FACTORs DETERMINING THE PROBABILITY OF SEIZURE AND OXIDATION OF METALS IN FRICTION

B. I. Kostetskii and V. N. Lozovskii


Based on modern concepts of structural imperfections in crystalline solids, an analysis of the seizing and oxidation of metals was carried out. It was shown that, viewed from this standpoint, both seizing and intense oxidation of metals in friction are based on the activation of contacting surfaces, the extent of which is determined by the degree of interaction between these surfaces. A change-over from one of these processes to the other (seizing to oxidation or vice versa) may take place as a result of only quantitative changes in one of the parameters characterizing the working conditions of a friction pair.

The seizing of metals has been studied by many investigators at home and abroad, [1-6]. This problem is attracting a good deal of attention not only because some means must be developed to eliminate seizing of moving machine parts, but also in connection with attempts to utilize seizing in certain technological processes (e.g., cold welding). Most of the research work in this field consists of experimental determination of the effect of various factors on the onset of seizing of metals under specified conditions. Only a few theoretical studies of this problem have been carried out [7, 8], and their conclusions are contradictory.

Apart from the sliding speed and temperature (which is partly determined by the sliding speed), the following are the factors that play an important part in seizing and oxidation phenomena: a) activity of the working medium (liquid or gaseous) in the friction zone; b) normal pressure and, correspondingly, the magnitude of plastic deformation of metal surface layers; c) character of the applied loads (static or dynamic); d) presence of various films or coatings on metal surfaces.

Of particular importance is the application of antioxidants and media that tend to reduce oxides of one or both of the friction-pair components.

The ability of a medium to prevent interaction between freshly formed (clean) metal surfaces depends on its physicochemical activity with respect to the metals in friction and on its ability to penetrate to the actual contact zones. The higher the adsorptive or the oxidizing power of a medium and the more readily it finds its way into gaps formed by rubbing surfaces, the more intensely it interacts with metals and the less likely is the establishment of a direct contact between clean metal surfaces and their subsequent seizure.

This is illustrated by the operation of parts of bolted-hinged joints in aircraft landing gear, rubbing surfaces of which may (depending on the lubrication conditions) become damaged as a result of seizing or intense oxidation. Thus, if these joints are not regularly greased, the most highly loaded regions of bolt and bushing working surfaces seize and become heavily corroded (Figs. 1 and 2).

Careful and systematic greasing of joints of this kind prevents the seizure and corrosion of the working part surfaces.

It is evident that seizing and intense oxidation of rubbing surfaces take place only when a lubricant is incapable of separating them and preventing the ingress of atmospheric moisture to the actual contact zones. No evidence of seizing or oxidation is found on the surfaces of universal joint components protected by adsorbed lubricant films, while the
interaction of metals with the products of decomposition of the lubricant in heavily loaded regions leads to formation of secondary protective structures in the metal surface layers.

Thus, if the surface of a metal part in a state of increased friction-induced activity reacts with the material of the mating part, with air, or with a lubricant, the result is, respectively, seizure of the metal surfaces and their intense oxidation or formation of wear-resistant secondary structures [9].

It should be pointed out that the corrosive attack in joints discussed above is confined to the working (rubbing) part surfaces; no corrosion occurs in other places more accessible to atmospheric moisture. This proves that metal surfaces in friction are characterized by increased activity which promotes not only the seizure of metals but also their intense oxidation.

Another factor that determines the probability of seizure of metals is the magnitude of normal pressure in friction and the degree of the resulting plastic deformation of metal surface layers. The higher the degree of plastic deformation, the larger is the actual contact surface area and the more intense is the destruction of surface oxide and adsorbed films. The re-formation of protective surface films in these circumstances is inhibited because the actual contact zones are not readily accessible to the gaseous or liquid working media; as a result, direct interaction between freshly exposed metal surfaces becomes more probable. This is exemplified by the character of wear of the teeth of reductor gears.

![Fig. 3. Distribution of oxidation and seizing zones on the working surface of a gear tooth.](image)

The nonuniform character of contact between the teeth is reflected in the fact that regions of wear of different kinds alternate on their working surfaces (Figs. 3 and 4). Some regions show evidence of metal pick-up and plastic deformation due to seizing, while other surface regions are coated with oxide films without any noticeable mechanical damage, all traces of machining having practically disappeared as a result of wear.

The variation in the character of wear of the gear tooth surface is attributable to the variation in the specific pressure due to surface undulations. In regions of high specific pressure, the metal surface layers undergo plastic deformation sufficient to produce seizing. No seizing takes place in regions of lower pressure and they become oxidized; as a result of gradual destruction and removal of thin oxide films, the wear in these regions takes place without any noticeable evidence of mechanical damage.

Thus, seizure takes place in regions where the specific loads are sufficiently high to produce plastic deformation of metal surface layers, ensuring intense destruction of adsorbed and oxide films and establishing a direct contact between the mating surfaces.

The behavior of metals in friction is substantially affected by their ability to diffuse into each other. Consequently, the formation of passive films or various coatings acting as diffusion barriers is an effective means of preventing the seizure of machine parts. For instance, thick anodized coatings produce a sharp increase in the resistance of aluminum alloys to wear and seizure [10].

Studies of the seizure of rubbing metal surfaces in media which tend to reduce the oxides of one or both friction-pair components (Fig. 5a) are of a particular interest. And so, in the case of copper and copper alloys working under friction conditions in glycerine, metallic copper produced by the reduction of oxide films was found on the friction surfaces [11]. As a result, the seizure and metal transfer in the case of steel/copper-alloy friction pairs working in