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STUDY AND EFFECT OF ABRASIVE WEAR BEHAVIOR OF KEVLAR

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Abstract - *Abrasive wear phenomena are simply caused by the passage of relatively hard particles or asperities over a surface. It directly affects the life of the component. A systematic study of abrasive wear of Kevlar has been carried out using a two body pin-on-disc wear machine. The objective of this study was to evaluate the abrasive wear of Kevlar fiber (after mixing it with epoxy resin) by grinding it at constant load of 10N but at different rpm. A Kevlar often described as being "five times stronger than steel on an equal weight basis". In particular, up to date aramid have been extensively used in personal protection, tires, equipment, shoes, building construction and marine application by virtue of their very strong tensile strength. So, in this thesis a study of abrasive wear of Kevlar at different speed were given to analyze the possibility of wear. A review of abrasive wear behavior of Kevlar using different wear rate speed has been discussed in this thesis. Mainly focus on the varying wear condition during varying rpm. As we all know that wear is very important parameter which directly affects the life of a component. The goal of this study was to evaluate abrasive wear only. The result of the study indicates several measuring wear rate technique till date.*

It is concluded that-

- *Wear volume increases with increasing applied load.*
- *The loss in mass is maximum at zero degree (horizontal position) for a particular load*
- *At horizontal position (zero degree) two body abrasion takes place most of the time.*

***Key Words*: Abrasive wear, Kevlar fibre, Epoxy resin, Aramid, Asperities**

1. INTRODUCTION

A synthetic material Kevlar® is a plastic strong enough to stop bullets and knives—often described as being "five times stronger than steel on an equal weight basis. Unlike most plastics it does not melt: it's reasonably good at withstanding temperatures and decomposes only at about **450°C (850°F)**." Kevlar is simply a super-strong plastic. Kevlar's amazing properties are partly due to its internal structure (how its molecules are naturally arranged in regular, parallel lines) and partly due to the way it's made into fibers that are knitted together. It's a proprietary material made only by the DuPont™ chemical company and it comes in two main varieties called Kevlar 29 and Kevlar 49 (other varieties are made for special applications).

1.1 Properties of Kevlar

- It's strong but relatively light. The specific tensile strength (stretching or pulling strength) of both Kevlar 29 and Kevlar 49 is over eight times greater than that of steel wire.
- Unlike its sister material, Nomex, Kevlar can be ignited but burning usually stops when the heat source is removed.
- Very low temperatures have no effect on Kevlar: DuPont found "no embrittlement or degradation" down to −196°C (−320°F).
- Kevlar can resist attacks from many different chemicals, though long exposure to strong acids or bases will degrade it over time.

There are two main stages involved in making Kevlar. First you have to produce the basic plastic from which Kevlar is made (a chemical called poly-paraphenylene-terephthalamide no wonder they call it Kevlar). Second, you have to turn it into strong fibers. So the first step is all about chemistry; the second one is about turning your chemical product into a more useful, practical material.

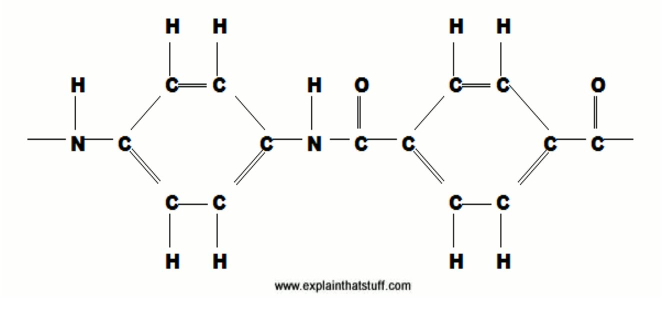


Fig-1 Kevlar's monomer: C=carbon, H=hydrogen, O=oyxgen, N=nitrogen, — is a single chemical bond, and = is a double bond. This basic building block is repeated over and over again in the very long chains that make up the Kevlar polymer.

