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A Review Paper on Abrasive Wear Characteristics & Tribological Behavior of Graphite.

Md. Majid[1], Mohd Shadab Khan[2], Dr. K.M Moeed[3], Z Fatima[4]
Research Scholar [1], Associate Professor [2]
Department Of Mechanical Engineering
Associate Professor & Principal [3], University Polytechnic
Assistant Professor [4], University Polytechnic (MES), I.U
Lucknow -India

ABSTRACT
Although Graphite is a non metal, however it is good conductor of heat & electricity. The main subjects of this paper are the abrasive wear & tribological behavior of graphite. Wear by abrasion is form of wear caused by contact between a particle and solid material. Abrasive wear is the loss of material by the passage of hard particles over a surface. Abrasion in particular is rapid and severe forms of wear and can result in significant costs if not adequately controlled. These differences extend to the practical consideration of materials selection for wear resistance due to the different microscopic mechanisms of wear occurring in abrasion. This review paper also explain classical as well as current wear theories. This paper also focused on versatile application of graphite due to its self-lubricating properties. Wear tests are conducted using pin on disc multi orientation apparatus.

Keywords:- Wear, Tribology, Abrasive wear, Modes & Mechanism of abrasive wear

I. INTRODUCTION

A continuous loss of material from the surface of any metallic & nonmetallic component is called wear. It is a material response to the External impact and can be mechanical or chemical in nature. As advanced Engineering materials, composites, polymers, reinforced materials are used in many applications where high wear resistance is required; these include electric contact brushes, cylinder liners, artificial joints and helicopter blades. In order to obtain optimal wear properties without compromising the beneficial properties of the matrix material, an accurate prediction of the wear of composites is essential.

Wear may be defined as: “The progressive loss of substance from the operating surface of a component as a result of relative motion of the surface with respect to another component.”[1]. Kloss et al[2] stated that it is a complicated thermal, mechanical and chemical processes and is therefore present in an extremely broad range of situations; from the rotating components in a motor to the impeller of a pump to the leading edge of a cutting tool. The loss of material has an greater effect on the working & life of a machine, tool or surface that is exposed to a wear process. Tribology is the science and study of interactions between surfaces in relative motion. Friction, wear and lubrication are fundamental concerns that make up this field [3]. Materials that are in contact have, at the interface, two material surfaces th will have individual characteristics and therefore a different effect on the tribological relationship. In very simple word we ca said that tribology consist of three words, friction, wear & lubrication.

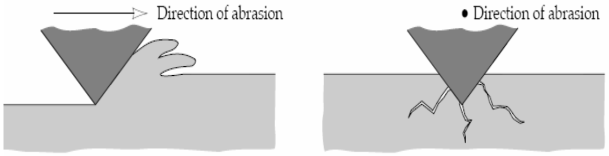
Wear models are used to predict the reaction of a material to a wear situation and to forecast the rate of material removal from the surface of a body. Classical wear theory begins by considering the rate of material removal as a function of the sliding speed, the hardness of the material, the load applied and the probability of a material to produce a wear particle in a given contact situation[7, 8]. There are four main theories that are used as a basis to begin a wear model: a mass balance approach, an energy balance approach, a stress/strain analysis and a contact mechanics approach to determine material behavior. Wear can occur in a number of different forms and these processes differ from each other when you consider the bodies that are in contact, the way in which material is removed and in what amount. The processes do not always occur exclusively i.e. several might be present in a given situation. The primary processes are: abrasion, adhesion, erosion, fretting and cavitation. For example abrasion occurs as a physical gouging effect where the harder of the two surfaces will dig into the softer material and subsequently remove material.

