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Design and Fabrication of wear Testing Machine

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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. 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. 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.*

I. INTRODUCTION

1.1 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.

1.2 Essential Study of Wear:

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.

1.3 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.

Wear & Failure Mechanisms

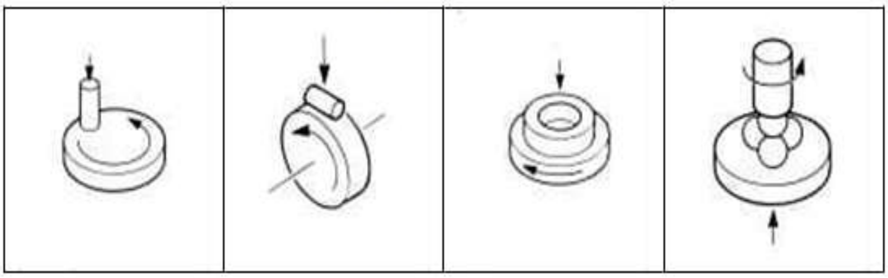
The more we can characterize the full scale problem the easier it becomes to ensure that the bench tests we run will provide useful information. Critical to the characterization process and ultimately to the interpretation of the test results, is the determination of the mechanisms of wear at work in the contact. Wear processes must be analyzed and defined before they can be modeled, for example abrasion, erosion, corrosion or other chemical action, de-lamination or adhesive wear, the involvement of wear debris identified, the appearance of failed surfaces established (for example, cracking, phase transformations, melting, chemical layers). The type of wear process will, to a large extent, govern whether it can be modeled at reduced scale and whether accelerated testing is valid. As a general rule, contacts involving both sliding friction and wear can be modeled at reduced scale and with accelerated testing. This is because it is usually possible to increase the loading conditions in the contact without changing the wear regime. Processes involving surface fatigue can in some cases be modeled at reduced scale, but for obvious reasons, not at a reduced number of cycles. These processes include rolling contact fatigue and fretting. Abrasive and erosive wear processes, where particle size, distribution, angle of incidence and, in the case of erosive wear, particle velocity, are critical to the wear process essentially have to be modeled at full scale, but this is possible in an appropriately designed test.

Bench Test Machine Categories

There is no shortage of choice when it comes to friction and wear test machines. Selection will depend very much on what kind of test you wish to perform and/or the application for your product. Available test rigs can usefully be divided into four categories.

Thermally Self-Regulating Continuous Energy Pulse

Fig 1



These are machines in which the point of contact is stationary with respect to one of the specimens and subject to constant speed uni-directional sliding. It is important to recognize that there are virtually no real life applications other than perhaps braking systems in which this occurs, thus introducing a degree of unreality to the test. However, these machines are widely used because they are simple. Examples include pin on disc, block on ring, crossed cylinder and sliding 4-ball test machines. Data generated by such machines rarely correlates with known field data. In each case the specimen geometry is simple and relatively easy and cheap to manufacture. This may be an important consideration when studying new materials where batch quantities are small.

Uses:

Historically, this type of machine has been used for fundamental wear studies of materials including metals, plastics, composites, ceramics and coatings in solid lubricated or dry conditions. They are less successful with liquid lubrication. Their principal advantage is that it is easy to cover wide load and speed ranges and therefore obtain a broad sweep of material performance. Wear mapping and parametric studies are readily performed.

Limitation:

For liquid lubricated tests, aimed at investigating lubricant additive performance, entrainment conditions associated with constant speed sliding result in a requirement for heavily loaded contacts in order to overcome hydrodynamic lubrication and thus promote mixed or boundary lubrication, and ultimately, film failure. Increasing the load to achieve film failure may bring to significance specimen material properties, which one may otherwise wish to eliminate from the test parameters. These machines typically do not emulate real lubricated contacts. The Energy Pulse for the fixed point of contact specimen is continuous: it lasts for the duration of the test. This highlights one of the main limitations of these machines as models of real surfaces. Instead of brief rubbing episodes frequently repeated, the machine subjects one specimen to continuous rubbing and the associated temperature field dominates.