1.2 Melting point of Kevlar

The melting point of Kevlar is above 500 °C (930 °F). The higher melting point of Kevlar, as well as its greater stiffness and tensile strength, partly results from the regular para-orientation of its molecules. In solution the polymer assumes a liquid-crystal arrangement, which orients the molecules so that they can be spun and drawn into highly ordered fibres of ultrahigh stiffness and strength

1.3 Abrasive wear

Abrasive wear takes place due to rubbing of softer surface by the harder surface. In the case of ductile materials, hard particles or hard asperities results in plastic flow of softer material. In brittle materials, wear occurs by brittle fracture. Abrasion is categorized depending on the types of contact, as well as contact environment. Depending on the types of contacts, abrasive wear can be classified as two-body and three-body wear. The former occurs due to an abrasive slides along a surface, and the later, due to an abrasive is caught between one surface and another. Figure shows the schematic representation of two body and three body wear mechanisms.

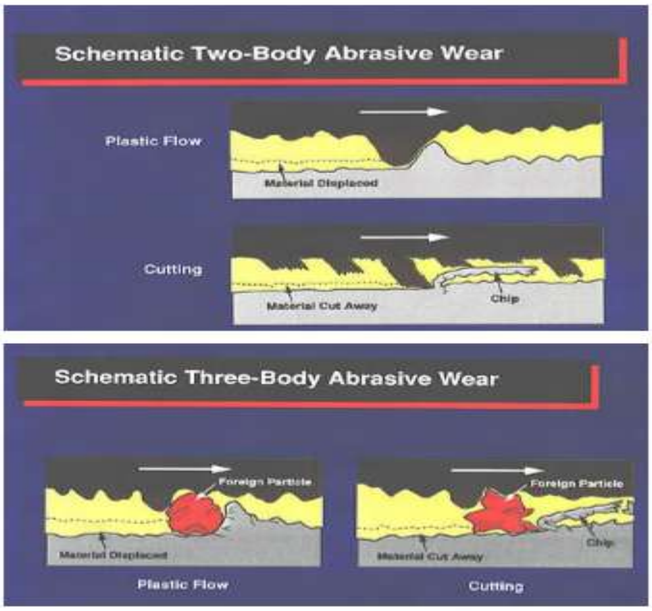


Fig-2

Two-body abrasive wear involves the removal of material by abrasive particles which are held fixed (as in abrasive paper) while being moved across a surface. This process produces a grooving form of wear.

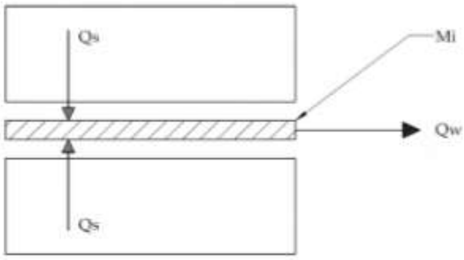
Three-body abrasion involves loose particles which may rotate as well as slide as they contact the wearing surface. Compared to two-body abrasion, three-body abrasion is much more common and also much more complicated than two-body abrasion.

2. PROBLEM FORMULATION

The problem stated above is based on mathematical model proposed by Fillot et al, according to Fillot et al the presence of wear particles in the system will act as a dry lubricant. To formulate an analytical model the author first composes a particular definition of the third body concept stating that wear is a process characterized by three distinct phases: material detachment from the surface of a body, the mass of particles within the contact area and finally the ejection of particulate matter from the system; referring to figure 1 these are Qs, Mi and Qw respectively. As a result the change in mass of particles within the system can be written as a function of the two volume flow rates, as given in equation; the author refers to this as the mass equilibrium equation (i.e. it is a mass balance).

$$dMi/dt = Qs - Qw$$

Subsequently the author defined two relationships that were essential in this wear analysis, these are the connection between Qs and Mi and secondly between Qw and Mi. Fig. shows graphical representation of three body concept.



