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Study on Wear in Engineering Materials: A Review

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ABSTRACT

Wear is a major problem in industry affecting directly the gross national product. Wear is defined as a process where interaction between two surfaces results in dimensional loss of one solid, with or without any actual decoupling and loss of material. Erosive wear, surface fatigue, fretting wear, adhesive wear, abrasive wear and sliding wear are some recognised wear mechanisms, out of which sliding wear is the most significant from the technological point of view. After studying the literature it has been learned that the wear is the main problem in mining industries. By surveying the various industries it has been noticed that blade wear is the main problem. So to overcome this problem, hard facing is recommended as the most appropriate method to resist over this wear and to increase the life of components generally made of enineering material. Hardfacing is economical method when compared to other surface treatment methods. Amongst the welding techniques, the manual metal arc welding (MMAW) is considered as far as the economics are concerned with the good appearance.

Keywords: Wear, Sliding Wear, Hardfacing.

1.1 INTRODUCTION

Wear is known to be as the degradation of material under plethora of service conditions and is considered as one of the major issue of the material used in engineering. So far, various types of wears have been recognized such as erosive wear, surface fatigue, fretting wear, adhesive wear, abrasive wear and sliding wear. Sliding wear is probably the most significant cause of failure of number of materials engaged in mechanical machinery and components, followed by abrasive wear. For combating with wear problem various methods have also been developed such as hardfacing, cryogenic treatment, coating and heat treatment of components which are chosen on the basis of various conditions under which the component has to perform the desired work. Hardfacing is commonly use to resist this failure, also considered as most appropriate and economically sound process, while others do have shown dependable results.

Wear is a major problem in industry and its direct cost is estimated to vary between 1 to 4% of gross national product (Goode, 1989). Wear is defined as a process where interaction between two surfaces or bounding faces of solids within the working environment results in dimensional loss of one solid, with or without any actual decoupling and loss of material (MA et al. 2008). Wear is a major problem in the excavation, earth moving, mining, automobiles, machines and mineral processing industries and occurs in a wide variety of items, such as bulldozers blades, excavator teeth, drill bits, crushers, slusher, ball and roll mills, chutes, slurry pumps and cyclones (Hawk et al. 1999). 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 (Wood et al. 2010). The wear behaviour of material is related to parameters such as shape, size of component, composition and distribution of micro constituents in addition to the service conditions such as load, sliding speed, temperature, environment and counter surface (Sarkar and Clarke, 1980). 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, surface fatigue, fretting wear, adhesive wear, abrasive wear and sliding wear.

1.1.1 Erosive Wear

Erosive wear can be described as an extremely short sliding motion and is executed within a short time interval. Erosive wear is caused by the impact of solid or liquid against the surface of an object (Stachowiak et al. 2008). The impacting particles gradually remove material from the surface through repeated deformations and cutting actions (Mamata and Saini, 2008). It is widely encountered mechanism in industry. Erosive wear at elevated temperature are important material removal mechanisms for many different engineering components, e.g. blades in gas turbines and crusher systems for sinter cake in steel production plants. The materials removal mechanisms under such conditions are superposed by the effect of oxidation (Katsich, 2010).

1.1.2 Surface Fatigue

Surface fatigue or fatigue fracture has been observed in turbines, is a process by which the surface of a material is weakened due to cyclic loading (Yang et al. 2014). In addition fatigue failure is considered as a major issue in biological studies and applications leading to consequences (Shaefi and Tanner, 2014). Fatigue wear is produced when the wear particles are detached by cyclic crack growth of micro cracks on the surface. These micro cracks are either superficial cracks or subsurface cracks (Balsone et al. 1995).

1.1.3 Fretting Wear

Fretting wear is concerned with surfaces in contact and generally seen as obstacle in various mechanical components such as fans and compressor blades in aerospace jet engines. Fretting damage is a result of corrosion (chemical), wear and fatigue. Basically it can be said that fretting is a degradation process which arises in mechanical components coming in contact having reciprocal relative displacement (Korsunksky et al. 2008). The regimes of relative displacement between the two contacting surfaces can be classified into full stick (no slip),partial slip (some part of the contact remains adhered, while some other pairs of contacting points experience relative slip) and gross slip (every pair of points in contact experience slip). Gross slip leads to the relief of stresses due to damage localisation, and the promotion of the phenomenon of fretting wear (Fouvry et al. 1996 and Kim, 2006).

