Abrasive Wear and Fatigue Wear

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Abstract. In the era of modern industrial civilization, with science and technology being developed rapidly, friction and wear become scientists' dedicated areas. The paper aims to reveal the mechanism of abrasive wear and fatigue wear, discussing the calculation formula, various factors and the way they affect with.

Introduction

It is well known that friction is unavoidable in the industry, we can only reduce it unceasingly, but cannot eliminate it. The inevitable result of the friction is wear, which is the constant damages' process where the objects being contact mutually in the process of relative motion on the surface of the material. Wear is a very complicated physical process, so the classification method that caused the wear is various. Abrasive wear and fatigue wear belong to the wear mechanism. The generation of abrasive wear is the phenomenon which is in the process of friction, with the material be separated out from its surface as a result of the hard particles or the hard bump, as shown in Fig.1 . Fatigue wear is the process where the surface will cause crack and gradually being expanded, finally make the material with crack being cracked and peeled off under the condition that the cyclic stress produced in the contact region exceeds the fatigue strength of materials when the two contacts being relatively rolled or sliding, as shown in Fig.2 .

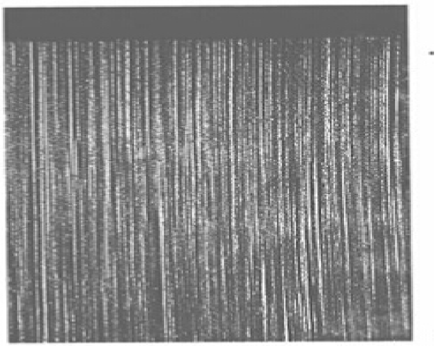

Fig.1

Fig.2

Abrasive wear: The basic principle of abrasive wear needs to be checked by carrying on the mathematical modeling, which was put forward by Archard[1~5] and Holm[1][6] originally and was used for the formula inferred from the wear mechanism. However, we finally found that there were also other similar expressions for other wear modes. In the process of derivation, we will introduce the concept of real contact area.

$$\frac{v}{L} = \frac{p}{H} k$$

Among which, v refers to the volume of being erased; p refers to the load being applied; L refers to the sliding distance, H refers to the hardness of materials; and k refers to the wear coefficient.

By the above formula, we can see that the abrasive wear rate is proportional to the load under certain abrasive conditions and the wear rate has nothing to do with speed, but it is directly proportional to the hardness of the material. But in actual cases, the wear mechanism is often more complicated than the above formula. Model itself may exist many deficiencies, such as the uncertainty of k .

Next, we shall discuss something about the mechanism of volume change in the wear process. There are two kinds of volume changes' mechanism. One is caused by plastic deformation. The other is a fracture caused by the removal process. First, here is a brief introduction about the removal process of plastic deformation, in which shall mainly occur a process of furrows and micro cutting.The occurrence of the furrows is mainly due to the fact that the material is uplifted towards the two sides because of being extruded by the abraser.However, this process does not cause deformation directly, and it will produce the material loss after many times of such occurrence. For the micro cutting, it is one of the most common wear in the production and experiments, especially in the fixed abrasive wear and rock-style wear. Then, let's talk about the removal process caused by fracture, which often happens in the process of brittle materials, so here we shall discuss the general situation of brittle materials.Here are several sketches of fracture formation, as shown in Fig.3

