

STUDY ON VARIOUS PROPERTIES OF HDPE COMPONENTS IN DETERMINING ABRASIVE WEAR DURING ROTATION

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ABSTRACT:

Abrasive wear may also occur when there is an abrasive slurry interposed between two surfaces, such that the two solid surfaces are not actually in contact, this is called three-body abrasion, with food acting as the abrasive agent, and occurs in the mouth during mastication. Abrasion is the key physiological wear mechanism that is present in dental materials during normal masticatory function. The tribological behavior of the considered contact was analyzed by tracking the number of cycles, the friction coefficient, the roughness of the wear track on HDPE, the HDPE weight loss and the damage mechanisms. The friction coefficient shows a gradual increase with the number of cycles for both AP and FE kinematics. The evolution of friction coefficient with the number of cycles is not affected by the value of the imposed normal load in the case of AP sliding. For the FE rotation, decreased friction coefficient is obtained when the imposed normal load increases. For both considered AP and FE kinematics, the roughness of the wear track on the HDPE is not affected by the imposed normal load. It shows a progressive decrease when the number of cycles increases. The wear of HDPE obeys the Orchard law and the wear coefficient increases with the normal force. This paper gives an overview over a selection of relevant test equipment and procedures. In addition, some examples are given for advanced studies on materials behavior combining tribological test, material analyses respectively material graph and mathematical methods in order to support for selected cases the acquired correlation of materials properties and wear resistance under severe conditions.

Keywords: HDPE components, abrasive agent, friction.

1.0 INTRODUCTION:

Component or structure failures may occur due to damage caused by physical deformation, the formation and propagation of cracks, corrosion or wear. However, the degradation of a mechanical component as a result of operating conditions is in most cases concentrated or starts at its surface due to, for example, wear phenomena. Equipment with moving parts such as ball bearings, pump impellers, spherical valves, gears, pulleys, wear plates, bearings and friction rings that accompany the clutch system, etc., suffer wear. As a result, the repair of equipment and the loss of production cost companies billions it is increasingly important, therefore, to develop materials with improved wear resistance. It must be considered that wear is not just an intrinsic property of the material, but results from the characteristics of engineering systems. A tribological system includes the surface that suffers wear, the agent of wear and the environment in which the parts involved are acting. Thus, the main factors that contribute to wear are: hardness, toughness, chemical composition, the constitution and microstructure of the materials in contact, pressure, speed, temperature, surface finish, lubrication and corrosion. All materials are prone to these phenomena. However, some materials

tolerate or resist wear more and have a low coefficient of friction under certain conditions

Polyolefin-based Nano composites:

Thermoplastic polyolefin like poly(ethylene)(PEs) and poly(propylene) (PP) are well-established polymers available at the market, each having a different structure and very different behavior, performances and applications. Several papers deal with their tribological properties, in the presence of different types of Nano fillers. High density poly(ethylene) (HDPE) was used as matrix for preparing Nanosilica coatings, the wear resistance of which was measured using a rotate drum abrader. It was found that this parameter, despite a significant increase in the mechanical properties of the Nano composites (stiffness, yield strength and fracture toughness), exhibited lower values with respect to the neat polymer. Johnson and coworkers manufactured and tested the wear behavior of HDPE/multi walled-carbon-nanotubes composites. Different weight percentages of nanotubes (1, 3 and 5%) were used for preparing the samples, which were tested on a block on-ring apparatus. Wear resistance and frictional properties of HDPE were found to improve in the presence of the Nanofillers; furthermore, the addition of multi-walled carbon-nanotubes to HDPE turned out to bring wear rates down to the level seen in ultrahigh molecular weight poly(ethylene) (UHMWPE). The effect of the presence of Alumina nano particles (5 wt.%) was exploited for investigating the abrasion resistance of low-density poly(ethylene) (LDPE)-based Nano composites

High Stress Grinding Abrasion:

This type of abrasive wear occurs during the progressive fragmentation or grinding of the abrasive which was initially of small size and takes place on the surfaces employed to grind the abrasive. The wear is believed to be caused by concentrated compressive stress at the point of abrasive contact and to result from plastic flowing and fatiguing of ductile constituents and cracking of hard constituents of the metal surface. The use of the words "high stress" in this classification is intended to imply that the crushing strength of the abrasive is exceeded.