The test configuration defines the thermal conditions in the contact. The contact temperature (unlike the bulk temperature) is self-regulating and cannot be controlled as an independent variable. High contact temperatures result in a number of problems, depending on the material under test. In plastics, the limit is the melting point (this usually is given the name PV - pressure/velocity limit and is in reality the melting point). Thermal collapse limits the contact at high velocity, whereas mechanical strength limits the contact at high pressure. With ceramics, which are poor thermal conductors, the heat is locked in at the surface and the heat/quench cycle generated can result in thermal fatigue of the specimens.

Standards

The majority of existing standards in sliding wear use uni-directional sliding machines. For the most common, the pin on disc, there are two generic standards (ASTM G-99 and DIN 50324), giving recommendations on their use, but acknowledging that the application will actually influence the final choice of test conditions. A further, more detailed guideline is available in the form of a publication from the UK Wear and Friction Forum, which looks at aspects of methodology and rig design.

Thermally Self-Regulating Cyclic Energy Pulse

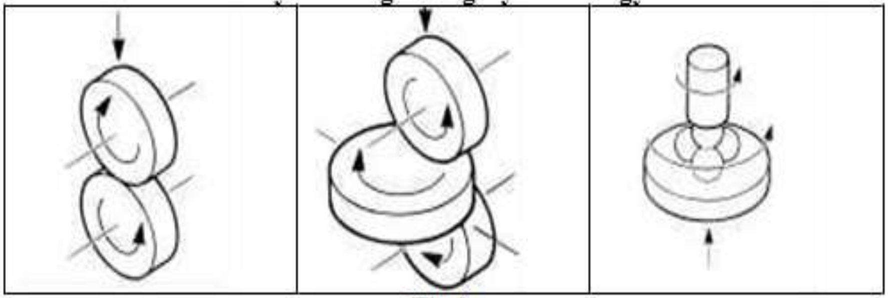


Fig 2

These are machines where the point of contact moves with respect to both contacting surfaces and there is a close approximation to the motion in actual machine components (for example, gears, cams, joints and mechanisms). These include a number of component test machines, using idealized or standardized components such as gears, cam/follower and rolling element bearings.

Uses:

These machines are essentially designed to emulate real contact conditions and typically operate under conditions broadly similar to those found in practical applications. To all intents and purposes these machines are "full scale" and are hence emulators of the real contact. Test piece production must be carefully controlled to ensure optimum reproducibility. These machines can usefully be divided into two subgroups:

Pure Rolling Machine

Here two specimens (usually rollers) are loaded together and are rotated at the same speed. The motion is pure rolling and such machines are used to address particular problems in the lubrication of gears and drives in the piezo-viscous region (elastohydrodynamic). They are also used to study pitting failure (rolling contact fatigue), caused by the cyclic stressing of the surfaces. Rolling element bearing test rigs and rolling four ball machines are included under this general heading.

1.4 Abrasion:

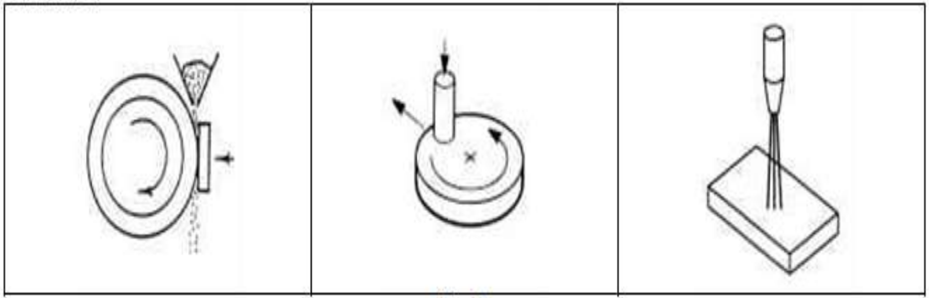


Fig 3

Abrasive and erosive testing of materials requires different types of machine from the primarily adhesive wear test machines discussed above, as a free body is usually involved. Although the size of test samples may be small compared with real life applications, satisfactory data can only be generated by matching conditions within the real life process, hence these are effectively ³real life´ and not scale model test devices.

II. ABRASION TESTS

Abrasion tests either use loose particles of a well-defined shape and size or particles bonded to a substrate in the form of abrasive paper. The former results primarily in three-body abrasion and the latter in two-body abrasion.Three body abrasion test rigs typically comprise a stationary specimen loaded against a rotating drum with abrasive particles introduced into the contact either dry or with a liquid transport medium.