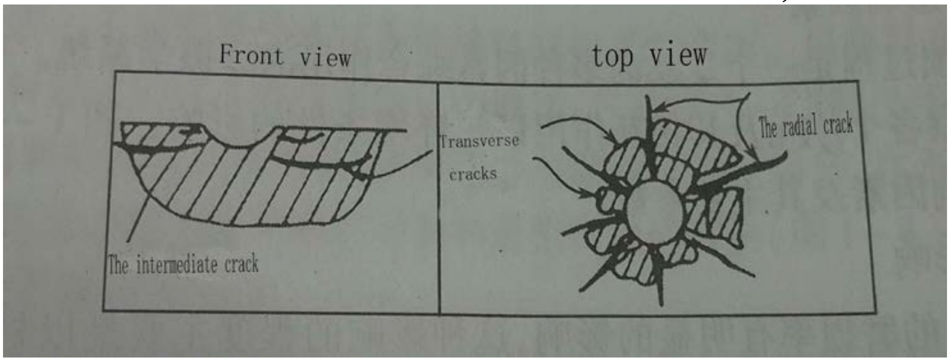

Fig.3

Of course, the two mechanisms can also be transformed with each other. In the process of abrasive, both the plastic material and the brittle material, may occur plastic deformation and fracture mechanism at the same time, which is just because of the different environmental conditions and material properties of wear.A kind of wear mechanism will dominate, which will often be transformed from one to another with the changes of the condition [7], as shown in Fig.4

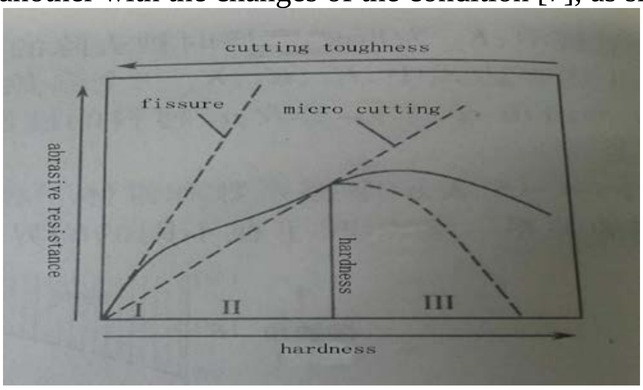

Fig.4

The factors affecting the abrasive wear are varied, from the above mechanism, we can know that it's related with the hardness of materials, the size of the applied load, the size of the abrasive, and the mechanical properties of material, then I will introduce them one by one. **Material hardness**, which shall be mainly marked by the ratio between the material hardness Hm and abrasive hardness Ha. We found that when Hm/Ha > 0.8, anti-wear ability was stronger, otherwise it would be smaller. Generally, the harder the material is the stronger ability it has to resist abrasion. **Abrasive size**, for which there is a critical dimension, where when it's more than this size, wear of materials will be sharply increased. However, different materials have critical dimensions, so the different materials are also influential to the critical size of abrasive. **The applied load**: when the applied load is proportional to the wear rate, there is also a critical pressure, the wear rate will be flat once being more than the critical pressure. **The performance of the mechanical properties of materials**: The performances of the materials include elastic modulus, strength, stiffness, plasticity, hardness, among which the elastic model is the most common. Based on a lot of experiments, the smaller of the elastic modulus, the smaller of the wear and tear, which is because that the improvement of the joint situation between the friction makes the load of local unit decrease; at the same time, when there's abrasive between surfaces, the elastic deformation of surface may allow the abrasive to across, thus can reduce wear [8].

Fatigue wear : Fatigue wear, which basically appears on the surface of machine parts in the rolling contact, such as the rolling bearing, gear, and wheel, etc. It's such a phenomenon of surface fatigue spalling caused by the long-term alternating contact stress. Fatigue failure can be divided into three types, pitting, shallow flaking, and deep spalling. Because pitting is more widespread in practice, the scientists put forward several theories to the pitting.

Oil wedge theory, which was first put forward after the theory of forming pitting from fatigue crack propagation by S.Way[9]. Formed on the surface of micro-cracks in the material,due to the rolling and sliding effect of the absorption of roller skating ,making the cracks get bigger,which makes the crack tip forming oil wedge. When lubricating oil produces a powerful liquid shock because of the contact pressure, at the same time, the contact area plugs the crack mouth, thus may make the pressure of the high-pressure oil gradually increase, so the crack becomes bigger and extended, and the small pieces of metal between crack and surface may be bent as a cantilever beam, which will break when the root strength is insufficient and turn into a pit on the surface. This is a pitting corrosion ,as shown in Fig.5.

