-days the newer and more general definitions of wear is very natural to the design or device engineer , who thinks of wear in terms of a change to a part that effects its performance. The focus is on the change which may be translated to damage. The implication of this generalization will be further explored in the discussion of wear measures.

What makes Study of Wear so essential?

Wear causes an enormous annual expenditure by industry and consumers. For some industries such as agriculture, as many as 40% of the components replaced on equipments have failed by wear. Estimates of direct cost of wear to industrial nations vary from 1% to 4 % of GNP and it is estimated that 10% of all energy generated by man is dissipated in various friction processes. Thus the magnitude of losses caused to mankind (which can be expressed in percentage points of GDP) makes it absolutely necessary to study ways to minimize it.

Thus minimizing wear, affects the economics of production in a major way.

WEAR MEASURES:-

Previously wear was defined as damaged to a surface. The most common form of that damage is loss or displacement of material and volume can be used as a measure of wear—volume of material removed or volume of material displaced. For scientific purposes this is frequently the measure used to quantify wear. In many studies, particularly material investigations, mass loss is frequently the measure used instead of volume. This is done because of the relative ease of performing a weight loss measurement. However there are some problems in using mass as primary measure of wear.

- Direct comparison of materials can only be done if their densities are same. For bulk material this is not a major obstacle, since the density is either known or easily determined. In the case of coatings however, this can be a major problem. The other problems are more intrinsic ones.
- A mass measurement does not measure displaced materials. In addition it is sensitive to wear debris and transferred material that becomes attached to the surface and can not be removed. This material does not necessarily have to be from the same surface; it can from the counter face as well.

From the above it can be seen that volume is the fundamental measure for wear when wear is calculated with loss or displacement of material. However, in engineering applications, is generally with the loss of a dimension, the increase in clearance or change in contour not the volume loss.

Volume, mass loss and a dimension are not the only measures for wear that are used in engineering. Life, vibration level, roughness, appearance, friction level, and degree of surface crack or crazing are some of the operational measures that are encountered.

CHAPTER 2

LITERATURE-REVIEW

TYPES OF WEAR:-

The various types of wear, there symptoms and appearance of the worn out surfaces are given below.

TYPES OF WEAR	SYMPTOMS	APPEARANCE OF THE WORN OUT SURFACE
Abrasive	Presence of clean furrows cut out by abrasive particles	Grooves
Adhesive	Metal transfer is a prime symptom	Seizure ,catering rough and torn out surfaces
Erosion	***Presence of abrasives in the fast moving fluid and short abrasion furrows***	***Waves and troughs***
Corrosion	Presence of metal corrosion products	Rough pits or depressions
Impacts	Surface fatigue , small sub micron particles or formation of spalls	Fragmentation ,peeling and pitting
Fatigue	Presence of surface and sub surface cracks accompanied by pits and spalls	Sharp and angular edges around pits
Delamination	Presence of surface cracks parallel to the surface with semi dislodged or loose flakes	Loose , long and thin sheet like particles
Fretting	Production of voluminous amount of loose debris	Roughening , seizure and development of oxide ridges
Electric attack	Presence of micro craters or a track with evidence of smooth molten metal	Smooth holes

(TABLE 2.1 VARIOUS TYPES OF WEAR, THEIR SYMPTOMS & APPEARANCE)

EROSION WEAR:-

Definition

Erosive wear has been defined as the process of metal removal due to impingement of solid particles on a surface. In this case particles are generally entrained in a fluid, such as in slurry.

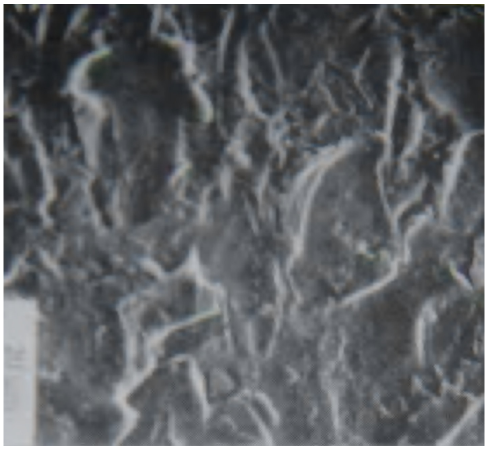
The wear caused in pipe lines handling abrasive slurries would be one example; another would be the wearing action caused by sand and grit in air streams.

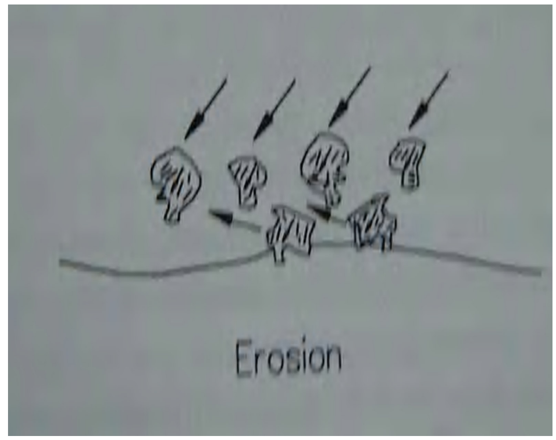
Mechanism of erosive wear :-

In erosive wear situation, particles that are normally entrained in a fluid can impact the wearing surface. The load between the particle and surface results from the momentum and kinetic energy of the particle. This difference in the loading situation results in a modification of equation used to describe the wear, which can be shown by a simple model for particle impact.

In erosion it has been established that the angle at which the stream impinges the surface influences the rate at which material removed from the surface and that this dependency is also influenced by the nature of wearing material. Such a dependency is to be anticipated. This can be seen by considering the impact of a single particle with a surface. This angle determines the relative magnitude of the two velocity components of the impact, namely the component normal to the surface and the one parallel to the surface. The normal component will determine how long the impact will last i.e. the contact time, tc, and the load. The product of tc and the tangential velocity component determine the amount of sliding that takes place. The tangential velocity component also provides a shear loading to the surface, which is in addition to the normal load that the normal velocity component causes. Therefore as this angle changes, the amount of sliding that takes place also changes, as does the nature and magnitude of the stress system.

Both of these aspects influence the way a material wears. These changes would also imply that different types of materials would exhibit different angular dependencies as well.





(2.1 EROSION WEAR SITUATION) (2.2 CHANGES IN SURFACE TOPOGRAPHY AS A RESULT OF EROSION)

- It has been demonstrated that the angle of attack between leading edge of the particle and the wearing surface determine whether or not cutting will take place. Below a critical value, deformation takes place.

  $\tan(90-Ac)=(1-\mu^2)/2\mu$

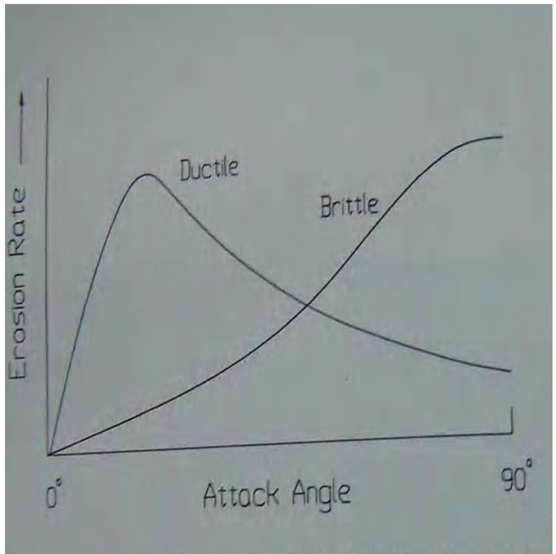
  Ac: Critical angle for cutting to occur

  μ: Coefficient of friction

- The angle of impact determines the two components of impact velocity.

