REVIEW ON ABRASIVE WEAR BEHAVIOUR OF AL 6061 AND SELECTION OF MATERIAL AND TECHNOLOGY FOR FORMING LAYER RESISTANT TO ABRASIVE WEAR

(Interaction of Graphene as layer resistance to Aluminum alloys)

Marij ahmed khan [1], Dr. Mohd. Shadab khan [2]

[1] Dept. of Mechanical Engineering ,Integral University, Lucknow, India

[2]Asscociate professor ,Dept. of Mechanical Engineering, Integral University, Lucknow, India

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Abstract — *This article deals with in-depth analysis of previous work done on the selection of materials for forming wear resistant layers within machine parts wear made of aluminum alloys (AL6061) and methods through which we can achieve required hardness, wear resistance and life extension of a machine parts and tools by the selection of a suitable material and surfacing technology.*

Keywords — Abrasive wear, resistant layers, Aluminium alloys, AL6061,Graphene.

Introduction

Surface Engineering can be defined as the study, characterization and improvement of a material's surface properties. These surface will be exposed to an external environment and will therefore deal with a different set of constraints and conditions than the bulk material. So that the bulk material can be selected based on structural requirements and the surface of the material can be altered in a number of ways to suit external conditions. These enhancements must be achieved in a cost effective manner without causing any detrimental effect on the beneficial properties of the bulk material. Some of the common cases where surface treatment is essential are: a cutting tool, punch and dies or dental tools. The classic example one of many surface engineering challenge is the gas turbine blade. The turbine environment is highly corrosive and blades are maintained at extreme temperatures; the blade will need to resist these demanding conditions at the surface and while also being strong enough, structurally, to transmit a torque to the central shaft of the turbine. The three typical methods of improving materials; heat treatment, alloying or surface engineering.

Tribology is the study and science of interactions between surfaces in relative motion. Friction, wear and lubrication are fundamental concerns that make up this field [2]. Materials that are in contact have are at the interface and two material surfaces which have individual characteristics will therefore have a different effect on the tribological relationship.

There are a number of inter-related variables which govern how two materials will react when in contact under Tribological situations. Some of the variables are the load applied to bring the materials into contact, the degree of contact between these materials, the presence of any lubricant, sliding speed of both the surfaces with reference to each other and the individualistic material properties. Every individual variable will have an overall effect on the system as a whole and it is very difficult to separate out and differentiate the individual contributions of any single factor. The material properties of main concern are the toughness, porosity, hardness and surface roughness. If any surface coating has been applied to a material then the adhesion of the coat to the substrate surface is important. Accurate measurement of these properties possess a major challenge in this field of tribology, especially in the case of coated materials. A good example of this is the phenomenon of varying hardness with the load applied on surface, or the depth reached in a given material, during an indentation test. This is known as the indentation size effect (ISE)[3] [4] and has led to much discussion and debate.

Wear can be defined as: "The progressive loss of substance from the operating surface of a body as a result of relative motion of two surfaces with respect to each other"[5]. Kloss et al[6] stated that it is a complicated mechanical, thermal and chemical process and is therefore present in an extremely broad range of situations; from the impeller of a pump to the rotating components in a motor and leading edge of a cutting tool. The loss of material has an adverse effect on the working life of the machine, tool or surface that is exposed to the wear process. Wear models generally predict the reaction of a material to different wear situations and to forecast the rate of material removal or MRR from the surface of a body. Classical wear theory begins by considering the rate of material removal as a function of the sliding speed of the surfaces, the hardness of the material, the load applied and the probability of the material to produce a wear particle in a given contact and mechanical situation[7, 8]. There are four main theories which can 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 may occur in a number of different forms and these processes differ from one another when you consider the bodies which are in contact, the way in which material is removed and what is the amount of material removed. These processes do not always occur exclusively i.e. several might be present in a given situation.