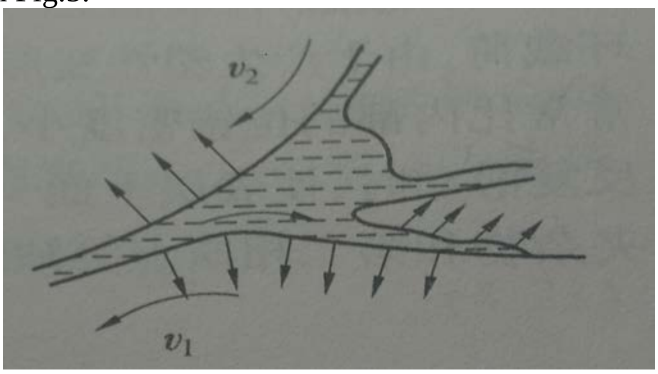

Fig.5

Maximum shear stress theory. Phakadix and Ramanson jointly think that pitting mainly occur in the contact surface under the maximum shear stress [10].They think that the pitting mainly occur in the contact surface and use the theory of dislocation to explain the occurrence of pitting corrosion of existence. In the process of rolling, with the repeated changes of the shear stress,dislocation movement may go forward and back,the resulting cavity ,forming blank hollow and finally cracks.From which we can achieve a judgment that:

$$T > \frac{2}{\beta}\left[\frac{rE}{D}\right]^{\frac{1}{2}}$$

Among which T refers to the critical shear stress; r refers to the plastic deformation of surface power+crack growth; E refers to the elasticity mode; D refers to the average grain diameter; β refers to the constant, which depends on the degree of positive stress three tropism.

After crack, under the effect of cyclic loading, the crack will be expanded, finally bend to the surface and form the pitting.

Factors that affect the fatigue wear: material hardness, the influence of lubrication, surface roughness, the influence of heat treatment of materials, and the influence of the environment. **Material hardness**: In the process of the above mechanism, what we stated is the condition of pitting corrosion, so the higher the hardness of the material, the more difficult for the crack to be formed, and the longer of the lifespan of fatigue wear. **The influence of lubrication**: we generally think that the lubricant with high viscosity will improve its lifespan because it's not easy to enter the crack, while the viscosity of lubricating oil is related to its pressure and temperature. The higher temperature,the smaller pressure and the smaller of the viscosity are equal to the more beneficial to the generation of cracks. **The roughness of the surface**: in actual production, it's impossible to be smooth for the surface of the parts, and there will always be a certain roughness. We think that the higher the roughness, the more serious the fatigue wear, so we can reduce the surface roughness through the process of fine grinding, polishing and so on. At the same time, carry on mechanical reinforcement method for the surface to obtain a good effect of composite strengthening, which can further reduce the fatigue wear. **The influence of heat treatment of materials**: carrying on the heat treatment to parts may produce a great influence on the fatigue wear, for different parts need different heat treatments, for example, for the rolling bearing, we need quenching and tempering at low temperature. For the 40CrNiMoA, we need normalization.For the steel, increasing the rest austenite content can increase the contact area, which may make the decline of the contact stress, thus may hinder the emergence and development of fatigue crack. **The influence of the environment**: in moist air, it will accelerate the expansion of the crack due to the moisture in the air going into the crack, or in the case of high temperature, the decomposition of lubricating oil and the accumulation of acidity material may reduce the fatigue life, thus the wear may be more intense.

Summary

No matter it's friction wear or fatigue wear, these are all inevitable. There is only one solution, which is to constantly reduce wear and tear according to the affecting factors. In the process of understanding wear and tear, first to carry on the mathematical modeling to the wear. Afterwards, infer the mathematical formulas according to the modeling situation. Finally,handle the really influencing factors according to the formula and the actual production process.

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