- The normal component (Vn) determines the contact time (tc) and the load. The product of tc and the tangential velocity component (Vt) determine the amount of sliding that takes place.

- The Vt also provides a shear loading to the surface, which is in addition to the normal load that Vn causes. Thus angle of impact determines amount of sliding and the nature and magnitude of the stress system.



The effect of attack angle on erosion rates of ductile and brittle materials.

(2.3 EFFECT OF ANGLE OF ATTACK ON
THE EROSION BEHAVIOUR OF DUCTILE
AND BRITTLE MATERIALS)

As evident from the figure- The effect of angle on erosion rate is significantly different for ductile and brittle materials, particularly the angle associated with maximum erosion rate. These differences can be understood in terms of the predominant modes of damage associated with these types of materials. Brittle materials fracture tends to increase the abraded wear volume over that caused by cutting or ploughing (plastic deformation). This could be as much as ten times. As a general rule, brittle materials are more likely to fracture under normal impact conditions (i.e. impacting velocity perpendicular to the surface), than ductile materials. Consequently as erosive condition moves from a more grazing situation to a more normal impact, brittle materials would experience a greater tendency to experience brittle fracture, which tends to mask the ductile or cutting contributions. For brittle materials the erosion rate would then be expected to monotonically increase with the angle. For ductile materials, cutting and ploughing (deformation) are the predominant modes and fracture is negligible. The model for abrasion indicates that the wear due to these two modes is proportional to product of load and distance. Since load increases with angle and the sliding decreases with angle, an intermediate angle should exist where the product of the two is maximum.

From Archards Equation for wear,

$$V=K\,(L/p)\,x \qquad \text{---------------- (1)}$$

Where,
V is the Volume of Wear

X is the Distance of sliding
L is the Load
p is the Penetration Hardness
K is the Probability that the rupture of any given junction will result in wear.

Suppose L is the normal load then it can be converted to frictional load by means of Amontons' law,

$$F=\mu L$$

μ is the co-efficient of friction.

Equation (1) Then Becomes,

$$V=K (Fx)/\mu p$$

Where the product Fx represents the energy dissipated by sliding during the impact. The total kinetic energy of the particle stream of total mass M, and particle velocity v, is given by

$$E=1/2Mv^2$$

As a result of the impact with the surface a fraction, β, of the energy is dissipated. Equating this loss to Fx the following expression is obtained

$$V=K \beta Mv^2/2\mu p \qquad \ldots\ldots\ldots\ldots. (2)$$

This angular dependency is contained in equation (2).Assuming that β can be separated into an angular factor, φ, and a factor independent of angle β', and combining several of the material sensitive parameters and numerical factors into one, Ke , the following expression can be obtained,

$$V = Ke\ \varphi\ Mv^2 / v \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

Examining this equation for erosive wear volume it can be seen that it does not provide an explicit dependency on duration. However, such a dependency is implicitly contained in M, the total mass of the particles. If Q is particle mass per unit time, then M is Qt, where t is the time of exposure to the particle stream. Including this into equation (3), the following form is obtained.

$$V=Ke\ \varphi v^2Qt/p$$

Another variation of equation (3) is frequently encountered in the literature. Many investigators like to compare erosive wear situations in terms of the relative amount of material removed from the surface to the amount of abrasive particles to which it was exposed. Letting d be the density of the particles, the following equation can be obtained.

$$V/Ve = Ke\ d\ \varphi\ v^2 /p$$

Where Va is the volume of abrasive used to produce the wear.

(Ke Values for Erosion)

TARGET MATERIAL	Ke
Soft Steel	8* 10^-3 To 4*10^-2
Steel	1*10^-2 To 8*10^-2
Hard Steel	1*10^-2 To 1*10^-1
Aluminium	5*10^-3 To 1.5*10^-2
Copper	3*10^-3 To 1.3*10^-2

(Table 2.2)

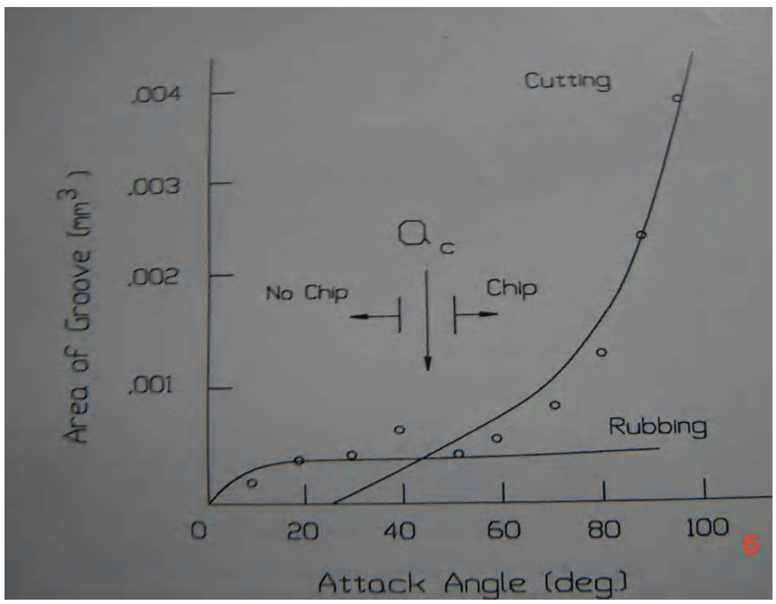
A compilation of Ke values is given in the above table. Comparing the K values with the K values for abrasive wear, it can be concluded that the wear mechanism is same in both the cases.

Factors Affecting Erosive Wear:-

- Attack angle
- Force of impingement
- Distance of fall

Attack Angle

It has been demonstrated that the angle of attack between leading edge of the particle and the wearing surface determines whether or not cutting will take place. below a critical value, deformation takes place.



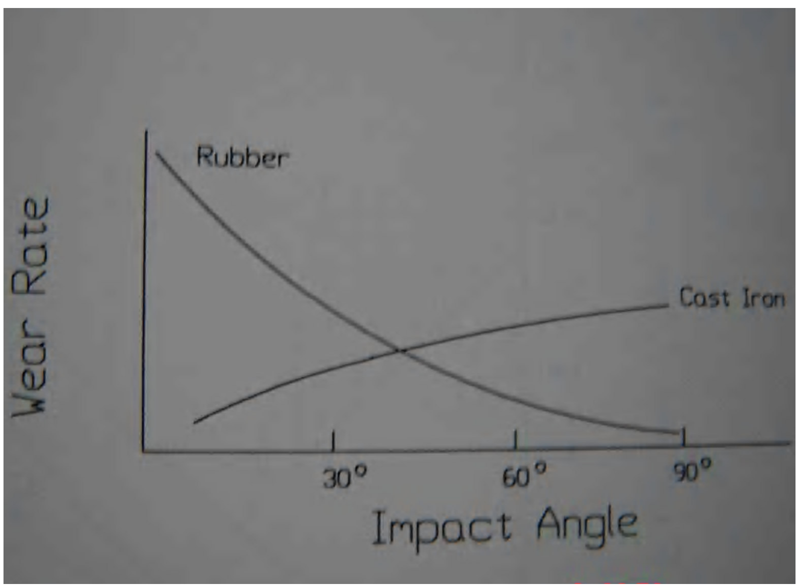
(2.4 The effect of attack angle on chip formation in abrasion)

It has been demonstrated that the angle of attack in the above diagram, between the leading edge of the particle and the wearing surface determines whether or not cutting will take place. Below a critical value, deformation takes place. The critical angle is primarily determined by the co-efficient of friction between the particle and the wearing surface, as shown by the above relation.

$$\tan(90-Ac)=(1-\mu^2)/2\mu$$

Ac: Critical angle for cutting to occur
μ : Coefficient of friction.