The first relationship (Qs - Mi) is referred to as the source flow activation and represents the particle generation process; as discussed, this was the sole concern of Archard's wear law. The author considers this in three stages. Firstly he states that the normal pressure applied across the contact will be equally shared by the surfaces and the third body. Furthermore he states that the total sliding distance occurring in the system will be composed of the sliding distance of the two surfaces and the sliding distance of the third body, which represents the shear occurring between particles, and uses this definition to arrive at equation 1.

$$dXtotal = dXFB + dXTB \quad (1)$$

Where dXtotal is the total sliding distance, dXFB is the sliding distance of the contacting surfaces and dXTB is the sliding distance of Mi. The total velocity of the system is the rate of change of distance with respect to time and therefore can be written in equation 2.

$$V = dXFB/dt + dXTB/dt \quad (2)$$

Where V is the total velocity of the system. The author now considers the occurrence of shear within the system, stating that, as a preference, shear will occur in the third body rather than at the contacting surfaces as long as it is "easier" to do so. This will cease to be the case when the maximum value of shear stress has been obtained within the third body; hence at τmax. The shear rate can then be expressed as a function of the max shear stress and therefore a function of the velocity within the third body and its thickness as shown in equation 3.

$$\nu = 1/HTB * dXTB/dt \quad (3)$$

Where ν is the shear rate, HTB is the height of the third body. If the shear rate of the system is assumed to be a constant then the velocity of the third body is proportional to its height. Therefore the mass of the third body can be related to the sliding velocity:

$$dXTB/dt = aMi \quad (4)$$

Where 'a' is a constant of proportionality. The variable Qs is considered with respect to the sliding velocity of the bodies in contact. Referring to Archard the volume of material removed from the body is proportional to the sliding distance; hence the rate of change of volume produced (volume flow-rate Qs) will be proportional to the rate of change of sliding distance (i.e. velocity)

$$dXFB /dt = bQs \quad (5)$$

Where 'b' is a constant of proportionality. Equations 5, 4 and 2 can now be combined to find a relationship between Qs and Mi and it is given as:

$$Qs = Cs\ (Mimax - Mi\ ) \quad (6)$$

From this last equation (eq. no. 6) it can be seen that the flow of material from the contact surfaces is proportional to the mass of material already trapped in the contact area. The author does not examine the process of material removal from the surfaces in great detail but he proposes that material removal will occur when the energy present in the system cannot be absorbed by the third body.

To conclude the author restates that the aim of this work was not to refine or continue existing wear laws and thinking but to look at this problem from a new angle in order to better describe, predict and understand wear. The author also raises the question surrounding the pin on disc test: i.e. why the wear process is dependent on the orientation in which the apparatus is configured. Therefore the author incorporates the way in which a particle leaves the contact area to try and account for this phenomenon. He suggests that a large amount of time has been spent in defining and investigating the various wear mechanisms but there is a distinct dearth of information on the methods of material expulsion.

3. METHODOLOGY

Numerous researches have been done in the field of abrasive wear. This work is also an experimental design in the field of abrasive wear evaluation via a newly designed wear test rig. In view of the objective a set-up was needed to be designed which can calculate wear rate at different speed (rpm) of work piece with respect to the main frame (horizontal position). A pin on disc wear test technique was adopted to test the wear behavior of specimens.

Wear rate and wear mass were evaluated at different orientation of the specimen. The tests were conducted for seven different orientations namely **400rpm, 500rpm, 600rpm, 700rpm, 800rpm, 900rpm, 1000rpm.** The wear mass of above said specimen evaluated at a constant time of **5min (300 sec).**

The set up has following different parts-:

(1)Controller (2)D.C. Motor (3)Flange Coupling (4)Bearing (5)Main Frame (6)Frame(Angular) (7)Acrylic Sheet (8) Grinding Wheel (9) Specimen (10) Screw Jack (11) Load Cell (12) Angular Lever.