The use of hopper fed systems for abrasive particles improves the uniformity of supply, which in turns enhances control of the particle loading on the contact. To avoid contaminating the abrasive particles, whether dry or wet, with wear debris from the test specimens, it is normal to use a single pass system and not re-circulate the abradant.

A key point to note with three body slurry abrasion is that increasing the particle loading on the contact may ultimately give rise to a two body abrasive mechanism, with abradant particles effectively trapped within the contact.

In two-body abrasion rigs the principal problem is controlling the condition of the abrasive paper. If a pin-on-disc test is carried out with abrasive paper attached to the disc, the paper rapidly degrades and becomes clogged with wear particles. Indexing the pin across the disc in a spiral pattern, thus ensuring that fresh abrasive paper comes into contact with the pin at all times, overcomes this problem.

2.1 Types Of Wear:-

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

Table 1

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
Delimitation	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

2.2wear:-

Definition:

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 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.

2.3 Factors Affecting Wear:

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.

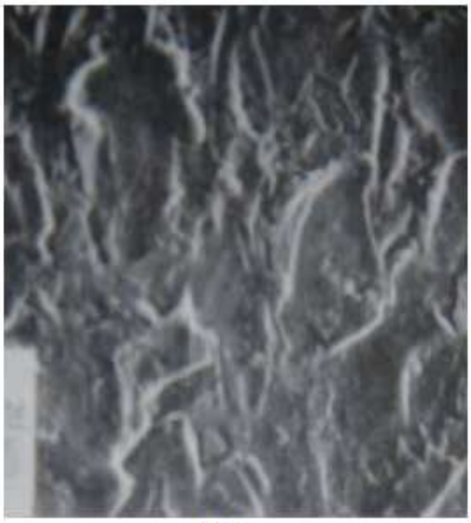


Fig 4

Erosion Wear Situation

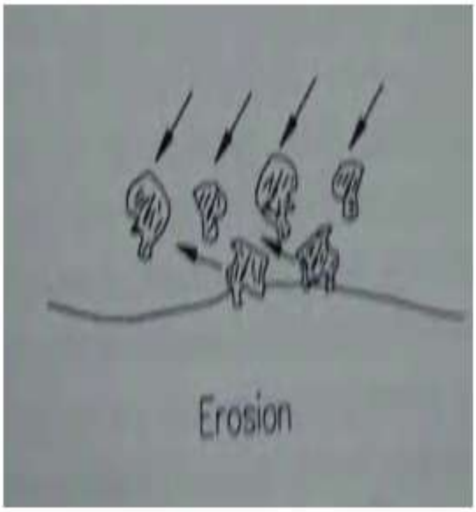


Fig 5

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.

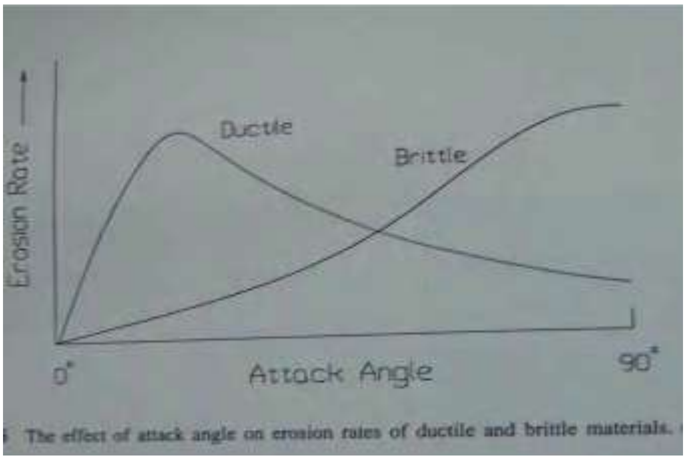
$\tan(90-A_c)=(1-\mu^2)/2\mu$

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

Fig 6

Effect Of Angle Of Attack

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 plugging (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 volume of wear

17 . $V=K(L/p)\,x$ ------- (1)

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

Eqn (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

$E=1/2Mv^2$……….(1)

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

$V=K\,\beta M v^2/2\mu p$ ………….. (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,

$V = Ke\,\varphi\,Mv^2 / v$ ……………(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.