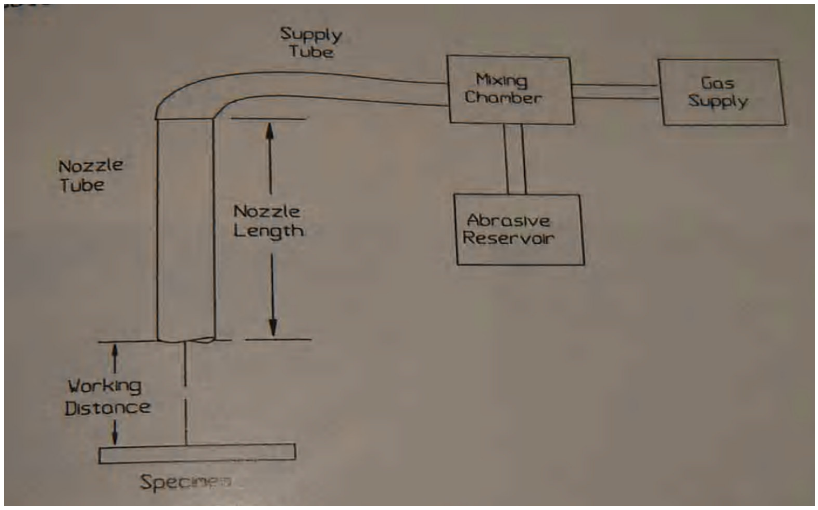
The critical angle is usually in the range of 30 to 60 degree. The SEM micrographs and profilometer traces illustrating these two actions is shown in the figure; in addition a transition or mixed mode is illustrated. The SEM micrographs as well as profilometer traces show the formation of lip or ridge along the groove for both the ploughing and the mixed or the wedge forming mode. The ridges are the result of plastic flow. The potential for debris or chip formation can be seen for the cutting and the wedge formation mode.



(2.5 Effect on Impact angle on Wear rate of different materials)

From the above diagram it should be noted that the desired angle should be on the right side of the critical angle i.e. for ductile materials it should be greater than the critical angle and for brittle material it should be lower than the critical angle. The differences are observed due to the physical properties. As ductile material has greater resistance to shear as compared to a brittle material. Similarly a lot of other factors like metallurgy, crystal structure, and other physical properties come into play.

Schematic Diagram of the Experimental Setup:-



(fig 2.6)

CONTROLLING FACTOR:-

- The angle of contact can be altered by rotating the specimen or holding the specimen at an angle. In the diagram it shown as perfectly horizontal i.e. normal to the impinging particles. To change the angle, the angle at which particles impinge can be changed.
- The distance of fall is altered by changing the "working distance".
- The force of impingement can be altered by changing the pressure of the gas supply.

As gas acts as a medium to entrain the silica sand particles, hence higher the pressure greater is the force and vice versa.

Erosion by solid particle impingement using gas jets has been used to investigate solid particle and to rank materials in terms of resistance to this mode of wear. Weight loss is the method used for determining the amount of wear that occurs. However the resistance to erosion is measured in terms of the wear volume per gram of abrasive, which is obtained through the use of a wear curve that is generated by measuring the mass loss at different time intervals. The slope of this curve is then used to determine an average wear rate. The mass loss rate is converted to a volume loss rate by dividing by the density of the specimen. This volume wear rate is then normalized to the abrasive flow rate to provide the erosion value (i.e. specimen wear per gram of abrasive). The smaller the erosion value, the more wear resistant is the material. Guidelines for the test duration are provided with the intention that the measurements be made in a period of stable wear behavior. Since two minutes or less is typically required for stabilization, it is specified that the first measurement be taken after two minutes. the test should be carried out for tallest a total of ten minutes but should not go beyond the point where the scar depth exceed one mm. The reason for this limit is that beyond that depth that shape of the scar becomes significant in determining the impact angle.

CHAPTER 3

EXPERIMENTAL PROCEDURE

Preparation & Experimentation

EROSION TEST

In the present investigation a self made erosion apparatus of the sand blast type was used. It was designed and fabricated in our laboratory.

1.CONSTRUCTION

The erosion testing machine has many parameters which can be varied. It has some distinct parts.

1.1. Nozzle

The nozzle is connected with the metallic tube through which pressured air enters the nozzle mouth. As pressurized air enters the nozzle along with the sand so the sand flows with high velocity and thus with high momentum, Thus eroding anything coming on its way.

1.2. Reciprocating Air Compressor

High pressured air is supplied from the reciprocating air compressor, present beside the erosion testing machine. It as a two cylinder compressor, the bigger cylinder contains air of low pressure and high volume. The smaller cylinder contains high pressured air. The machine sucks air from the atmosphere and first stores in the larger cylinder with high pressure, and then it moves to the smaller cylinder with pipes.

1.3. Fixture Arrangement

The fixture arrangement is provided to hold the sample or specimen at different angles to the nozzle. The fixture arrangement has one metal plate which moves over a gradually marked arrangement.

The fixture can be arranged at different angles and it can also be moved linearly to locate the specimen exactly under the nozzle.

N.B.:- Angle is measured with respect to the nozzle and not the base line.

1.4. Funnel Arrangement

Funnel connected with a pipe to the nozzle is provided at the top. The funnel is used to pour sand in it.

EXPERIMENTAL PARAMETERS

1. Angle

The angle can be varied by using the fixture arrangement. Different angles which can be used are 30º, 60º, 90º.

2. Pressure

Different values of pressure which can be used are 4Kgf/mm2, 5 Kgf/mm2 and 6 Kgf/mm2.

3. Stand off distance

It is the distance between the nozzle tip and the specimen of the surface. The stand off distance can be varied by adjusting nozzle height using the screw arrangement. The different values of stand off distance used were 100mm and 200mm.

4. Erodent size

Sand particles of particular size can be achieved by sieving. Mesh size used was 400 microns.

EROSION TEST PROCEDURE

1. Before conducting the test the specimen surface was cleaned properly.

2. The sample is clamped at the fixture. The required angle and stand off distance was adjusted.

3. The air at required pressure is mixed with the erosive particle and is directed to the a specimen for specified time duration.