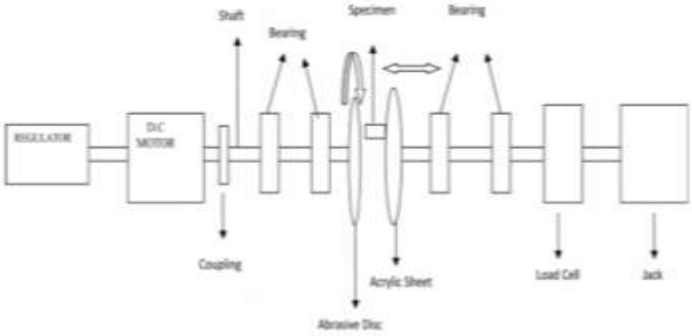


Fig-3

3.1 Working of set-up

DC motor is connected to regulator through a suitable electrical wiring. Further, flange coupling connects D.C motor to a shaft. A key is provided for connecting DC motor and shaft. Grinding disc is connected to one end of the shaft which is supported by two bearings. The specimen is fitted in specimen holder. The specimen holder is made of wood; a slot equal to the size of cross-section of specimen is made in it, to properly hold the same. The samples are fastened with the fixture in these slots, one at a time and the wear test is performed. The fixture is fitted in acrylic sheet having multiple holes along the radius of the sheet. These holes are made in such a way to get fresh surface along grinding disc. At the end of the acrylic sheet there is attachment to apply a load. The load is applied with help of screw jack, as the screw jack moves forward it pushes the acrylic sheet with help of shaft which connects screw jack and acrylic sheet.

3.2 Specimen’s material

The specimen was selected for present investigation is a mixture of two materials namely **Kevlar & Resin.**

As Kevlar is in the form of fibers, it is not possible to apply abrasion process on fibers in pin on disc setup. To resolve this issue **Epoxy Resin** is used which holds the fibers on its exact shape and location.

Resin-- Generally it is a viscous (liquid or semi liquid) substance that reacts to certain conditions (usually heat) or another substance (aka a hardener). The reaction is polymerization, which is the formation of long molecular chains transforming the substance into a solid with adhesive properties during the transitioning.

4. RESULT

The results on weight loss have been presented as a function of sliding distance against grinding Disc. The wear rate has been evaluated in term of weight loss in the entire specimen investigated.
All the calculations is investigated by weighting the specimen before grinding and after grinding and then the loss of weight after abrasion is considered as the wear rate. The wear rate increases gradually at different rpm.

As the wear studies were conducted against the abrasive media (grinding disc). The selection of applied load and the position of the specimen for wear studies were taken as 10N and 0º. Seven reading of wear were taken from seven specimens at different rpm. The result shows that as the speed (rpm) increases the wear rate of the specimen increases for a same load.

Wear Initiated at Different rpm

(rpm)	Weight before grinding	Weight after grinding	Total weight loss
At 400 rpm	9.487 gm	8.883 gm	0.604 mg
At 500 rpm	7.459 gm	6.722 gm	0.737 mg
At 600 rpm	9.203 gm	7.970 gm	1.233 gm
At 700 rpm	8.876 gm	7.047 gm	1.829 gm
At 800 rpm	10.056 gm	7.114 gm	2.942 gm
At 900 rpm	9.659 gm	6.245 gm	3.414 gm
At 1000 rpm	8.386 gm	5.060 gm	3.326 gm

5. CONCLUSION

It is concluded from the above discussion that wear is function of orientation and applied load. Initially, it was understood that wear depends upon applied load, surface parameters and mechanical properties such as hardness, toughness etc. But now it clear that it not only depends upon the above said parameters but also depends on orientation of surface in contact with the abrasive media with the horizontal surface. The movement of the debri particles plays an important role in this regard. At horizontal position the weight and centrifugal force are parallel to each other and most of the debri particles falls due this resultant force from abrasive media , due to this the specimen gets fresh abrasive surface most of the time which results in higher abrasive wear. If orientation changes from 0º to 90º the wear resistance increases or wears decreases.

It is concluded that:

- The loss in mass is maximum at zero degree (horizontal position) for a particular load.
- The loss in mass is minimum at 90 degree (vertical position) for a particular load.

- Maximum wear occur when the test specimen is held at 0º angle
- Minimum wear occur when the specimen is held at 90º angle for given applied load
- At horizontal position (zero degree) two body abrasion takes place most of the time.
- Two body abrasion converted into three body when orientation of set up changes from 0 to 90 degree due change in the behavior of debri particles.
- It was also apparent from the quadratic regression equations that regression coefficients positive in case of applied load and negative in case of orientation hence wear rate is directly proportional to the applied load and inversely proportional to the orientation as it changes from 0º to 90º. of the model surface to be best fitted, as the regression equation was highly significant. Thus, the fitted mathematical equation gives fairly accurate prediction of wear rate.

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