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Study on Abrasion Wear: A review

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ABSTRACT

Wear is a major problem related with engineering components, due which they fail under severe service working conditions. Plethora of wear mechanisms have been recognised such as erosive wear, surface fatigue, fretting wear, adhesive wear, abrasive wear and sliding wear, out of which abrasive wear is the most common problem. Also has been estimated that 50% of all wear problems in industry are due to abrasion. After studying the literature it has been that the wear in agricultural equipments and tillage is the main problem. Hardfacing is economical method when compared to other surface treatment methods, also other aspects were analysed but those were also not considerable on the bases of feasibility and economics. For hardfacing the surface, welding techniques were considered favourable.

Keywords:Wear,Abrasive wear, Hardfacing,Heat Treatment

1.1 INTRODUTION

Wear is a process where interaction between two surfaces or bounding faces of solid within the working environment results in dimensional loss of one solid, with or without any actual decoupling and loss of material. Wear is a major problem in the excavation, earth moving, mining and minerals processing industries, and occurs in a wide variety of items, such as bulldozer blades, excavator teeth, rock drill bits, crushers, slushers, ball and rod mills, chutes, slurry pumps and cyclones. The complex nature of wear has delayed its investigations and resulted in isolated studies towards specific wear mechanisms. The abrasive wear in agriculture equipments is the most common problem. The high wear rate of ground engaging tools led to huge loss of material, recurring labour, downtime and replacement costs of worn out parts. Hard facing is commonly used method to improve surface properties of tillage tools.

Wear is said to be a degradation of surface under different service conditions. Wear is related to interactions between surfaces and more specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface (Rabinowicz, 1995). Many engineering components fail primarily due to wear and corrosion in aggressive interacting environments. Tribological components in gas turbine plant and hydro power plant are usually subjected to such severe working conditions, and consequently fail more frequently due to wear and corrosion (Gupta and sharma, 2011). There are plethora of wear mechanisms, but some commonly types referred to wear mechanisms are adhesive wear, surface fatigue, fretting wear, erosive wear, abrasive wear etc. These are briefly discussed as follows. First is Erosive wear, which is an extremely short sliding motion and is executed within a short time interval. Erosive wear take place due the impact of solid or liquid against the surface of a component under severe conditions (Stachowiak et al 2008). The gradual impact of particles removes material from the surface through repeated deformations followed by cutting actions (Mamata and Saini 2008). It is widely encountered mechanism in industry. Surface fatigue, also known as fatigue fracture has been perceived in turbines, is a process by which the surface of a material becomes inadequate due to cyclic loading (Yang et al 2014). In addition fatigue failure is one of the most considerable issues in biological studies and applications leading to serious consequences (Shaefi and Tanner 2014). It has been analysed that fatigue wear is initiated when the wear particles are detached by cyclic crack growth of micro cracks on the surface. These micro cracks are generally superficial cracks (Balsone et al 1995). Fretting wear is commonly defined as the wear related to surfaces in contact and generally seen as a drawback in various mechanical components. Fretting wear is a combined result of corrosion, wear and fatigue. Basically it can be said that fretting wear mechanism involves degrading of mechanical components coming in contact, when in reciprocal relative displacement (Korsunksky et al 2008). Adhesive wear is considered as the relocation of material from one surface to another as a result of localised bonding between contacting surfaces (Deuis et al 1996). This phenomenon of degradation of surface can generally be seen in many components. For instance, in the fast breeder reactors, many important components inside the reactor core are subjected to sliding wear, and due to poor tribological properties a couple of components are observed to have low sliding wear resistance, unstable friction qualities, subsurface damage and formation of strong adhesion due to surface sliding over the another surface (Li and Wang 2008). Sliding is a two-body wear in which the degradation of surfaces is a result of a relative motion between two surfaces and the initial mechanical contact between the surfaces. The differentiation between sliding and abrasive wear is not sharp. Both are part of wear spectrum ranging from pure cutting to ploughing type deformation without formation of cutting chips (Rigney et al 1988). Abrasive wear, also called as abrasion wear is three-body wear consists of wear caused by abrasives in motion that is sliding as well as rolling degrades the surfaces of the asperities. During the sliding of two solid bodies, a transfer layer often forms at the interface (Rigney 2000). In order to reduce the time and cost of research, tribological tests have been performed on pin-on-disc tests tribometer referred to the G-99 standard of ASTM due to its simplicity, allowing the evaluation of a larger number of alternatives to material and process parameters (Cho et al 2008).