1.1.4 Adhesive Wear

Adhesive wear is defined as the transfer of material from one surface to another during relative motion by a process of solid-phase welding or as a result of localised bonding between contacting surfaces (Deuis et al. 1996). For instance, in the fast breeder reactors, many important components inside the reactor core are under dry sliding contact and subjected to sliding wear, a couple of components exhibit poor tribological properties such as low sliding wear resistance, unstable friction qualities, subsurface damage and formation of strong adhesion when it is sliding against itself (LiandWang2008).

1.1.5Abrasive Wear

Abrasive wear by loose solid particles is a frequent problem in the industry, commonly known as three-body abrasion (Hosseini and Radziszewski, 2011). It has been estimated that 50% of all wear problems in industry are due to abrasion, and as such, much laboratory work has examined and sought to rationalise the abrasive wear behaviour of a wide range of material (Eyre, 1976). However two body abrasive wear generally arise when particles are in sliding movement, between hard and rough surface, and are able to move freely. 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 of materials under three-body conditions (Stevenson and Hutchings, 1996).

1.1.6 Sliding Wear

Sliding wear may be defined as a two-body wear in which a relative motion between two surfaces and the initial mechanical contact between the asperities results in degradation of surfaces. The distinction 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). During the sliding of two solid bodies, a transfer layer often forms at the interface. The importance of this transfer layer on friction and wear rate has been well acknowledged (Rigney, 2000). For example, in a clutch system, the tribological contact between the friction materials coming in contact with each other in form of sliding contact results in formation of complex tribological film which is believed to control and determine the frictional behaviour efficiency of the system (Frenandes et al. 2013). To reduce time and cost of research tribological tests have been performed on pin-on-disc tests tribometer due to the simplicity of the device, allowing the evaluation of a larger number of alternatives to material and process parameters (Cho et al. 2008).

1.2REMEDIAL ACTIONS.

To deal with wear problem, various aspects has been studied and observed. The most optimal solution found is modification of the functional surfaces to work satisfactorily in the aggressive working environment (Gupta and Sharma, 2011). While plethora of wear have been observed till the date and after studying the tribological behaviour of material, number of remedial actions came into existence (Anasyida et al. 2010).

1.2.1 Cryogenic Treatment

Cryogenic processing or cryogenic treatment, often referred to as 'cryotreatment', involves lowering the material to sub-zero temperatures and holding or 'soaking' for a defined period of time before raising the material back to ambient temperature. The objective of cryotreatment is therefore to cause permanent changes to the microstructure of a material (Thronton et al. 2011). It is widely used in production of engineering material and automotive parts (Mohan et al. 2001). Cryogenic treatment is classified in two types that are shallow and deep cryogenic treatment (Baldissera and Delperete, 2010). It has been reported that during the cryotreatment (shallow/deep) of metals, the expansion of the metal increases the density of dislocations in the metal matrix, for example, improves the average metal wear resistance and hardness (Farhani et al. 2012), in addition it has been reported that the cryotreated samples showed longer life in the high-cycle fatigue field (Baldissera and Delprete, 2010). The parameters that are typically controlled and varied during cryotreatment are: cooling rate, soaking temperature, soaking time, heating rate and the position of the cryotreatment within the overall treatment cycle in cases where materials or components are to be tempered (Darwin et al. 2008) .

1.2.2Coating

Coating is one of the widely used methods to resist or reduce wear during the sliding contact. Generally it is applied to improve the surface characteristics over those of the bulk properties (Mohanty et al. 1996). There are several main stream coating processes that allow improving surface properties or repair. For instance, Fe-Cr-C alloy systems have proven to be very attractive coatings to protect surfaces, which are heavily exposed to various wear and corrosion mechanisms and to increase the lifetime of costly machinery equipment (Dogen et al. 1997). Based on the energy source and deposition processes used, there are key groups of weld-based processes, namely: arc welding deposition, thermal spraying and laser cladding (Gandra et al. 2013). A substantial number of the world's industries utilize thermal spray for many critical applications (Dorfman, 2002).Thermal spray processes are easy to use, cost little to operate, and have attributes that are beneficial to applications in almost all industries. The benefits are typically lower cost, improved engineering performance and/or increased component life (Herman et al. 2000). In the last decade a lot of carbon-based low-friction coatings, also known as diamond-like carbon coatings (DLC) were developed, which provide a wide range of mechanical properties, especially tribological properties like high wear resistance (Podgornik et al. 2012).