The primary processes are: adhesion, abrasion, erosion, fretting and cavitation. For example abrasion may occurs as a physical gouging effect this is due to the harder of the two surfaces will dig into the softer material surface and subsequently remove material. Fretting operates as a fatigue type action where the buildup of incremental strains will lead to material failure. The difference between these wear processes result in many possible differences in the failure mechanism of the same material e.g. through crack initiation and propagation or through shearing away of material; hence it is important to consider wear process when modelling. Researches that are focused on a specific application or material in a wearing environment may also include process-specific parameters that will therefore lead to increase in the consistency of models with their application. An example of this would be the inclusion of disparate material regions within a nano-composite coating [9], modelled in an FEA package, or the incorporation of a linked thermo-mechanical simulation to represent a tool wearing situation where heat generation is a very significant factor [10].

Empirical testing is a vital stage in the development of any theoretical model. Through experimentation a proposed model can be verified and problems or inconsistencies are highlighted. It is vital again to account for which wear mechanism is present and to define/ design the test to best represent the situation under examination (WRT bodies interacting, materials, sliding speed, loads etc.).

In recent decades, aluminum alloy based metal matrix composites are gaining important role in several engineering applications. Al6061 alloy has been used as the matrix material because of its good formability, excellent mechanical properties and manufacturing properties. Wide spectrum of the applications in the commercial and industrial sectors. Inclusion of Frit particulates as reinforcement in Al6061 alloy material system has shown improvements its hardness, tensile strength, wear resistance. The preparation of Al6061-Frit particulate composites produced by 'VORTEX' method with varying percentages of Frit particulate from 0 wt% to 10 wt% in steps has shown significant improvements in material properties. The as-cast matrix alloy and its composites have been subjected to solution zing treatment at a temperature of 5300C for 2 hours followed by quenching in ice. The quenched specimens were subjected to both natural and artificial ageing. Microstructure studies were conducted on as cast and composites in order to investigate the distribution of frit particles retained in matrix material system. Densities of Al6061 matrix alloy and Al6061-Frit particulate composites were measured. Mechanical properties such as Hardness and sand abrasive wear test have been conducted on both Al6061 alloy matrix and Al6061-Frit particulate composite before and after treatment. It has been observed that under identical treatment conditions adopted, a Al6061-Frit particulate composites exhibited significant improvement in hardness, wear resistance and reduced density when compared with Al6061 matrix alloy. [3]

Some studies has shown, a mathematical approach by developing models to predict the abrasive wear behavior of Al 6061. The experiments have been conducted using central composite design in the design of experiments (DOE) on pin-on-disc type wear testing machine, against abrasive media. A second order polynomial model has been developed for the prediction of wear loss. These models often are developed by use response surface method (RSM). Analysis of variance technique at the with different confidence level was applied to check the validity of the models. The effect of volume percentage of reinforcement, applied load and sliding velocity on abrasive wear behavior was analyzed in detail. To judge the efficiency and ability of the model, the comparison of predicted and experimental response values outside the design conditions was carried out. The result shows, good correspondence, implying that, empirical models derived from response surface approach can be used to describe the tribological behavior of the above composite. [1]

Studying wear is characterized by many different aspects and it is mostly influenced by the complexity of materials interaction on a functional surface as well as by operation conditions. In machine elements, there is a gradual wear in the result of friction. This is considered to be an undesirable effect in most cases. Therefore, we have to search for the possibilities to prevent it thus extending the technical life of a component. Surfacing presents one of these possibilities. Searching for the possibility of cutting the costs of changing the worn or damaged machine elements has led to the development of a wide range of surfacing technologies. Increasing the safety and extending the technical life of machines and devices are important requirements of modern technology. We can also add the requirement for simple maintenance, as well as simple and less time-consuming repairs in solving the random failures or operation accidents. [2]

Literature survey

H.C. How and T.N. Baker (1997)

In their investigation of wear behavior of Al6061-saffil fiber, concluded that saffil are significant in improving wear resistance of the composite. [1]

Liang Y. N. ET. al. (1997)

In their investigation they reported that the MMCs containing SiC particles exhibit improved wear resistance. [2]

R. Clark ET. al. (2005)

In their studies on Al7075reported that, pre-aging at various retrogression temperatures improves the hardness, tensile properties and electrical resistivity. [4]

Chandra mohan G., ET. Al (2006).