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)

Table 2

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

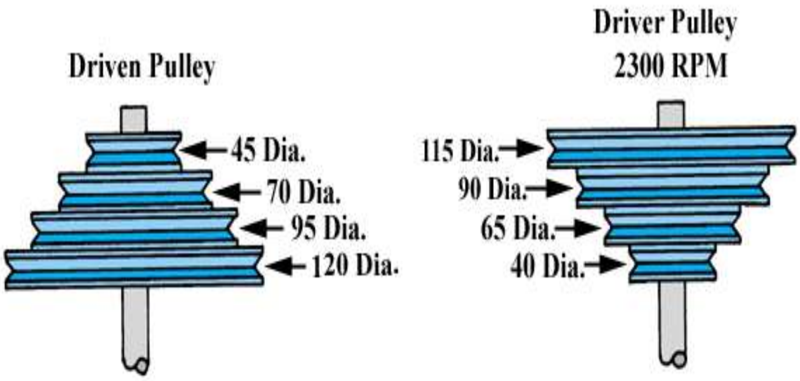
Sl.No	**COMPONENT**	**MATERIAL**	**QUANTITY**
1	**½ HP Motor**	**------**	**1**
2	**Pulley**	**CAST IRON**	**2**
3	**Smaller Pulley**	**CAST IRON**	**1**
4	**V-Belt(A 41)**	**-------**	**1**
5	**Disc**	**EN 8**	**1**
6	**Beam**	**Aluminum**	**1**
7	**Beam Post**	**MILD STEEL**	**1**
8	**Load**	**MILD STEEL**	**1**

Motor:

This reversible electric motor can replace worn out or broken motors in blowers, sanders, saws, conveyor belts and other tools! Designed with a durable rigid base, this electric motor can reach speeds up to 1725 RPM to power your equipment like new. At 1/2 HP output, this electric motor can give your tools the boost they need to work at peak efficiency.

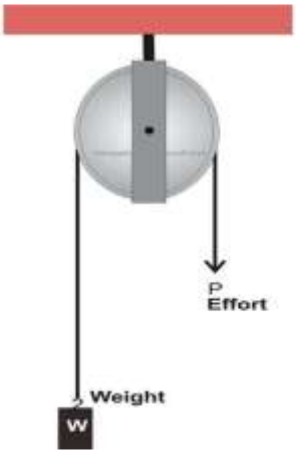
- NEMA Frame: 56
- Utilization Volts: 115/230
- Shaft diameter: 5/8 in.
- Maximum speed: 1725 RPM
- Reversible

Pulley:



- Used to transmit motion and torque
- Change speed of rotation
- Stepped cone pulleys
- Pulley belts used to transport products
- Pulley belts used as band saws
- Pulleys used for lifting.

Smaller Pulley:



A simple pulley basically consists of two components, the wheel and the string; the wheel may be made up of wood or metal and includes a grove cut along its circumferential periphery. The string is allowed to slide or pass through this groove with a load that is to be lifted fixed at one of its ends and an effort applied at the other end in order to lift the load. The pulley wheel is supported over a rigid frame about its central axis. The applied effort through pulling of the string rotates the pulley and pulls the load upwards, helping the load to be lifted with ease.

A classic example of this mechanism can be witnessed over wells where the pulley and rope are used for lifting water-filled bucket. 24

V Belt:

Belts are the cheapest utility for power transmission between shafts that may not be axially aligned. Power transmission is achieved by specially designed belts and pulleys. The demands on a belt drive transmission system are large and this has led to many variations on the theme. They run smoothly and with little noise, and cushion motor and bearings against load changes, albeit with less strength than gears or chains. However, improvements in belt engineering allow use of belts in systems that only formerly allowed chains or gears Power transmitted between a belt and a pulley is expressed as the product of difference of tension and belt velocity

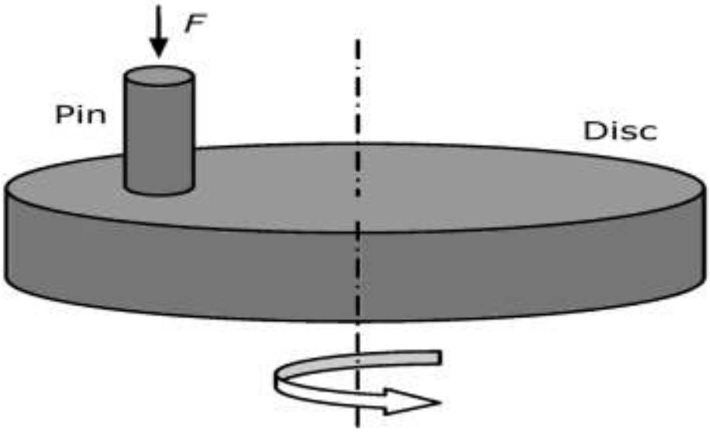
$$P = (T_1 - T_2)v$$

where, T_1 and T_2 are tensions in the tight side and slack side of the belt respectively. They are related as:

$$\frac{T_1}{T_2} = e^{\mu\alpha}$$

where, μ is the coefficient of friction, and α is the angle subtended by contact surface at the centre of the pulley.