1.2 ABRASION WEAR

Abrasive wear, commonly known as three-body abrasion and can also be written as abrasion wear, by loose solid particles is a frequent problem in the industry, (Hosseini and Radziszewski 2011). It has been estimated that 50% of all wear problems in industry are due to abrasion (Wirojanupatump and shipway, 2000). The cost of abrasive wear losses is high and has been estimated as ranging from 1 to 4% in the gross national product of an industrialized nation. Eighty to ninety percent of machine parts in the industry are known to fail because of damage of surface wear (Ming-Lin et al 2010). Several laboratory works have been examined and sought to rationalise the abrasive wear behaviour of a wide range of material (Eyre 1976). However two-body abrasion wear generally arise when particles are in sliding movement, between hard and rough surface, and are able to move freely. Agricultural machinery that is operating in sandy environment is vulnerable to sand particles entering and becoming entrapped between components, causing abrasive wear (Woldman et al 2012). Abrasive wear processes have typically been divided into two regimes: high or low stresses (Hawk et al 1999). The rubber wheel abrasion test (RWAT) as described in ASTM standard G65 is commonly used to evaluate the abrasive wear behaviour.

1.3 ABRASION WEAR IN AGRICULTURAL EQUIPEMENTS

As far as agricultural mechanization is concerned, abrasive wear of soil-engaging components is a serious problem because of huge loss of material and increased the cost of and time lost in replacing worn parts of agricultural machinery (Par and ER U, 2005).

In addition the optimizing tillage is one of the major objectives in mechanized farming to achieve economically viable crop production system (Jayasuriya et al, 2000). Carbon or low alloy steels are generally preferred to make tillage tool under low stress abrasive wear (Yu and Bhole, 1990). while tillage having composites with alumina ceramics and boron, medium and high carbon heat treated steels offers great potential the severity of abrasive wear in soil-engaging components (Foley et al, 1984). The wear of tillage implements in most soils is caused by the stones and gravel content (Simonson et al, 2002).

In addition wear on parts of a plough body, more systematically, depends on the wear resistance of the plough parts dependent on their thermal processing and shape, the tillage conditions, as plough area (or time), plough speed and tillage depth, the normal forces between the soil and the surfaces of the plough area, the proportion, hardness, sharpness and shape of soil particles, the moisture content of the soil, the density and mechanical properties of the soil (hardness, shear strength and brittleness) and environmental effects and weather changes (Bayhan, 2006). While the wear resistance of plough is mainly associated with their surface hardness and shape of ploughshare, which in turns related to the soil type and the cutting edge thickness (*National Research Council Canada*, "A strategy for tribology in *Canada*", 1986, (*Publication*: *26556 p*. *36–39*).

1.4 REMEDIES

Wear is considered a genuine problem with engineering material globally, for instance, it has been reported that there is total losses in agricultural sector due to wear is about $940 million every year in Canada (Ulusoy , 1981) the similar losses costing about $4.4 million in Turkey every year (Gupta and Sharma , 2011). In case of abrasion wear of tools, abrasion with hard soil particles is dominating (Gahr KH, 1998).

In order to combat with problem of wear several attempts have been made in various aspects such as characterization of tillage and improvements of its design, operational modelling, some attempts have also been made is changing the material of ploughshares followed by the surface treatment which is by hardfacing for the tools and equipment by alloying it or using a welding technique. For instance, geometrical characterisation in some cases by the help of computer programmes help to study the behaviour of different designs (Gutierrez et al, 2011). As far as the material used in mechanical machinery must be having an enough hardness to resist wear but also tough and strong enough to resist impact and distortion (Foley et al, 1984). Boriding has been an important hardening process; basically it is a thermo-chemical surface hardening process in which boron atoms are diffused into the surface a metal to form a hard layer of metal borides (Hunger et al, 1994). In comparison with other conventional methods such as carburising and nitriding, boriding is more promising to have considerable hardness of the tool (Shadrichev and Rumyantsev, 1982). However, wear protection methods have the essential assumption that higher the hardness is higher will the resistance against the abrasion wear, but the influence of material is very much complex as only hardness is not enough (Horvat et al, 2008). To gain these desired properties, the surface treatment has been preferred method for which various processes has been found so far, such as hardfacing, coating, cryogenic treatment and heat treatment processes. In addition, to achieve optimal solutions for abrasion wear protection, investigations were combined tribosystem analysis as well as laboratory and exploitation investigations (Baldissera, 2010). Hardfacing and coating are generally preferred for abrasion wear as cryotreatment found its application in the high-cycle fatigue fields (Bayhan, 2006). A couple of studies found, who investigated these surface treatments followed by hardfacing. Amongst the plethora of these methods hardfacing by welding techniques has been considered as the most appropriate method (Ivusic V and Jakovljevic, 1992).

Hardfacing is a commonly known method employed to improve surface of the tillage tools where an alloy properties homogenously deposited onto the surface of substrate material by welding technique (Mihaljevic T, 1993). Hardfacing process is considered as the effective method to reduce wear problem, also economical one (Buchley, 2005), In addition Hardfacing welding is a widely used method on severe worn, corroded or oxidized surfaces to regain its functionality (American Welding Society 1998). The hardfaced deposits are chosen on the basis of welding deposits (Mohanty et al 1996). The hardfacing alloys such as Fe-Cr-C and Fe-C-B are commonly employed for bulk materials to improve their tribological performances (Badisch et al 2008). Plethora of methods for depositing these alloys onto the surface have been recognised so far, few of them are oxyacetylene gas welding (OAW), gas metal arc welding (GMAW), Shielded metal arc welding (SMAW), Manual Metal arc welding (MMAW) and submerged arc welding (SAW) etc. Manual metal arc welding (MMAW), for example, is commonly used due the low cost and easier application. Coating is another widely used resistant method against the wear problem (Gandra, 2013). Based on the criteria such as energy used and deposition processes various processes are designed such as laser cladding, thermal spraying etc. (Dorfman, 2002). Thermal spray is utilized as the first preference in world's industries (Brinell, 1921).