Low Stress Scratching Abrasion or Erosion:

The result of this type of abrasive wear is scratching of the metal surface, and the scratches are usually minute. The stress imposed on the abrasive particle does not exceed the crushing strength of the abrasive. Abrasive counterparts or particles are grooving the functional surfaces of machine components or parts, like tools, guidance's, and raceways, under various tribological interactions. Numerous basic operations to process raw materials, among them crushing, classifying or conveying, are typical for mining, steel and many other industries, and unavoidably related to abrasion and different damaging effects due to abrasive particles, like erosion, peening-like processes and also impacting. Core components of converting plants such as crushers are exposed to heavy wear and require efficient surface protection measures in order to avoid costly downtimes and to reduce costs for expensive spare parts

2.0 LITERATURE REVIEW:

[1] **P. Sećdlak · B. Białobrzęska (2015)** the recording program of the test system enabled the visualization and registration of the following parameters: specimen rotation and load value, linear wear of specimen, friction coefficient, and temperature of specimen and environment. The wear of the specimens was evaluated by weight loss and their wear mechanisms were investigated using scanning electron microscopy. The predominant wear mechanism between a polymer and steel was adhesion. However, at the high sliding velocity, when a higher temperature was generated, the predominant mechanism of wear was thermal wear. Impregnation of PPs moved the thermal wear into the higher sliding velocity values and caused better resistance of the PPs to melting and plastic flow. The most important finding of this investigation was that impregnation of PPs improved their tribological properties at a low value of load represented by the sliding velocity

[2] **Marcos Dorigão Manfrinatoa (2014)** a component, it leads to loss of efficiency, vibration and misalignment. In extreme cases, some cracks may lead to fractures, and the fragments formed can often damage the equipment. Thus, the study of the factors which contribute to wear and the precise study of the materials that undergo friction in a particular application are invaluable tools to assess the durability of an assembly safely and reliably, saving time and reducing spending on field tests. The current study aims to determine the wear resistance and coefficient of friction generated at the contact between 1045 steel and nylon 6.6 composites with different types of

reinforcement or Alpha 66 NBR rubber. 1045 steel is used for the manufacture of clutch discs, and it will be assessed if coating one of the components of the assembly with nylon 6.6 and nitrile NBR rubber would increase the service life of the part. In such a case, the nylon composite and rubber would serve as sacrificial materials, thus avoiding the need for replacement of the steel.

[3] **Volodymyr Pakhaliuk, Alexander Polyakov (2014)** The advanced model of wear in the spherical joint of total hip prosthesis comprising an acetabula cup of ultra-high molecular weight polyethylene in combination with a metal or ceramic femoral head is developed. The wear model is based on the classical Orchard-Lancaster equation in common with all other studies reported in literature. The finite element solution of the contact problem between the cup and the head was employed under the loading and angular motions results in terms of the cumulative linear and volumetric wear at a constant wear factor, chosen from the known literature, and as a variable parameter, defined by various expressions, found them quite close agreement. As well as there was found a good agreement with the well-known previous studies taking into account the differences of mechanical properties of the polymeric materials, nature of the load and their test methods.

3.0 METHODOLOGY:

Conditions for specific test procedures:

Different wear mechanisms and the resulting wear amount show a major influence on both the affected materials and the abrasive matter, e.g. depending on the kinematic and kinetic properties of abrasive particles,

which is not surprising from a tribological point of view. Though the systems' approach should govern the considerations of wear behavior a prevailing attitude can be observed in order to characterize the applicability of materials for certain conditions simply from material oriented tests. This is especially true for the design and selection of hardfacing materials like iron-based alloys that are to protect machinery equipment.

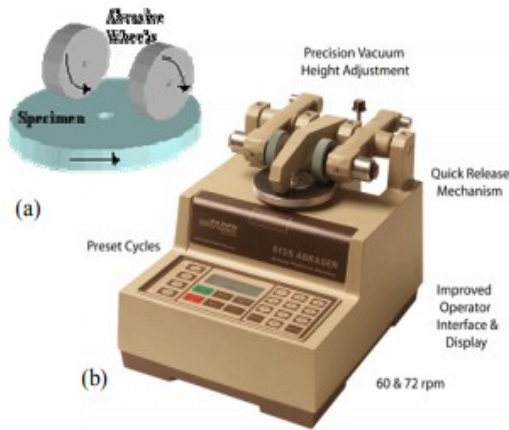


Figure: Rotary Platform Abrasive: (a) test principle and (b) test setup

Spherical abrasion test method:

The spherical abrasion test method has been introduced as Cal wear respectively Calo test (R) Tester by CSM Instruments SA as an instrument for a simple identification of coating thickness but also to investigate the abrasive wear behaviors of coated and uncoated materials. The determination of the wear coefficient is carried out by the wear crater technique. Thereby, a steel ball rolls over a sample (in a special setup or even on real parts, with defined parameters, like rotation speed and normal load, covered with an aqueous suspension of abrasive material (silicon carbide). This ball generates a spherical crater which will be

sized with an optical objective. These measured diameters correspond to the abrasive wear coefficient.