4. The initial mass and the mass of the specimen after erosion were found out using the weighing machine.

5. The above steps are repeated for different parameters mentioned.

CHAPTER 4

RESULT & DISCUSSION

TABULATION

MILD STEEL

SOD=100mm

PRESSURE= 4Kgf/cm2

TIME	30^0	60^0	90^0
0	27.770	27.750	27.740
2	27.760	27.740	27.740
4	27.750	27.740	27.730
6	27.750	27.740	27.730

SOD=100mm
PRESSURE=6Kgf/cm2

TIME	30^0	60^0	90^0
0	28.540	28.560	28.580
2	28.540	28.550	28.570
4	28.530	28.550	28.570
6	28.530	28.540	28.560

SOD=200mm
PRESSURE=4Kgf/cm2

TIME	30^0	60^0	90^0
0	28.530	28.510	28.490
2	28.520	28.500	28.490
4	28.510	28.500	28.480
6	28.510	28.490	28.480

SOD=200mm
PRESSURE=4Kgf/cm2

TIME	30^0	60^0	90^0
0	28.450	28.470	28.480
2	28.450	28.460	28.480
4	28.440	28.460	28.470
6	28.440	28.450	28.470

ALUMINIUM

SOD=200mm
PRESSURE=4Kgf/cm2

TIME	30^0	60^0	90^0
0	131.740	131.720	131.710
2	131.730	131.720	131.700
4	131.720	131.710	131.700
6	131.720	131.710	131.700

SOD=200mm
PRESSURE=6Kgf/cm2

TIME	30^0	60^0	90^0
0	131.700	131.680	131.660
2	131.690	131.680	131.660
4	131.690	131.670	131.660
6	131.680	131.660	131.650

SOD=100mm
PRESSURE=6Kgf/cm2

TIME	30^0	60^0	90^0
0	131.610	131.590	131.580
2	131.600	131.590	131.570
4	131.600	131.580	131.570
6	131.590	131.580	131.570

SOD=100mm
PRESSURE=4Kgf/cm2

TIME	30^0	60^0	90^0
0	131.650	131.640	131.620
2	131.640	131.630	131.620
4	131.640	131.620	131.610
6	131.640	131.620	131.610

STAINLESS STEEL

SOD=100mm
PRESSURE=4Kgf/cm2

TIME	30^0	60^0	90^0
0	33.840	33.810	33.790
2	33.830	33.800	33.780
4	33.820	33.790	33.770
6	33.810	33.790	33.770

SOD=100mm
PRESSURE=6Kgf/mm2

TIME	30^0	60^0	90^0
0	33.740	33.760	33.770
2	33.730	33.750	33.770
4	33.730	33.750	33.760
6	33.720	33.740	33.760

SOD=200mm
PRESSURE=4Kgf/mm2

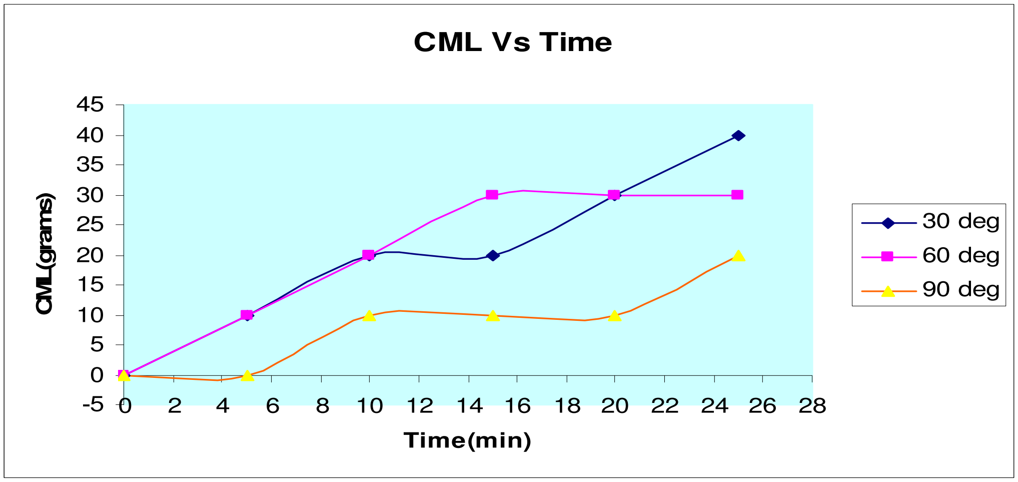
TIME	30^0	60^0	90^0
0	33.720	33.710	33.700
2	33.720	33.710	33.690
4	33.710	33.700	33.690
6	33.710	33.700	33.690

SOD=200mm
PRESSURE=6Kgf/cm2

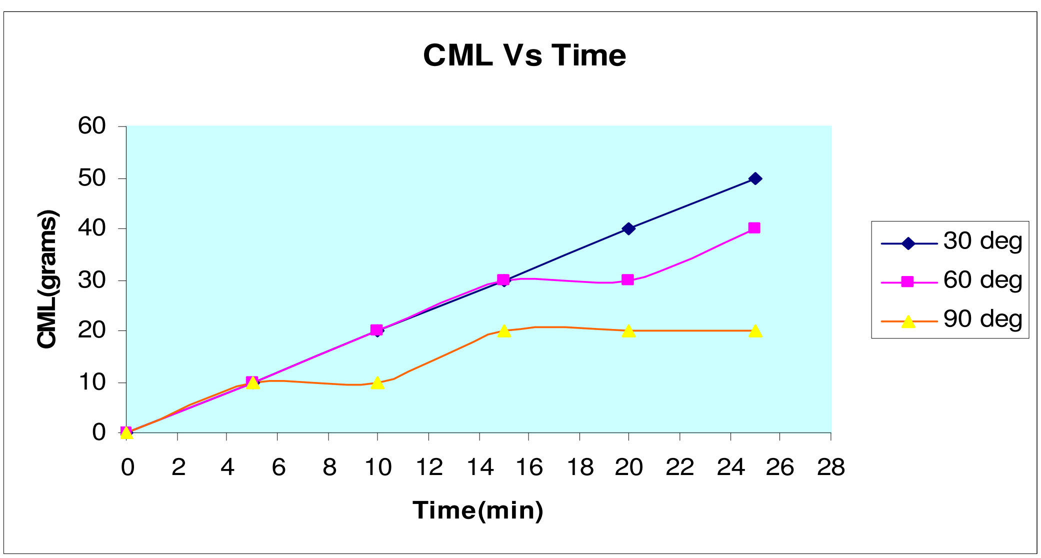
TIME	30^0	60^0	90^0
0	33.660	33.680	33.690
2	33.650	33.670	33.680
4	33.650	33.670	33.680
6	33.640	33.660	33.680

GRAPHS

Graph for Mild Steel
SOD = 100mm
Pressure = 4kgf/cm2



Graph for Mild Steel
SOD = 100mm
Pressure = 6kgf/cm2



Graph for Mild Steel
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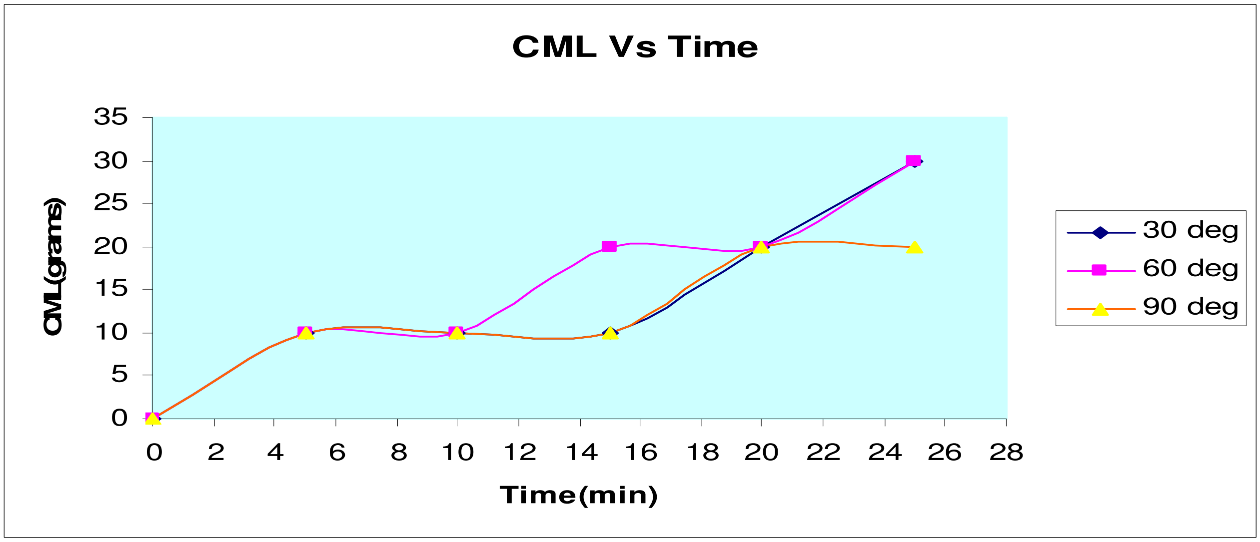