Reported that the sliding distance has the highest effect on the dry sliding wear behavior of MMCs than that of the load and sliding speed. [5]

Basavarajappa S. ET. al. (2006)

Stated that the microstructural characteristics, applied load, sliding speed and sliding distance affect the dry sliding wear and friction of MMCs. However, they conclude that, at higher normal loads (60N), severe wear and silicon carbide particles cracking and seizure of the composite occurs during dry sliding [6]

Q Wang, Z H Chen, Z X Ding and Z L Liu (2008)

Conducted study on Performance of abrasive wear and erosive wear of WC-12Co coatings sprayed by HVOF. They used WC-Co cermet's as wear resistant materials. Their work examines the performance of such conventional and nanostructured materials in the form of coatings deposited by high velocity oxy-fuel (HVOF) thermal spraying

The results indicated that: microstructures of nanostructured and multimodal WC-12Co coatings prepared by HVOF are dense with little porosity, and their micro hardness values are obviously higher than conventional WC-12Co coatings, though Nano WC did during spraying. As well, it was found that nanostructured and multimodal WC-12Co coatings exhibited better abrasive and erosive wear resistance in comparison with conventional one.

Simon J. Montgomery et.al (2009)

The objective of this work was to examine a number of models that have been used for analyzing wear of materials. It highlights some key details and techniques used by authors to ascertain wear rates and gives examples of modern approaches to wear measurement for coated engineering samples like classical wear theory and current wear theory. [9]

Dharma R. Maddala, Arif Mubarok and Rainer J. Hebert (2010)

They conducted study on Sliding wear behavior of $Cu_{50}Hf_{41.5}Al_{8.5}$ bulk metallic glass. Sliding wear behavior of a copper-based bulk metallic glass ($Cu_{50}Hf_{41.5}Al_{8.5}$) was investigated for both as-cast and annealed samples. The wear resistance increased during isothermal annealing near the glass transition temperature. Nanocrystals developed during the annealing for annealing times up to 300 min. A linearrelation between hardness and wear resistance was observed during the early stages of devitrification, but at longer annealing times the wear resistance increased1

N R Prabhu Swamy, C S Ramesh and T Chandershekar (2010)

They studied the effect of heat treatment on strength and behavior of Al-SiC_p composites and concluded that microhardness of composites increased significantly with increased content of SiC_p. Heat treatment has a significant effect on microhardness of Al6061 matrix alloy and its composites. Tensile strength of composites increased significantly with increased content of SiC_p. Abrasive wear loss of composites decreases, with the increase in content of SiC_p in matrix alloy under identical test conditions.

Veeresh Kumar.G.B, C.S.P.Rao, Bhagyashekar.M.S., Selvaraj.N (2011)

Reported that artificial neural network (ANN) can be effectively applied to study the tribological behavior. The studies conducted regarding wear resistance properties of Al6061-SiC & found that the ANN model can predict the Wear Factor and Wear Height Loss up to 95% accuracy

Y. Reda ET. al. (2011) Vol.9, No.1

They have Studies on Al6061-SiC and Al7075 - Al2O3 Metal Matrix Composites and suggested the optimum parameters [10]

S.W. Kim et. al. (2013)

They have studied on the hardness of Al7075 and concluded that the hardness of aged Al7075 alloy increases.

Rupa Dasgupta et.al.(2013)

Reported the improvement in the hardness, mechanical and sliding wear resistance properties attained as a result of heat treatment and forming composites by adding 15 wt.% of SiC.

T.J.A. Doel et.al.(2013)

Reported the improved tensile strength and lower ductility of the Al7075 reinforced with 5 and 13 μm SiC particles than that of unreinforced material.

K. Komai et.al.(2013) Reported the superior mechanical properties Al7075-SiCw composites.

Mohd Shadab Khan et.al.(2014)

They conducted an experiment on the effect of orientation and normal load on alloy of copper and zinc, *i.e*. Brass, and calculates weight loss due to wear. To do so, a multi-orientation pin-on-disc apparatus was designed and fabricated. Experiments were carried out under normal load 05-20 N, speed 2000 rpm. Results show that the with- increasing load weight loss increases at all angular positions. The loss in weight is maximum at zero degree (horizontal position) and minimum at ninety degree (vertical position) for a particular load.