Abrasive Wear

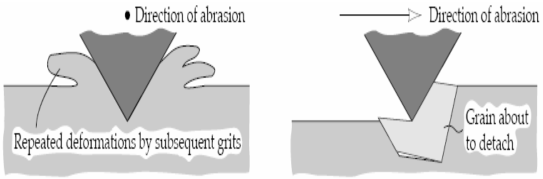
Abrasive wear occurs whenever a solid component is loaded to particles of a material that have equal or greater hardness. A common example of this problem is the wear of shovels on earth-moving machinery. The extent of abrasive wear is far larger than may be observed. Any material, even if the bulk of it is very soft, may cause abrasive wear if hard particles are present. For example, an organic material, such as sugar cane, is associated with abrasive wear of cane cutters and shredders because of the small fraction of silica present in the plant fibers [1]. A major obstacle in the prevention and control of abrasive wear is that the term 'abrasive wear' does not precisely describe the wear mechanisms involved. There are, in fact, almost always several different mechanisms of wear acting in concert, all of which have different characteristics.

Mechanisms of Abrasive Wear

It was originally thought that abrasive wear by grits or hard asperities closely resembled cutting by a series of machine tools or a file. However, microscopic examination has revealed that the cutting process is only approximated by the sharpest of grits and many other more indirect mechanisms are involved. The particles or grits may remove material by microcutting, microfracture, pull-out of individual grains [2] or accelerated fatigue by repeated deformations as illustrated in Figure 1



a) Cutting b) Fracture



c) Fatigue d) Grain pullout

Fig. 1 *Mechanisms of abrasive wear: microcutting, fracture, fatigue and grain pull-out [2]* The first mechanism illustrated in (Figure 1a), cutting, represents the classic model where a sharp grit or hard asperity cuts the softer surface. The material which is cut is removed as wear debris. When the abraded material is brittle, e.g. ceramic, fracture of the worn surface may occur (Figure 1b). In this instance wear debris is the result of crack convergence. When a ductile material is abraded by a blunt grit then cutting is unlikely and the worn surface isrepeatedly deformed (Figure 1c). In this case wear debris is the result of metal fatigue. The last mechanism illustrated (Figure 1d) represents grain detachment or grain pull out. This mechanism applies mainly to ceramics where the boundary between grains is relatively weak.In this mechanism the entire grain is lost as wear.

Modes of Abrasive Wear

The way the grits pass over the worn surface determines the nature of abrasive wear. The literature denotes two basic modes of abrasive wear:· two-body and· three-body abrasive wear.Two-body abrasive wear is exemplified by the action of sand paper on a surface. Hard asperities or rigidly held grits pass over the surface like a cutting tool. In three-body abrasive wear the grits are free to roll as well as slide over the surface, since they are not held rigidly.[7] Until recently these two modes of abrasive wear were thought to be very similar, however, some significant differences between them have been revealed [7]. It was found that three-body abrasive wear is ten times slower than two-body wear since it has to compete with other mechanisms such as adhesive wear [8]. Properties such as hardness of the "backing wheel", which forces the grits onto a particular surface, were found to be important for three body but not for two-body abrasive wear. Two-body abrasive wear corresponds closely to the'cutting tool' model of material removal whereas three-body abrasive wear involves slower mechanisms of material removal, though very little is known about the mechanisms involved[9]. It appears that the worn material is not removed by a series of scratches as is the case with two-body abrasive wear. Instead, the worn surface displays a random topography suggesting gradual removal of surface layers by the successive contact of grits [10].

Classical Wear Theory

According to the literature [11], there have been three major stages or trends observed in the development of wear models from the mid to late twentieth century. They are as follows: those based on empirical equations, those founded on a contact mechanics approach and those based on a failure mechanics approach. Here we are going to disscuss D.Tabor classical theory of wear, which are as follows. D. Tabor states that the actual amount of contact between two bodies is actually much less than the apparent contact area. He has described this phenomenon by saying “flat surfaces are held apart by small surface irregularities which form bridges”[11].