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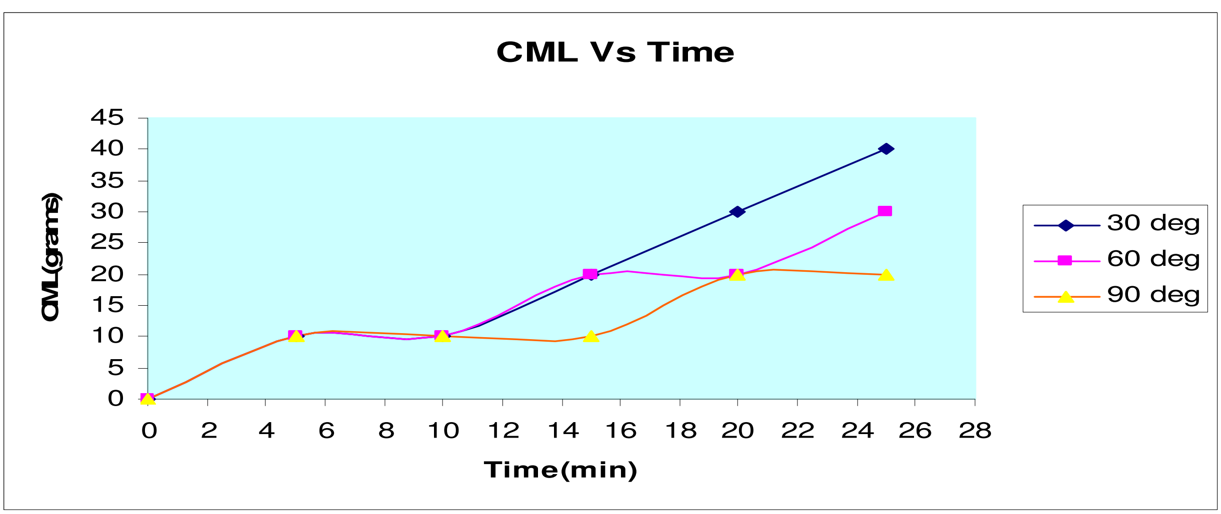

Graph for Stainless Steel
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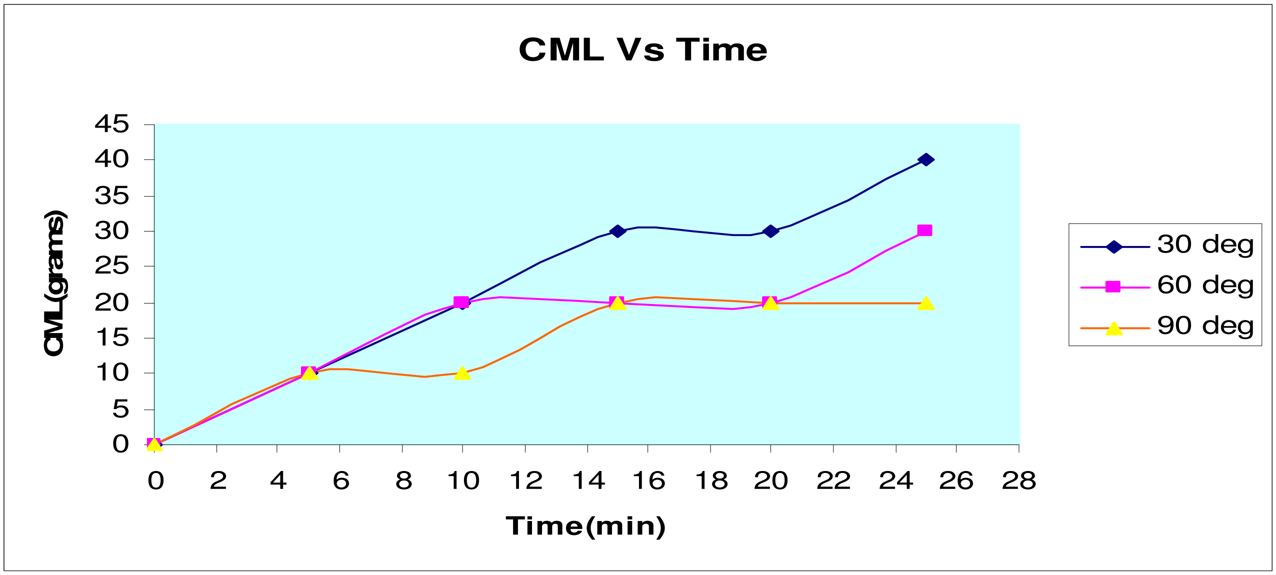
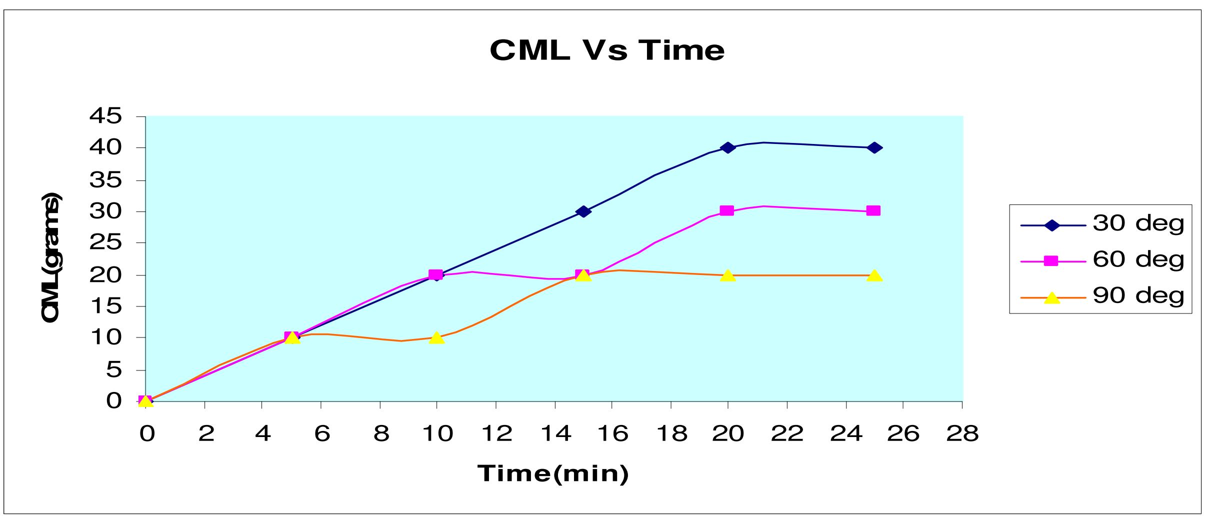
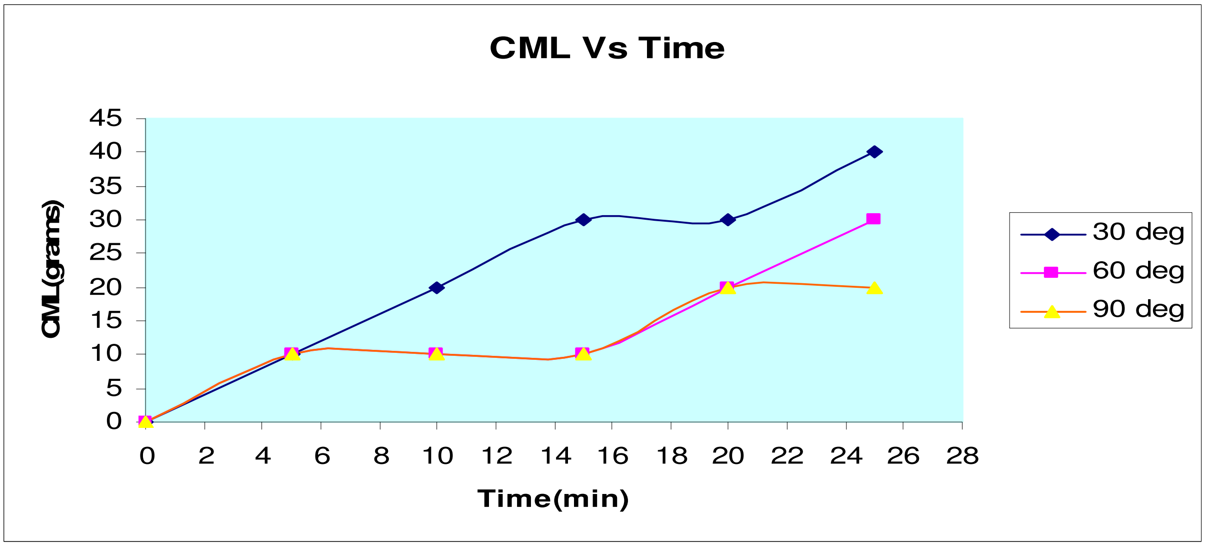