Mani Deep. Nomula *et al (2015)*

They conducted an experimental investigation 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. 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".** 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.

Abrasive wear

Abrasive wear is such type of wear that can occur most frequently in machine elements of the industrial installations and it presents up-to 80% of overall volume of all wear occurred [4]. It can also originate from other wear types in which the free particles are being formed. These particles can becomes stiffer than the parent material. This happens under the influence of either air oxygen oxidation, or intensive plastic deformation. Abrasive wear rate can be reduced by:

- load reduction – due to which particles will not be imprinted so deeply into the material surface and also the riffles will be shallower due to less load applied

- hardening – with the same effect as it is in previous possibility [6]

Abrasive wear consists in separation of surface parts by undulation of another surface or particles that are situated between the friction areas. It mainly depends on load, slide-way length and hardness. The influence of number, size and shape of the particles is also very important [5]. Riffles belong to typical surface damages in abrasive wear.

In abrasive wear, it is necessary to distinguish between two critical phases, namely the process of imprinting the abradant into the surface where the imprint hardness and destruction process are the limiting factors. Interatomic bond force and the composition strength between structural components reciprocally at the borders of grains play a decisive role [4].

Studying wear is characterised by many different aspects and it is mostly influenced by the complexity of materials interaction on a functional surface as well as by operation conditions. In machine elements, there is a gradual wear in the result of friction. This is considered to be an undesirable effect in most cases. Therefore, we have to search for the possibilities to prevent it thus extending the technical life of a component. Surfacing presents one of these possibilities. Searching for the possibility of cutting the costs of changing the worn or damaged machine elements has led to the development of a wide range of surfacing technologies. Increasing the safety and extending the technical life of machines and devices are important requirements of modern technology. We can also add the requirement for simple maintenance, as well as simple and less time-consuming repairs in solving the random failures or operation accidents.

Wear is the (permanent) change of shape, size or features of material layers that usually form the surface of solids. It occurs as a result of friction and out of technologically required shaping or required change of material characteristics [4].

Slovak technical standard 01 5050 classifies wear as follows: adhesive, abrasive, erosive, fatigue, cavitation and vibration wear. Wear can have many forms that depend on the surface topography, contact conditions and environment.

Aluminium alloys (Al6061)

Improvement in the mechanical properties of wear resistance of Aluminium matrix composites can be achieved by adopting suitable treatment; (Das et al., 2008) have reported the abrasive wear behavior of as-cast and treated SiC reinforced Al-Si composites. They have reported that un-reinforced matrix material suffers from higher wear rates then that of Al-Si/SiC composites in both as-cast and heat treated conditions. Further, heat treated Al-Si/SiC composites exhibits better performance under all studied conditions. (Modi et al., 2001) have reported the three body abrasive wear behavior of Aluminium-Zinc/ Al2O3 composites exhibited excellent wear resistance under all the test conditions employed.[3]

A comparative study by (S.Das et al. 2007) on wear resistance of Zircon sand and Alumina reinforced AMC`s, revealed improved abrasive wear resistance with the decrease in particle size. Adhesive wear behavior of cast Al6061-TiO2 composites studied by (Ramesh et al., 2005) reported that, the wear resistance of composites is superior when compared to Al6061 matrix alloy. Further, it increases with increase in TiO2 particle content.S.Das (2004) reported the effect of load on abrasive wear rate of LM13-alloy and LM13 – SiC composites, results revealed that wear rates increases as the applied load increases for both as-cast alloy and its composites.[3]

An extensive review work on the dry sliding wear characteristics of composites based on aluminum alloys have been under taken by (Sannio et al., 1995) and abrasive wear behavior by (Deuis et al., 1996).In their studies and discussions, the effect of reinforcement volume fraction, reinforcement size, sliding distance, applied load, sliding speed, hardness of the counter face and properties of the reinforcement phase which influence the wear behavior of this group of composites are examined in detail.[3]