His description of surface asperities in contact was substantiated by his empirical investigation into this phenomenon. Tabor and his associate, Bowden, have referenced a number of key developments in the area of contact mechanics. Firstly Hertz’[12] theory on elastic deformation and calculation of the variance of contact area with load was a fundamental beginning. Following on from this Bidwell [13] investigated the conductance between two crossed cylinders. Employing this theoretical basis Tabor et al[11] began to investigate the actual area of contact between two bodies. He proposed that since the materials are held apart by the surface asperities an applied load would force greater contact between the bodies and the conductance would therefore be increased. He developed two theoretical equations to predict behaviour of the contact. Using an elastic assumption he stated that the conductivity between the bodies would be dependant on the cubed root of the load applied; similarly, using a plastic assumption, he stated that the conductivity would be dependant on the square root of the load applied. This hypothesis was tested and verified using a crossed-cylinders apparatus. The findings showed that the actual conductivity (and hence the actual contact area) increased with increasing load and greatest correlation was found with the equation developed using a plastic deformation assumption. Through this work the authors have contributed to the confirmation of Amonton’s law of friction. They state: “The total cross section of the junctions and hence the tangential force required to break them will be directly proportional.

Current wear theory

Savio et al (2008)[4] Savio et al, as a focus for their research, the polishing of glass moulds and the inherent material removal process. This is a very tedious application where two primary wear or “damaging” mechanisms will be in operation at any one time. There will be a polishing element due to the polishing tool and an abrasive action due to the slurry used to aid in material removal. In addition there may also be an erosive element but this is not discussed here. This particular application has received a wide range of interest and attention in the literature and a number of key theorems have been notable [5].

The first assumption is that of a chemical action: a film of material is produced due to dispesion of the slurry into the upper levels of the glass and subsequent removal of this layer. The second theory proposes an abrasive type of action whereby a large number of fine cracks are induced into the material due to mechanical contact & relative motion of the component, the subsequent failure is due to the fracture of asperities. Thirdly a plastic flow concept is introduced where peaks of the material are heated due to friction and then deformed due to the pressure applied to them. Finally a frictional wear theory is a development of the chemical action described whereby the mechanical removal of the film is now attributed to a further chemical interaction between the grains suspended within the slurry and the constituents of the glass. After study of the relevant literature in his chosen area the author selected has decided that the most suitable method for his examination is that of the abrasion deterioration. He proposes to verify the variables of concern to the process.

Tribological behavior of graphite.

Graphite fiber is one of the most useful reinforcement materials in composites, its major use being the manufacture of components in the aerospace, automotive and other electrical & electronic industries .The special features of carbon fiber are low density, high strength, high modulus and high stiffness leading to the active part of the machine consists of 2 identical co-rotating and intermeshing screws, hence the name "twin screw extruder". The screws are mounted on shafts, supported by bearings and rotate inside a fixed closed housing called "barrel". To adapt this equipment to different industrial applications, the screws, which perform most of the work of transporting, conveying, mixing, compressing, or shearing of raw materials, have been designed to be totally modular. The screw segments are stacked one beside another on a splined shaft. Their composition can be rapidly modified depending on the products to be processed and the final product desired. Twin screw technology offers the advantages of a progressive process that is both flexible and easy to operate .The multi functionality of this technology results in a compact design of the equipment, reduces the investment costs, often uses far less water and allows the use of greater diversity of raw materials. This continuous processing machine has multiple functions such as conveying, melting, shearing, mixing, cooking, cooling, washing, bleaching, shaping etc depending on the industrial applications. Beside this graphite with other alloying element is widely used as ring in D.C motor, it is also used in battery.

An experimental investigation is carried out by **Mani Deep et.al**. to study the effect of normal load, weight fraction of graphite and abrading distance on the abrasive wear behavior of graphite reinforced polymer. Wear studies are carried out using PIN ON DISC APPARATUS. Weight loss of composites during abrasion has been examined as a function of sliding distance, normal load and weight fraction of graphite. Specimens with varying weight fraction of 10, 15, 20, 25, 30 of graphite have been taken and wear test is conducted using pin on disc apparatus under dry contact conditions. Weight loss is determined for loads of 10N, 20N, 30N with a track diameter of 40 mm, disc rotating speed of 500 rpm, using 400 grade silicon carbide emery papers. A series of experiments are conducted to find out the weight loss due to wear and thus estimate the specific wear rate coefficient of each specimen using **"ARCHARD'S EQUATION".** In this experiment it is shown that with increase in graphite percentage at various loading conditions and variation of specific wear rate against applied load with increase in graphite percentage at various abrading distances.[14]