1.5 ABRASIVE WEAR AND ITS TESTS

Abrasion wear is known to be as the three-body abrasion in which the specimen is loaded against a rotating wheel with abrasive particles being, entrained into the contact zone. It is standardised by ASTM as G65 (a dry sand-rubber wheel abrasion test) (Wayne, 1990).The abrasives can be used depending on the application such as, industrial equipment for grinding grain, paints, plastics, coatings, slurry abrasion, construction and farm equipment. A wide range of materials can be tested for example; metals, ceramics, plastics, composite materials and coatings. Parametric flexibility (e.g. load, sliding speed and distance, sand size and quality) of this set-up can provide many advantages in simulating various tribological systems (Hadad and Siegmann, 2012). It has been reported that the wear resistance decreases with increase in content of material used for coating and increasing grain size (Borik, 1970). The rubber wheel abrasion test has been the subject of a large body of research with comparatively little published work addressing abrasion with a steel wheel. Indeed, in relatively early work on the rubber wheel apparatus, commercially available apparatus supplied with steel wheels were being modified for use with a rubber wheel (Hosseini and Radziszewski , 2011). It has been studied the 3-body abrasion phenomenon, is generally classified in two classifications “low stress abrasive wear” and “high stress abrasive wear” depending on the type of experimental apparatus used. For example a rubber wheel used to simulate the 3-body testing is more representative for “low stress abrasive wear” and the steel wheel testing is more representative for “high stress abrasive wear”. Steel wheel abrasion test which can be conducted to study the wear and abrasive breakage of grains which can be useful to consider as it is seen in ball mills and other industrial applications (Hosseini and Radziszewski, 2011). Steel wheel abrasion test is also useful for mining industry devices, as it provides similar working conditions (Radziszewski, 2002). For the first time Rubber wheel abrasion test (RAWT) as described by ASTM standard G65 (Haworth, 1949). Haworth used rubber to maintain the contact pressure as the specimen wore, because he had noted that the pistons of slurry pumps were made from rubber in order to maintain pressure as the liner wore. The specimen was held against the vertical edge of the wheel and was 3 in (76.2 mm) long and 1 in (25.4 mm) wide, twice the width of the wheel (Stevenson and Hutchings, 1996). The apparatus of RWAT is shown schematically in Fig 1.1.

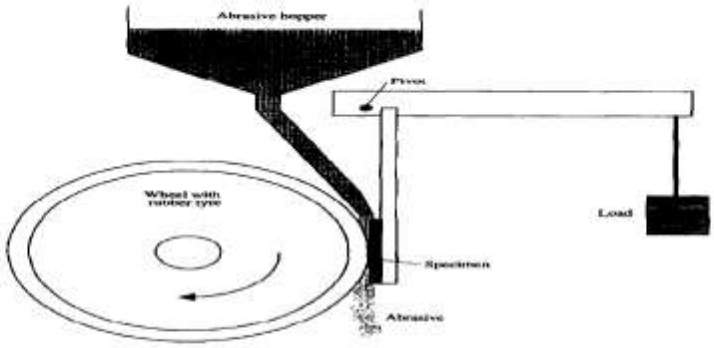

Fig 1.1. Schematic diagram of the rubber wheel abrasion testing (RWAT) apparatus described by ASTM G65 (Annual Book of ATSM Standards volume 03.02, pp. 247-259).

mineral processing industries and occurs in a wide variety of items, such as bulldozersblades,excavator teeth,drillbits,crushers,slusher, ball and roll mills,chutes,slurry pumps and cyclones[3]. Also, on other side when the situation is the case of rotating shafts which are held within lubricated support, bearing need oil of anti-wear properties, giving the effect of wear [4].The wear behaviour of material is related to parameters such as shape, size of component, composition and distributionof micro constituents in addition to the service conditions such as load, sliding speed, temperature, environment and counter surface[5]. The complex nature of wear has delayed its investigations and results in isolated studies towards specific wear mechanisms. Some commonly referred to wear mechanisms include erosive wear, surfacefatigue, frettingwear, adhesivewear, abrasivewear and sliding wear.

2 CONCLUSIONS

1. Wear is a major issue with having an estimated direct loss of industrial components costing of 1-4% of gross national product.
2. To combat with wear problem, several methods such as hardfacing, coating, cryotreatment and heat treatment have been opted in accordance to service conditions on material or component.Hardfacing and Nitriding are consideredas the most appropriate and economical method.
3. In some cases, heat treatment has been reported as root cause for surface fatigue.

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