Reinforcement of hard particles in Al matrix protects the matrix alloy surface against destructive action of the abrasive during the abrasive wear behavior and rake angle of the abrasive affects the behavior (ZumGhar K.H., 1979, Hutchings.J.M, 1987, Kulik.T et al., 1989, Jain-main.T 1985, Axen N, 1992). (Wang et al., 1989) Reported that coarse abrasive particles and high volume fraction of reinforcement results in decreased resistance; this is attributed mainly due to fragmentation of reinforcement phase. On the other hand, it was mentioned with decrease in the abrasive particle size. [3]

Graphene aluminum interaction

The interaction of graphene with aluminum was done on an micro level by M. Barathi and A. Santhana kirshn kumar by preparing a novel aluminum oxy hydroxide [Al–O(OH)] modified graphene oxide by a chemical precipitation method so that Al3+ ions could interact effectively with the different functional groups of graphene oxide (GO). The prepared (GO–Al–O(OH) adsorbent was tested by them for the effective DE fluoridation of water. The Al3+ modified graphene oxide adsorbent was characterized using a FT-IR, FT-Raman, SEM-EDS, XRD and XPS studies. The thermodynamically feasible adsorption is supported by the pseudo second order kinetics and a high Langmuir maximum adsorption capacity (51.42 mg g−1) for the GO–Al–O(OH) adsorbent. Furthermore, we could treat 2.0 L of 5.0 mg L−1 fluoride ion solution to bring the level within the permissible limits and the regeneration of the adsorbent was done using ammonium hydroxide. [11]

COCLUSION

The present study is an overview of latest research works on Abrasive Wear. It will give you a brief information about the Abrasive Wear, its parameters and about the techniques used to optimize the parameters and wear resistance of aluminum alloys.

REFERENCES

[1] Mohd Shadab Khan[1], Zahir Hasan[2], Yaqoob Ali Ansari[1] [1]Department of Mechanical Engineering, Integral University, Lucknow, India [2]Jahagirabad Institute of Technology, Jahangirabad, India

[2] Silvia Revesová, MSc. Eng., Pavel Blaškovitš, Professor, PhD. - Department of Welding, Institute of Production Technologies, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology Bratislava, J. Bottu 25, 917 24 Trnava, Slovak Republic

[3] D.Ramesh[1]*, R.P.Swamy[2] & T.K.Chandrashekar[3] [1]Research scholar, Sri Siddhartha Institute of Technology, Tumkur-572105, India

[4] Dostupné-na-internete:http://www.stifner.sk/skola/doc/afm/texty_AFM_2004.doc [cit. 2009-11-12]

[5] Ahmad S.N., Hashim J. and Ghazali M.T., (2005), "The effect of porosity on MechanicalProperties of Cast Discontinuous Reinforced Metal-Matrix composites", Journal of composite Materials, Vol.39, No 5, (pp 451-466).

[6] Jozef Balla, Professor, PhD. – Slovak University of Agriculture in Nitra

Pavel Kovačócy, Assoc. Professor, PhD. - Department of Welding , Institute of Production Technologies, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology Bratislava

[7] Aigbodin V.S. and Hassan S.B., (2007) "Effects of Silicon carbide reinforcement on Microstructure and properties of cast Al – Si – Fe / SiC particulate composites", Journal of material sciences and Engineering A, 447, (pp 355-360).

[8] Aigbodion V.S., Agunsoye J.O., Kalu V., Asuke F., Ola S., (2010) "Microstructure and Mechanical properties of ceramic composites", JMMCE, Vol.9, No.6, (pp527-538).Axen N, ZumGhar K.H. , Wear, 1992, 157,189.

[9] Banerji A., Prasad S.V., Surappa M.K. and Rohatgi P.K., (1982) "Abrasive wear of cast aluminium alloy-Zircon particle composites", Wear, 82, (pp 141-151).

[10] Bermudeza M.D., Martinez-Niccolas G., Carrion F.J, Martin-Mateo I., Rodriguez J.A., Herrera E.J., (2001) "Dry and lubricated wear resistance of mechanically-alloyed aluminium-base sintered composites", Wear, 248, (pp 178-186).

[11] M. Barathi,a A. Santhana Krishna Kumar,a Chinta Uday Kumara and N. Rajesh*a