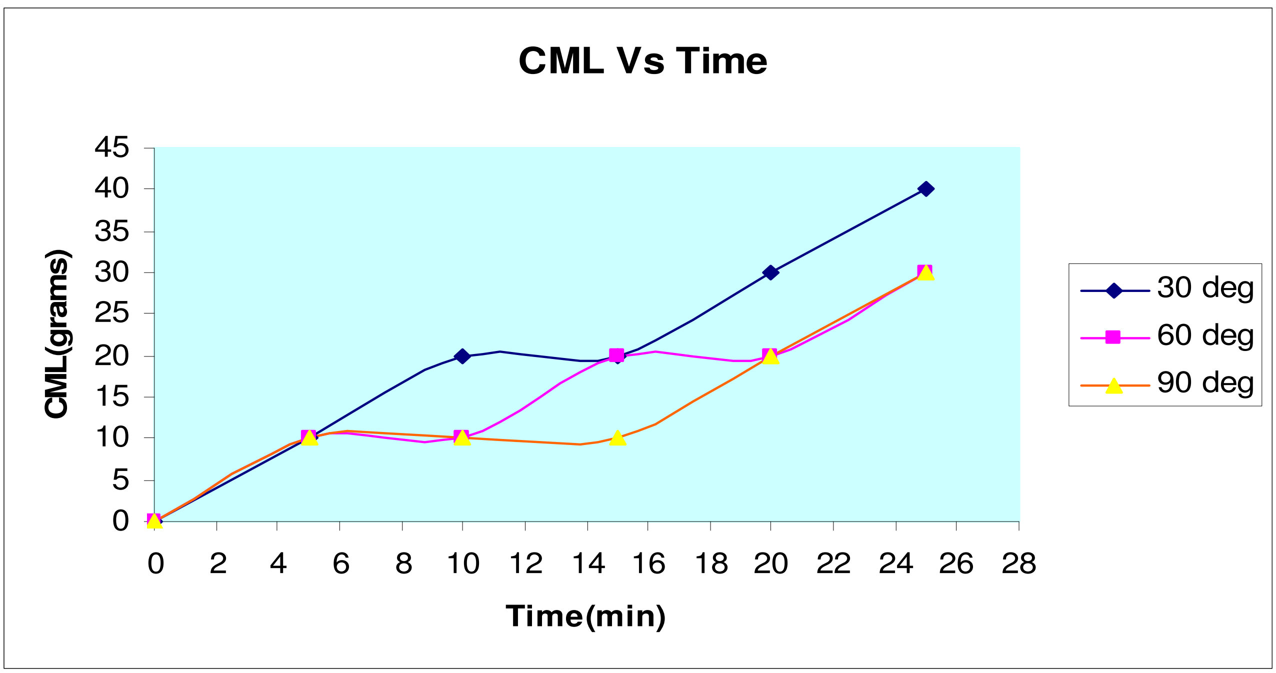
Graph for Stainless Steel
SOD = 100mm
Pressure = 6kgf/cm2



Graph for Stainless Steel
SOD = 200mm
Pressure = 4kgf/cm2



Graph for Stainless Steel
SOD = 200mm
Pressure = 6kgf/cm2



Graph for Aluminium
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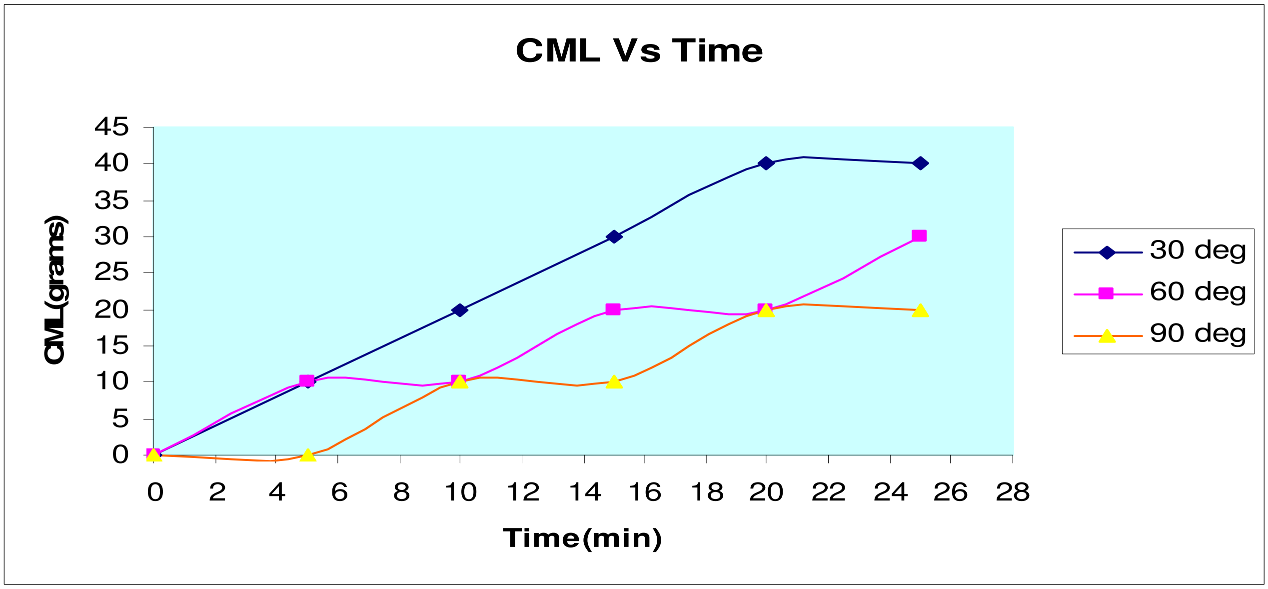
Pressure = 4kgf/cm2