Table: Test parameters used for wear tests

Test parameters	Values
Force applied in contact	600 N
Contact area	0,0008 m ²
Specific pressure	750x10 ³ Nm ²
Sliding velocity	14,05 m/min
Total cycle	200000 cycles

The fluctuations in the coefficient of friction can be attributed to factors such as wear, oxide breakage, load variation, velocity and with phenomena associated with the removal of wear debris, as well as the vibration created by the moving parts of the equipment or the environment, among others. The average of the coefficient of friction varied for Pantaleón16: in the first 3.000 s, the variation in the mean of the test parameters showed values that decreased. The same behavior was observed for the different test loads; and stability of the polymer. Temperature depends on the test conditions and the heat generated by friction at the interface; the dissipation of frictional energy in the contact zone leads to an increase in temperature17. To analyze temperature discrepancies, various temperature values were collected every 20.000 cycles – a distance corresponding to 156.4 meters. This temperature is influenced by the friction and frequency of contact between the frictional components.

4.0 RESULTS AND DISCUSSIONS:

The morphology of the tested samples, all were observed under SEM to measure the diameter of the craters and to evaluate what type of abrasion occurred. These observations enabled it to be concluded that, two-body abrasion, typical abrasion scar Composite C, at 40 s curing time under abrasion test of 300 rotations. Took place for all the materials, which is a typical mechanism that happens in the mouth whenever there is a tooth-to-tooth contact, in a process that dentists commonly call attrition. The wear scars, which have a very regular shape deep scars due to two-body abrasion can be detected in the composite surface.

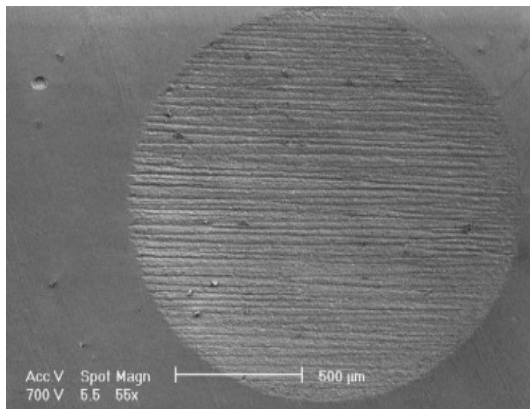


Figure: Typical abrasion scar. Composite A, at 40 s curing time under abrasion test of 300 rotations

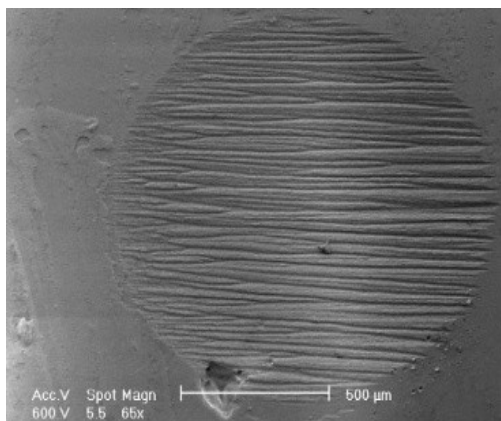


Figure: Typical abrasion scar Composite B, at 60 s curing time under abrasion test of 100 rotations

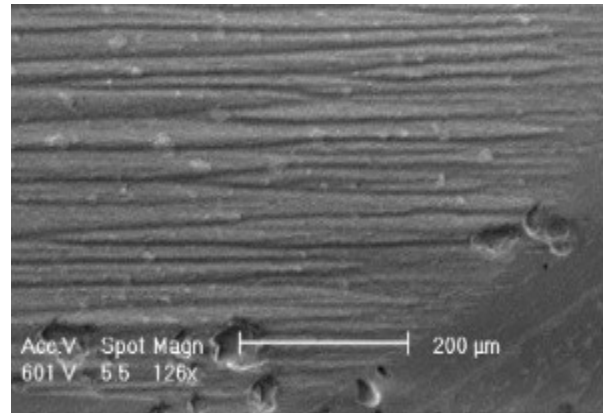


Figure: Detail of an abraded surface with reinforcement particles visible. Resin composite E, at 60 s curing time under abrasion test of 100 rotations.

5.0 CONCLUSIONS:

The absolute hardness value is not a safe criterion for correctly choosing the material, composite or amalgam, for a dentistry application where abrasive resistance is the more important factor. Although, for each of the materials tested, an increase in the hardness value usually led to improved abrasion resistance. The dissipation of frictional energy in the contact zone leads to an increase in temperature to analyze temperature discrepancies, various temperature values were collected every 20.000 cycles a distance corresponding to 156.4 meters. To this end, we used a Retek PM plus model PM20 laser temperature measuring instrument. This temperature is influenced by the friction and frequency of contact between the frictional components.

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