The abrasive wear and frictional properties of graphite micro particle filled polyamide 6 matrix composites are investigated by **Srinivas Lakshmi et.al**. In this experiment the composites with varying weight fractions of graphite have been prepared by melt mixing technique. Wear tests were conducted using a pin on disc apparatus under dry contact conditions. Mass loss was determined as a function of sliding velocity corresponding to the loads of 5N, 10N and 15N with an abrading distance of 314.2 m. The wear tests showed that graphite fillers improved the wear resistance and reduced the coefficient of friction of the PA6. The best properties achieved with the composite filler content of 25%.[15]

Suresha B et.al. investigated the influence of graphite filler additions on two-body abrasive wear behavior of compression moulded carbon–epoxy (C–E) composites have been evaluated using reciprocating wear unit and pin-on-disc wear unit under single pass and multi-pass conditions respectively. The carbon fabric used in the present study is a plain one; each warp fiber pass alternately under and over each weft fiber. The fabric is symmetrical, with good stability and reasonable porosity. Abrasive wear studies were carried out under different loads/ abrading distance using different grades of SiC abrasive paper (150 and 320 grit size). Graphite filler in C– E reduced the specific wear rate. Further, the wear volume loss drops significantly with increase in graphite content. Comparative wear performance of all the composites showed higher specific wear rate in two-body wear (single-pass conditions) compared to multi-pass conditions. Further, the tribo-performance of C–E indicated that the graphite filler inclusion resulted in enhancement of wear behaviour significantly. Wear mechanisms were suggested and strongly supported by worn surface morphology using scanning electron microscopy.[16]

Sbbaya K.M et.al investigated an experiment on three body abrasive wear of C-E with addition of graphite. The three-body abrasive wear behavior of carbon fabric reinforced epoxy (C-E) composites has been evaluated by the addition of graphite (G) particles as a secondary reinforcement. Three-body abrasive wear test were conducted using dry sand rubber wheel abrasion tester as per ASTM G-65 with three process parameters load, abrading distance and filler content. To assess the abrasive wear behavior of particulate filled C-E composites satisfying multiple performance measure, grey-based Taguchi approach has been adopted.

The experiments were designed according to Taguchi's orthogonal array (L27). The grey relational analysis was applied to convert a multi response process optimization to a single response. Using analysis of variance, significant contributions of process parameters have been determined. The results indicate that the addition of graphite particles into C-E composite increased the wear resistance considerably. It was observed that highest wear resistance of C-E composite was achieved with incorporation of 10 wt% of graphite filler. Results indicate that the filler content and grit size of abrasive paper were found to be the most significant factor which has influence on the abrasive wear of C-E composite.[17]

Lagiewka M et.al. work deals with the influence of the addition of soft graphite particles on the abrasive wear of composite reinforced with hard SiC particles. The discussed hybrid composites were produced by stirring the liquid alloy and simultaneous adding the mixture of particles.

The adequately prepared suspension was gravity cast into a metal die. Both the composite castings obtained in this way and the comparative castings produced of the pure matrix alloy were examined for the abrasive wear behavior. Photo macrographs of the sliding surfaces of the examined composites were taken, and also the hardness measurements were carried out. It was found that even a small addition of Cgr particles influences positively the tribological properties of the examined composite materials, protecting the abraded surface from the destructive action of silicon carbide particles. The work presents also the results of hardness measurements which confirm that the composite material hardness increases with an increase in the volume fraction of hard reinforcing particles.[18]

II. CONCLUSION

The mechanisms of abrasive wear is extremely interesting for interpreting the wear because abrasive wear is very common type of wear in mining, agriculture, cement industry, civil engineering, metallurgy. The one important point may also be noted that the wear resistance properties of C-E, Composite, polymer, PA6 & PA66 is increases with graphite addition .Abrasion wear test of various engineering materials with addition of graphite are performed by various wear testing method like PIN ON DISC method, two body abrasion & three body abrasion method. No work is reported on abrasive wear test of pure graphite or say more than 90% graphite in an engineering materials. Therefore my work of objective is to find out abrasive wear characteristics & tribological behavior of graphite with help of specified apparatus.

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