Graph for Aluminium
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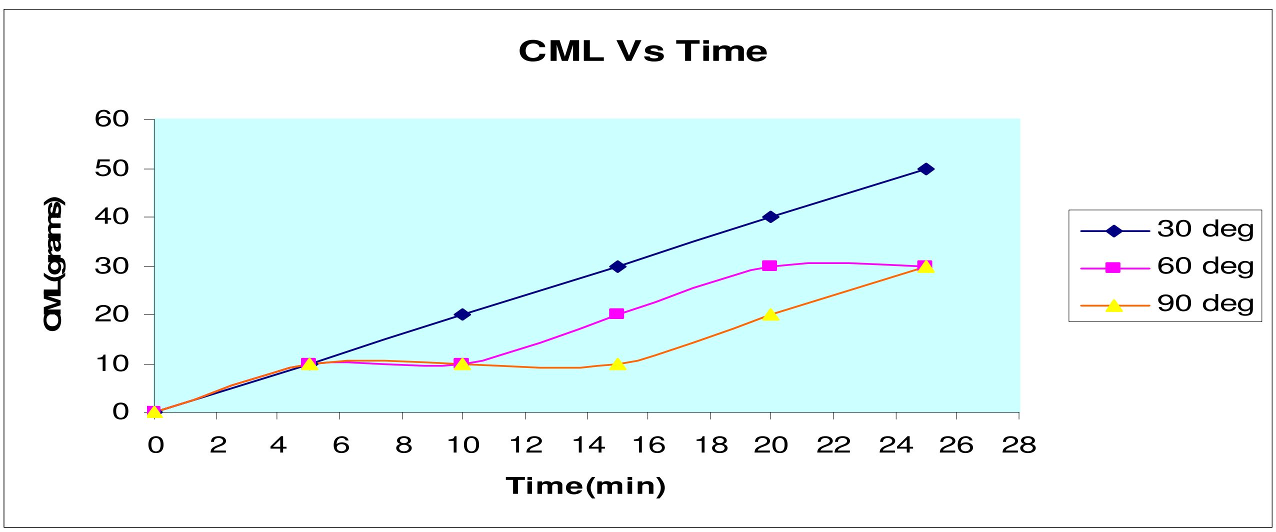
Pressure = 6kgf/cm2



Graph for Aluminium
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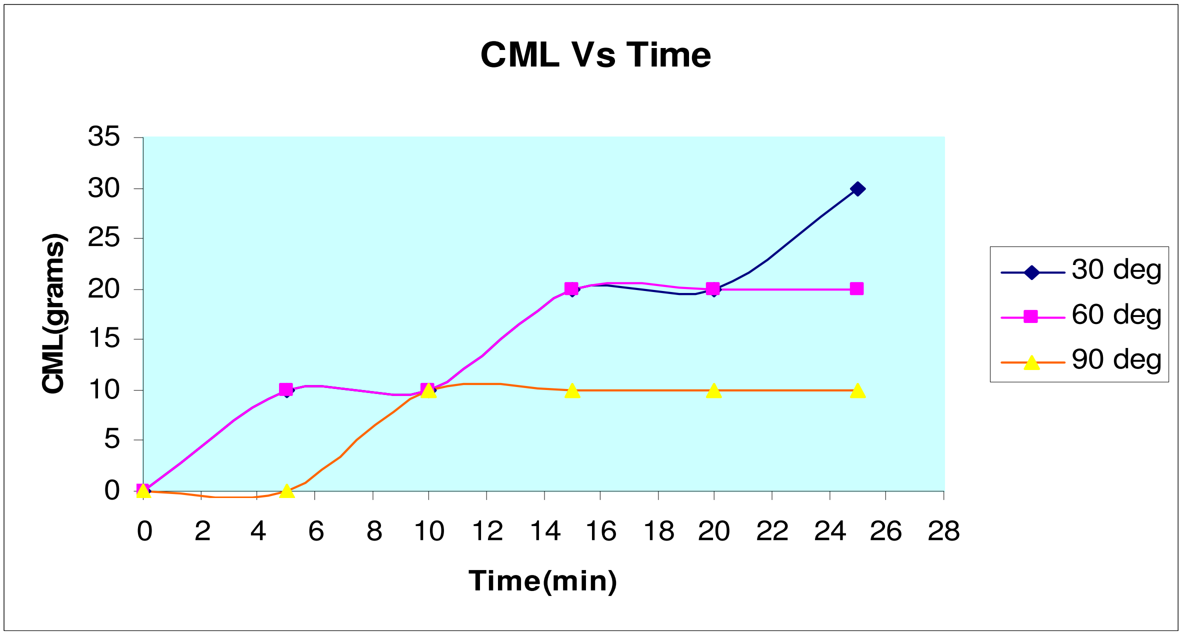
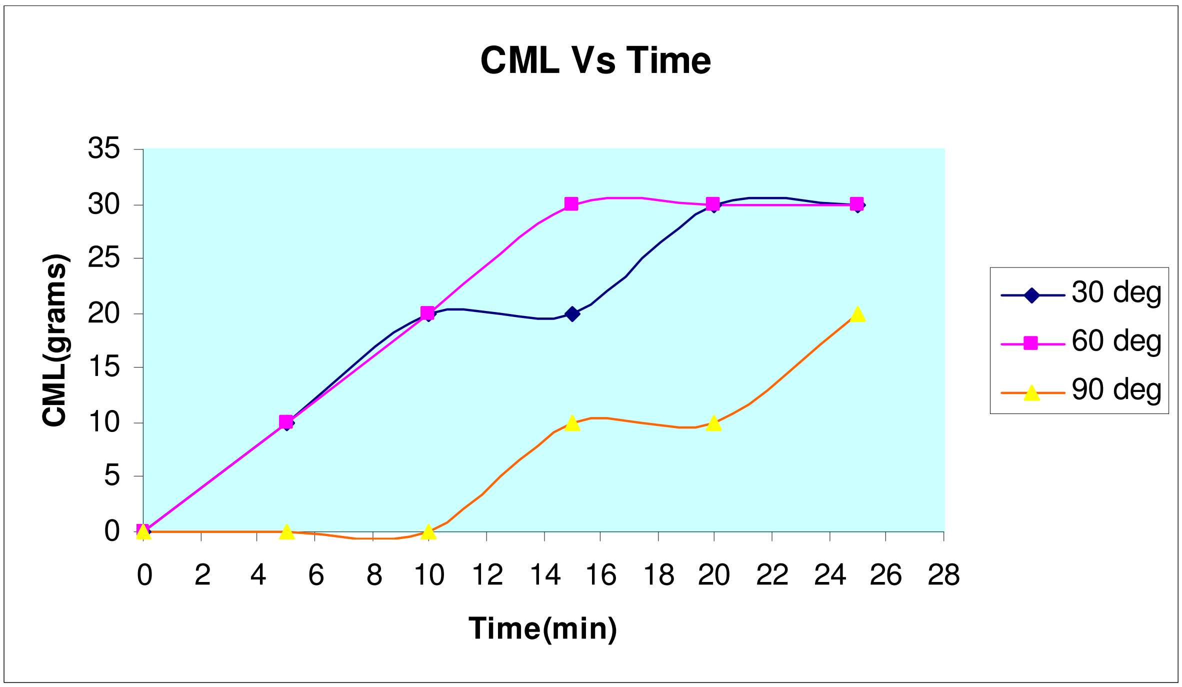
Pressure = 4kgf/cm2



