STRUCTURAL CHANGES ASSOCIATED WITH FRETTING CORROSION

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The characteristics of dislocation structures formed during fretting corrosion were studied and the conditions of their formation were analyzed. The possibility of fatigue phenomena playing a leading part in fretting corrosion was postulated. The energetic-structural conditions necessary for progressive damage by fretting corrosion were discussed.

When metal surfaces in contact with each other vibrate or are in reciprocating motion, they are subject to damage due to fretting corrosion. This phenomenon is distinguished from other kinds of wear by a higher intensity of the process of metal destruction which is characterized by the following specific features: 1) in spite of the low velocity of the relative motion of the surfaces involved, fretting corrosion of metals is accompanied by the formation of large quantities of the products of wear in the form of oxides (with a negligible nitride content) [1-3]; 2) a large proportion of the products of wear is not removed from the contact zone; 3) there is no correlation between fretting corrosion and the susceptibility of a given metal to corrosion or oxidation [2, 3]; moreover, measures that are effective in preventing corrosion are ineffective as means of combating fretting corrosion [2]; 4) hardness and strength of metals cannot be used as measures of their resistance to wear due to fretting corrosion [4, 5].

The existing oxidation-mechanical theories of fretting corrosion [6-10] do not explain all the physicochemical phenomena involved in this process. Most of these theories differ in their phenomenological approach to the problem of fretting corrosion and they establish which factor predominates in the process of destruction: the mechanical factor (wear) [6, 7] or the chemical factor (oxidation) [8, 9].

In a large majority of investigations of fretting corrosion, insufficient attention is paid to the structural damage of metal surface layers which is accompanied by substantial changes in the fine crystal structure. It is very likely that structural changes, to a large extent, predetermine the nature of the products of fretting corrosion.

Using 1Cr18Ni9Ti and transmission electron microscopy, we studied certain specific characteristics of the formation of dislocation structures during fretting corrosion of flat specimen surfaces in plane contact. The displacement amplitude was 30-50 μ and the frequency was 50 cps. We studied damaged regions of plates 0.1 mm thick. The examination of dislocation structures in successive surface layers of specimens which, after a previous annealing treatment, were subjected to fretting corrosion, made it possible to distinguish between three different zones: zones adjacent to the actual contact zone (Fig. 1a, b), zones of primary influence (Fig. 1, c-f), and zones of secondary influence (Fig. 1g).

The contact zones are characterized by exceptionally high dislocation densities; in this case it is difficult to distinguish between separate dislocations and to recognize the initial grain boundaries (Fig. 1a). These zones show some evidence of a loss of strength produced, possibly, by the intersection of orthogonal slip planes [11] (Fig. 1b).
In the zones of primary influence (Fig. 1, c-f) one observes elements of ordered defective structure associated with the presence of microslip lines [12] which represent a set of straight packets intersecting grains in one or in several directions and forming relatively large rhomboid cells (Fig. 1c, d). No such multiple slip is observed, for instance, in uniaxial tension, when ordinary dislocation networks are formed (becoming more complex with increasing degree of deformation).

Zones of primary influence do not directly participate in the acts of contact, but are nevertheless acted on by considerable stresses. It is very likely that the characteristic structure of these zones is a result of the action of alternating tangential stresses which, in favorably oriented grains, produce characteristic multiple slip (Fig. 1c, d), arrays of stacking faults (Fig. 1e), and twins (Fig. 1f). Zones of primary influence can often be observed in regions adjacent to the actual point of contact (Fig. 1c).

No transcrystalline multiple slip is observed in zones of secondary influence (Fig. 1f) farther removed from the actual contact zones; dislocation structures observed in these zones are characteristic of moderate degrees of deformation. Some of the dislocations remain in their slip planes and form pile-ups at the Lomer-Cottrell barriers. There is some evidence of a tendency to form dislocation networks as a result of the intersection of jogs on dislocations and as a result of the interaction of dislocations with point defects.

It should be noted that zones with sufficiently high dislocation densities are produced in the very early stages of fretting corrosion (after a few tens of cycles). Such an active reaction may be associated with singularities of the state of free surfaces and with the special part played by the subsurface sources of dislocations under conditions of alternating contact. On the one hand, it must be borne in mind that the surface grains in polycrystalline materials are more favorably situated to deform by slip than interior grains, since they are not completely constrained by the adjacent grains. On the other hand, the critical stress for a subsurface source of dislocations (which have only one anchorage point) is considerably lower than that for internal sources with two anchorage points [13-16].

Consequently, the high dislocation density observed in the surface layers of specimens subjected to fretting corrosion may be due to a high activity of subsurface sources of dislocations; the generation of dislocations by subsurface sources therefore becomes the factor that controls the critical shear stress.

There is also a possibility of the influence of certain factors inhibiting the emergence of a large proportion of dislocations on the crystal surface. A free surface provides an exit for the field of a dislocation that has reached this surface because the dislocation field is not counterbalanced by the material on the other side of the surface; as a result, a force driving the dislocation to the surface is produced (mirror image force [17]). However, the emergence of a dislocation on the surface leads to the appearance of a step;