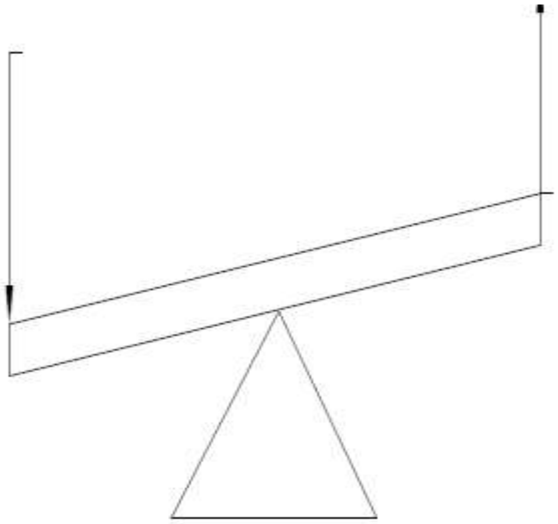
Disc:



This study was carried out to design and fabricate a cost effective and efficient weartester (pinondisc)used in the metallurgy search field. Design and calculations were established and the machine was fabricated with well selected materials and components all sourced locally. The performance of the fabricated machine was finally evaluated against a standard wear machine in

He Standards Organization using statistical methods and the result showed that the locally fabricated machine is 97% effective.

Fulcrum lever:



The fulcrum is again placed at one end of the beam, but now the load and effort points are reversed, with the load on the opposite end of the beam from the fulcrum and the effort applied at some intermediate location. Many muscles that operate animal limbs work as type of levers. A pair of tweezers is a two-beam.

Working diagram:

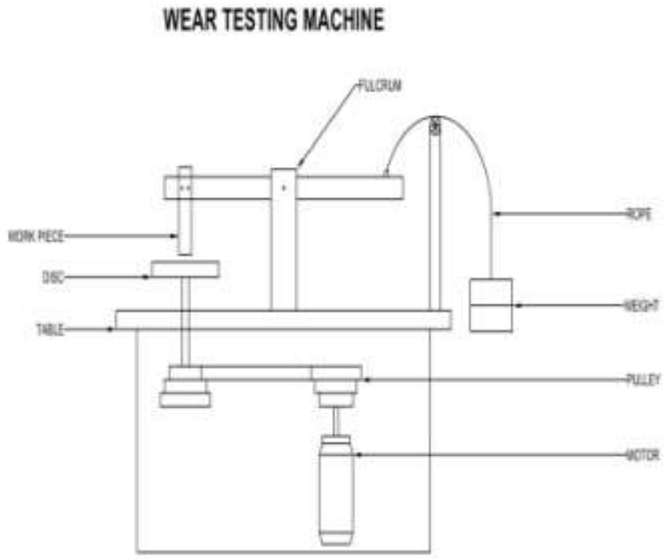


Fig 7

Cost estimation:

Sl.No	**Component**	**Material**	**Quantity**	**Cost Rs**
1	**½ Hp Motor**	**---------**	**1**	**2000**
2	**Pulley**	**Cast Iron**	**2**	**750**
3	**Smaller Pulley**	**Cast Iron**	**1**	**180**
4	**Belt(A 41)**	**---------**	**1**	**220**
5	**Disc**	**En 19**	**1**	**720**
6	**Beam**	**Aluminum**	**1**	**1800**
7	**Beam Post**	**Mild Steel**	**1**	**800**
8	**Load**	**---------**	**1**	**380**
9	**Other Cutting Charges&Table**	**--------**	**-----**	**2850**
	Total	¤	**-----**	**Rs.9700**

Table 2

III. CONCLUSION

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, Aluminum, 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 in to effort

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