Graph for Aluminium
SOD = 200mm
Pressure = 6kgf/cm2



EROSION RATE AT VARIOUS ANGLES

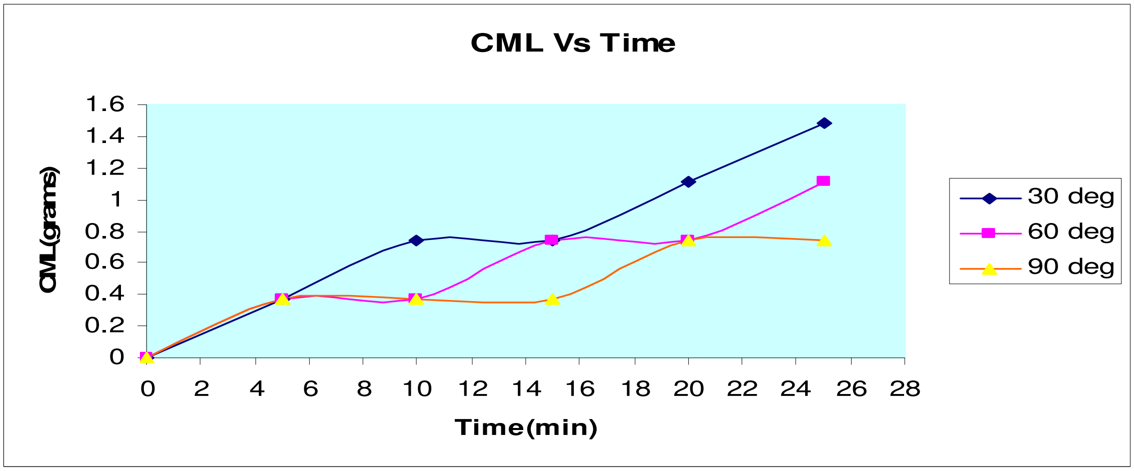
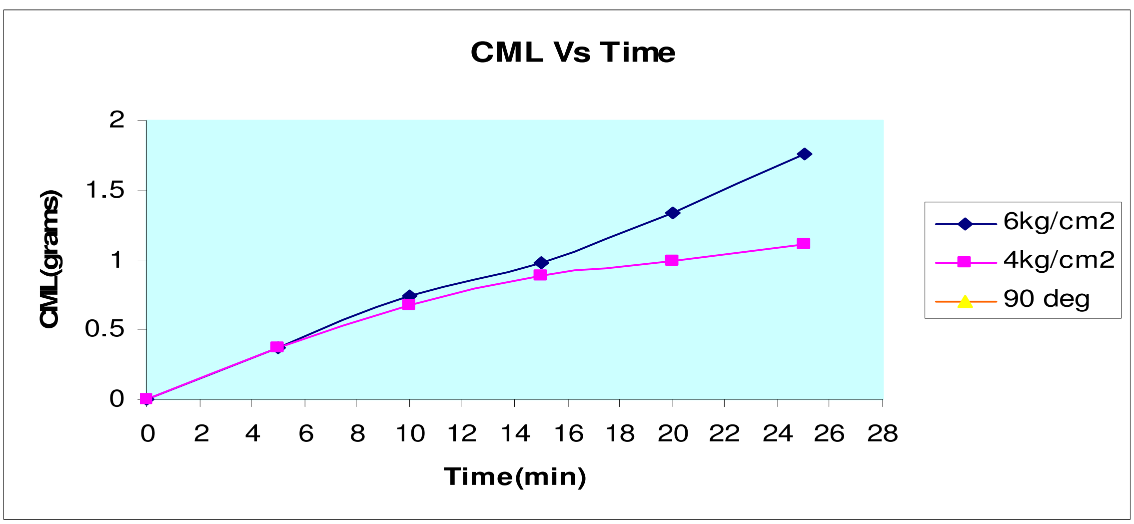


Fig a

EROSION RATE AT VARIOUS PRESSURES



DISCUSSION

The typical incremental erosion curve is presented in revious page. The erodent particles strike the coated samples at various angle of impact. It is seen that initially the cumulative mass loss increases rapidly and later on becomes almost stagnant. This trend is observed in case of erosion carried out at all other impact angles i.e. 60^0 and 90^0. In all these cases, a transient regime in the erosion process seems to exist, during which the mass loss increases monotonically and tends to attain a constant steady state value. This constant value is referred to as the *steady state erosion rate.*

The cumulative increment in material loss due to erosion wear with exposure time (or erodent dose) has been reported earlier by Levy [7]. He has shown that, the incremental erosion rate curves of materials start with a high rate at the first measurable amount of erosion and then decreases to a much lower steady state value [8]. In the present work also, this trend is found in case of all three metals subjected to erosion test at various impact angles. This can be attributed to the fact that the fine protrusions on the surface of metals are relatively loose and can be removed with less energy than what would be necessary to remove a similar part from the bulk of the metal. Consequently, the initial wear rate is high. With increasing exposure time the rate of wear starts decreasing and in the transient erosion regime, a sharp drop in the wear rate is obtained. As the coating surface gradually gets smoothened, the rate of erosion tends to become steady.

Figure. a (previous page) illustrates the effect of impact angle (α) on the erosion rate of metals subjected to solid particle erosion. The erosion results for metals(MILD STEEL, STAINLESS STEEL AND ALUMUNIUM) at impact angles of 30, 60 and 90 degrees are shown. The erosion mass loss is higher at smaller angle of impact and the maximum erosion takes place at $\alpha = 30^0$. This is typical of all ductile materials.

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The results obtained in the present work show that for 30^0 impact angle the metals lose maximum mass as compared to that of $\alpha = 60^0$ and $\alpha = 30^0$ at a constant SOD and pressure. This variation of erosion wear loss confirms that the angle at which the stream of solid particles impinges the metal surface influences the rate at which the material is removed. It further suggests that, this dependency is also influenced by the nature of the material. The angle of impact determines the relative magnitude of the two components of the impact velocity namely, the component normal to the surface and parallel to the surface. The normal component will determine how long the impact will last (i.e. contact time) and the load. The product of this contact time and the tangential (parallel) velocity component determines the amount of sliding that takes place. The tangential velocity component also provides a shear loading to the surface, which is in addition to the normal load that the normal velocity component causes. Hence as this angle changes the amount of sliding that takes place also changes as does the nature and magnitude of the stress system. Both of these aspects influence the way a metal wears. These changes imply that different types of material would exhibit different angular dependency.

CHAPTER 5

CONCLUSIONS

CONCLUSIONS

- Erosion rate with respect to angle of impact is maximum at 30degree and minimum at 90degree.

- Erosion rate with respect to stand of distance is maximum at 100mm and lower for 200mm. This implies that lower the stand of distance greater is the rate of erosion.

- Erosion rate with respect to Pressure increases as the rate of erosion increases.

- From the predicted mechanism it is found that the erosion behavior is valid for ductile materials. Hence our observation also follows the same rule.

Having calculated the ideal angle of contact, force of impingement and the distance of fall for an Mild Steel, Aluminium, Stainless Steel, we would now be in a position to predict the condition that should be maintained to minimize wear. However it should be noted that wear being highly specific to geometry, physical properties, metallurgy and a host of other factors all our predictions will pertain to the samples used only. As such it cannot be generalized to all samples. This is one of the major impediments to wear studies. Also as indicated wear may occur due to various reasons and modes however we would be in a position to study only one mode i.e. erosion wear .Hence all our predications will be made under the assumption that wear is occurring only due to erosion and no other factor or mode is coming into effect.

CHAPTER 6

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