



*Research Paper*

# REDUCTION OF SLIDING WEAR OF ALLOYS BY USING OXIDES

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Formation of oxide has a significant effect on friction and wear of high temperature alloys during reciprocating sliding in air. A smooth wear protective oxide layer is developed on the load bearing surface in these alloys above a certain temperature of 150-250 °C. However at lower temperature the metal-metal contact is reduced due to the oxide debris which in turn reduces the friction and wear rate. Due to transient oxidation of metal surface, removal of such oxide and then reoxidation of exposed metal, the oxide debris is formed. Oxide debris develops a wear protective layer between the sliding surfaces. As limited asperity growth occurs before the asperity becomes sufficiently large hence the friction during sliding is less. This research paper covers the relation between the sliding wear of alloys and the effect of oxides on it.

Keywords: Oxidative wear, Friction, Wear-protective oxides

## INTRODUCTION

Due to formation of oxides on metal surfaces wear and friction is reduced. Therefore such oxides play a significant role reducing the friction and wear. For instance their application can be in gas turbine engines. For many alloys there is a well-defined temperature above which the wear oxide protective layers are effective for reducing the friction and wear. These layers can be deformed plastically during sliding and they also produce a very smooth surface. The examples include NiO and Cr<sub>2</sub>O<sub>3</sub>. In the temperature range of 560-670° iron base alloys have more application

than cobalt and nickel base alloys. In this paper emphasis has been laid on the role of these oxides in the wear process.

## EXPERIMENTAL METHODS

The wear apparatus consists of a flat disc which slides in the horizontal motion against the spherical specimen under a load of 1.2 kg at a speed of 350 revolutions per minute. The specimens were brought in contact and they were brought to approximately same temperature in about 10 minutes. When there was a thermal equilibrium between them the sliding was started. The coefficients of friction

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were recorded continuously during sliding. The coefficient of friction and wear rates were relatively similar for the given alloys. Wear rates of these oxides comes less than  $3 \times 10^{-7}$  mm<sup>3</sup>/s. The presence of oxide on the load bearing regions is also reduced. With respect to time and temperature the wear rate decreases. The coefficient of friction also changes with respect to time. For the production of oxides there are two types of processes. In the first one transient oxidation occurs in the apparent areas of sliding contact and then removal of that oxide occurs. In the second mechanism metal debris formation occurs in the early stages of sliding due to which fresh areas of metals are exposed to oxidation. Due to oxidation of debris a considerable quantity of oxides are produced. Above transition temperature compacted debris is produced between the sliding surfaces due to which the wear protective oxides are formed. The oxidation mechanism is not significant at lower temperature, i.e., the oxidation is less rapid. The main effect of it is that the comminution of metal debris occurs before any significant oxides are produced. Moreover the variety of layers formed can also be called Inorganic materials.

First of all we should consider the effect that the temperature has on the wear protective oxide layer particularly at temperatures above 250 °C. Oxide debris produced at lower temperature reduces the metal-metal contact. The wear oxide protective layer has not been fully developed. With development of compact and adherent wear protective oxide layer the sliding time always decreases with increase in temperature. One of the main reasons can be that at higher temperatures the oxidation

rates are faster. Below transition temperature no oxide layers are developed. The experimental evidence has also concluded that transition temperature is not that temperature below which no wear protective oxide layers are formed but it can be defined as the temperature below which the wear protective oxide layer is unstable.

Development of wear protective oxide surface takes place due to steady oxide state which takes place during normal sliding. This may not take place at room temperature as at room temperature the layer may be broken down and it may happen due to sliding action. Thus we can say that the formation of wear protective oxide layer may not require an ambient/ room temperature but we may get an additional benefit by increasing the temperature. Low ambient temperature always causes breaking of oxide during sliding.

The mechanical properties of oxide should change with temperature due to which the coefficient of friction will increase and thereby the ambient temperature will decrease during sliding which takes place between the wear protective oxide layers. On decreasing the temperature shearing forces at sliding interface will increase causing the breaking of wear protective oxide layer. Oxides are more adherent at higher temperature and less adherent at lower temperatures during sliding. If Ni-Cr alloys are taken then the nickel oxide scale on nickel to form wear protective oxide layer at room temperature during sliding. Due to friction and rising of surface flash temperature there is an increase in the vicinity of contacting oxide asperities which also causes the development of wear protective oxide layers. However experimentally we can

say that there is a rise in mean surface flash temperature during sliding.

The coefficient of friction is relatively insensitive to a small rise in ambient temperature. A wear protective layer is formed at low speed and hence it does not depend on the temperature.