1.2.3 Heat Treatment

Heat treatment is of various types such as annealing, tempering, quenching and many more applied in numerous industries for better serviceability of mechanical components. It has been reported that heat treatment is found in increasing the strength of material such as aluminium against wear, which has wide application in internal combustion engines, pumps and many more (MA et al. 2008). In addition grain refinement has become a standard melt treatment practise in aluminium foundaries world-wide with well documented technical and economic advantages (Alipour et al. 2013). Also new developments in heat treatment processes like thermochemical controlled process have reported in good strength, weld ability and toughness (Wei et al. 2011). Heat treatment is also playing a vital role in determining the life of forging dies, being highly wear resistant, used in mechanical press working at high temperatures (Min–xian et al. 2012). Apart from traditional heat treatment, laser heat treatment is an important industrial technique finding its use in improving surface hardening (Ki and So, 2012). The abrasion and corrosion resistant properties also depend upon the chemical composition, the microstructure and heat treatment conditions (Lee et al. 2012).

1.2.4Hardfacing

Hardfacing welding is a widely used method on severe worn, corroded or oxidized surfaces to regain its functionality. Over the last couple of years it has become a large field of applications and technology development to manufacture new components as to extend lifetime in diverse industries (American Welding Society, 1998). In this an alloy is homogenously deposited onto the surface of base material (usually low or medium carbon steels) by welding, with the purpose of increasing hardness and wear resistance without significant loss in ductility and toughness of the substrate (Buchly et al. 2005). During hardfacing process, both the hardfaced coating and the substrate material are melted to improve the metallurgical bonding between the hardfaced coating and the substrate (Khedkar et al. 1997). Preparation of hardfacing deposits requires the choice of the welding consumable and a welding procedure (Dawson et al. 1982). In addition, for metal-metal sliding 0r rolling contact applications, in which there is plethora of wears occur while in metal-metal dry sliding material face wears such as oxidative wear , adhesive wear are dominating wear mechanisms for which deposits of 0.1 and 0.7% and up to 20% of alloys (Cr ,Mn, Mo, W, V) are used (Koteki and Ogborn, 1995). For instance, Containing a large number of M7C3 carbides in its microstructure, high chromium cast iron work pieces with good wear resistance and low price, were widely applied in mining, metallurgy and machinery industries, which has a high service life at normal temperature and low stress abrasion conditions(Feifei et al. 2010), similarly hardfacing alloys Fe-Cr-C and Fe-C-B are commonly employed for bulk materials to improve their tribological performances (Badisch et al. 2008) and for the failed work pieces (Wen et al. 2006). Also iron-based hardfacing are a popular choice and their wear-resistance is attributable to microstructure in which hard carbides are dispersed in a relatively soft matrix (Atamert and Bhadeshia,1990). Various method of depositing these alloys onto the surface are there such as 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.

1.3 Method for deposition of hardfacing

The major differences among these techniques can be obtained by welding efficiency, the weld plate dilution and the manufacturing cost of consumables (Wo and Wu, 1996). Manual Metal Arc Welding (MMAW) welding is the most flexible and one of the most widely used arc welding processes. Fig. 1.1 shows the process of manual metal arc welding. In this process an arc is drawn between a coated consumable electrode and the work piece. The metallic core-wire is melted by the arc and is transferred to the weld pool as molten drops. The electrode coating also melts to form a gas shield around the arc and the weld pool as well as slag on the surface of the weld pool, thus protecting the cooling weld pool from the atmosphere. The slag must be removed after each layer. Manual Metal Arc welding is still a widely used hardfacing process. Due to the low cost of the equipment, the low operating costs of the process and the ease of transporting the equipment, this flexible process is ideally suited to repair work.

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