The wear protected oxide layer consists of compacted debris. The surface oxide is postulated on this compacted debris which produces a smooth and shiny appearance. Generally the oxides are regarded as brittle due to the properties which they possess in the normal tensile strength. Minute cracks or flaws develop in the brittle material under normal tensile condition. These minute cracks act as stress enhancer and cause increase in the effective tensile strength. Due to the increase in effective tensile strength a large hydrostatic pressure is produced which in turn promotes the healing of cracks or flaws.

## RESULTS AND DISCUSSION

During sliding it is observed that plastic deformation of oxide and the development of wear protective oxide layer occur when the oxide-oxide asperity contacts are sufficiently small for the hydrostatic pressure developed which causes effective prevention of crack propagation. The hydrostatic pressure has a significant effect on the surface deformation while the frictional behavior depends on the plastic properties. Smooth and shiny surface is formed due to the plastic deformation of oxide asperities. Then the formation of adhesive contacts occurs between the oxide asperities. This can be regarded as one of the main reasons for low coefficient of friction and wear rate. The

increase in size of asperity junction occurs due to junction growth which in turn takes place during sliding. The main effect of it can involve reduction in contact pressure which in turn can lead to decrease in hydrostatic pressure thereby preventing the brittle failure. However it is very difficult to find the particular point at which junction growth terminates. Oxide and oxide coated metal debris is formed during sliding and the mechanism is known as metal debris mechanism. If adhesive and cohesive forces are greater than the frictional forces then the substrate alloy remains in a wear track. The adhesive and cohesive forces are responsible for binding the debris together while the frictional forces tend to remove the debris from the metal surface. Cracking and fragmentation may occur at the junctions which will cause the fragmentation of debris due to which smaller debris particles are formed. Compaction takes place due to the generation of smaller debris particles. Plastic flow of oxide occurs without cracking due to reduction in compacted debris. With respect to the plastic deformation, the thickness of wear protective oxide is consistent. This wear protective oxide layer is formed from many individual oxide particles. The surface oxide also originates from many individual oxide particles. Thus we can say that the thickness of agglomerated oxide surface layer is the depth to which the plastic flow has occurred. Since the number of contacting junctions for oxide-oxide sliding is high the load supported by any one of junctions is quite small. Thus the rise in surface and flash temperature is also expected to be much low.

Surface rise in metal-metal contact =  
Temperature rise in oxide-oxide contacts.

Oxide layer is a contact of several species and on the degree to which it has been compacted, its ability to absorb and conduct heat depends. It is possible to speculate about the material properties if a wear protective oxide is deformed plastically and its tribological characteristics are known. It is not possible to control the nature of wear oxides formed but we can adjust the oxidation conditions which will favor the growth of relatively more ductile oxides. The formation of a wear-protective surface layer for any particular oxide occurs more at higher ambient temperature. Moreover effective lubricants are formed when the surface coatings are mixtures formed from relatively soft oxide like PbO, BaO and CaO. These effective lubricants exhibit low friction and wear over a wide range of temperature. By adding oxides to lubricating greases wear rate is directly proportional to the oxide hardness. The work of Gupta (1974) suggests that two-phase ceramics should be tougher and more crack-resistant than single-phase systems, the presence of particles of a harder phase causing a significant increase in the energy required for crack growth. Thus, if a wear-protective oxide is to be both tough (to resist surface and subsurface cracking) and yet amenable to plastic flow, a two-phase system may be more effective than a single-phase system. An effective oxide layer is formed due to a low coefficient of friction as the tensile stress of the asperity junctions' increase with increasing the friction force. Brittle fracture and an increased wear rate would be expected if the coefficient of friction increased appreciably. It has been observed that the coefficient of friction for sliding oxide surfaces increases with decrease in temperature (Stott *et al.*, xxxx).

Since the friction is an intrinsic, not an extrinsic variable therefore coefficient of friction should be low for a wear protective oxide layer. Oxide debris should be relatively compact for rapid formation of wear protective oxide layer. This may lead to flat and smooth oxide surface and layer. The contacting oxide asperity junctions should fail fairly easily during sliding for friction and wear between such surfaces to remain low. High friction and severe wear results when the surfaces are very plastic and form very good adhesive bonds at the contacting asperities. Therefore the most effective oxides have minimum degree of plasticity.

In other words, Oxide that deforms sufficiently to develop the smooth surface forms the most effective wear protected oxide layer as to maintain the low friction and wear the resulting oxide-oxide contacts break.

## CONCLUSION

Smooth and adherent wear-protective oxide layers, resulting in relatively low coefficients of friction and wear rates. Due to transient oxidation and removal of oxides wear protective oxide layers are formed. Since the surface is relatively small, oxide debris compacts to form a layer. Moreover due to large hydrostatic pressure healing of cracks in oxide particles takes place during sliding and the junction growth of oxide asperities is relatively very small. 🌀

## ACKNOWLEDGMENT

I would also like to dedicate this research work to my father late R S Mishra and mother K L Mishra.

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