UNIVERSITY OF NIŠ
The scientific journal **FACTA UNIVERSITATIS**
Series: **Mechanical Engineering** Vol.1, N° 4, 1997 pp. 429 - 432
Editor of series: Nenad Radojković
Address: Univerzitetski trg 2, 18000 Niš, YU,
Tel: (018) 547-095, Fax: (018)-24-488

STUDIES ON FORMATION AND DESTRUCTION OF SURFACE LAYERS UNDER SEVERE FRICTION

UDK: 669.017

A.V. Kolubaev, S.Yu. Tarasov

Institute for Strength Physics & Materials Sciences, Tomsk, Russia

Abstract. *The present work has been carried out to study the evolution of the initial microstructure of metals under severe friction conditions with an eye to the influence of microstructural distinctions on the formation and destruction of surface layers in the process. The materials in rubbing may be characterized by its bearing capability. In an effort to gain better understanding the preference has been given to high strength austenitic alloy as having great scientific and practical importance*

Key words: *Friction, Surface Layer, Friction coefficient, Wear*

1. INTRODUCTION

It has been shown that friction results in the transformation of surface metal layers involving the fragmentation of structure by shear or rotational modes of deformation. The high resolution microscopy techniques allowed to establish that multi-layer structure is formed having different grades of deformation, depth and structural dispersion that are varied with the type of material and test conditions. Various heat treatments were used to disclose the influence of phase composition on the mechanism for formation of surface layer. High strength alloy of composition (by weight): 34.1%Ni, 12.5%Cr, 2.5%Ti, 1%Al, 1%Mn, <0.05%C and Fe was employed in the structurally different conditions, namely - quenched and aged ones. Water quenched state of alloy had the structure of solid γ-solution and 870^{o}C aged one was differed only by having discontinuous precipitated microvolumes of γ-phase. Mechanism of discontinuous precipitation together with structures obtained are well studied in [1] and are not addressed here. Friction tests of alloy specimen in rubbing with medium carbon steel counterpart were carried out using SMT-1, UMT-1 setups under dry friction conditions. Sliding velocity was varied in 0-2m/s range. Contact pressure was within 0 - 20MPa. The structures were observed by optical and electron microscopy to reveal the grain size of 10-15x10^{-6}m in quenched alloy

Received September 30, 1996

and microregions of discontinuous precipitation in aged ones. Specimens intended for structural investigations were prepared by electropolishing technique. In addition, TEM was conducted using wear particles without any extra treating. Structures that were observed in both cases were similar in terms of the fragments sires and misorientations. This evidenced that no distortions have been introduced during the preparation.

2. EXPERIMENTAL RESULTS

As result of friction, scores and "stick-slip" motion were the characteristics for quenched specimens' friction. Wear particles were more than $1x10^{-6}$m in size. Regular structures in the form of a set of discontinuities were found at the surface of aged specimen after friction instead of scores. These structures had a tendency to be aligned transversely with the direction of sliding. Average size of a wear particle not exceeded $0.5x10^{-6}$m. Cross section views of specimens revealed the depth and microstructure of deformed subsurface layers. These layers exhibited a specific inner morphology reminiscent of liquid flowing, their depth was within $20\text{-}30x10^{-6}$m and a sharp interface separated them from the base metal. As was established this layered structures were formed under condition of adhesive wear.

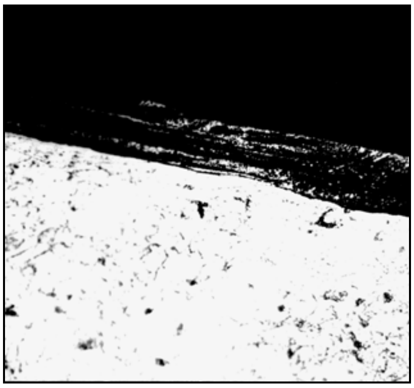

Figure 1. Contact surface layer

Fig.1 shows the morphological distinctions in the character of flow wear, probably stemming from the initial structure of specimens. The turbulent character of this flow corresponded to the aged specimen and did not fall into the scheme for formation of friction layers proposed in [1], when layers were formed being parallel to the surface of sliding. TEM observations demonstrated that, in either case, these layers structurally consisted of fine fragments of base metal preferably oriented with {110} parallel to the plane of sliding. This orientation plausibly offers better accommodation for deformation. Fragments of $0.01\text{-}0.1x10^{-6}$m in size are presented by their own reflections and are found to be several degrees disoriented relative to each other. As a matter of fact the initial grains were transformed into ultrafine subgrain polycrystals. The same size of fragments and values of disorientation were observed on wear particles. These findings offer a clearer view of deformation and enable us to conclude that the fine-crystalline layer formed under severe friction exemplifies the final stage of deformation. The increase in the load and sliding speed raises the temperature and this has a crucial effect on the structure of deformed layer and, consequently, on friction. A superplastic flow is the case under these circumstances in quenched specimen. The structure of base metal below the fragmented layer was found to be typical for the stage of plastic flow that may be characterized by only fluent misorientations. The total depth of plastically deformed zone is approximately $0.1x10^{-3}$m. As was shown there also were corresponding distinctions in friction and structure of surface friction layers. Friction - normal force dependencies for both states of the material evidenced that the precipitated microvolumes are found to provide better bearing capability of aged specimen over non-hardened one - Fig.2. It might be well to point out that adhesion in dry friction is observed at 1MPa for aged specimen and at 0.5MPa in case of quenched one. These values of contact pressure are correlated with peak values in wear curves. As friction coefficient increased with the load, the adhesion is observed on the surface of the specimens. It is notable that despite friction coefficient increase wear rate tended to fall to a minimum and increased back only at much higher loads. The reason is that the wear mechanism is changed. Wear is by microcutting and microscratching under normal friction when structure of surface layers is similar to initial one. Wear rate, thus increased with the load. As the friction suffers the transition to the extreme adhesive regime, the microstructure undergoes intense deformation. Surface layers flow under the action of the friction force and this results in the reduction of wear within the limited range of loading. Under these circumstances the cohesion is much stronger than adhesion and fragmented layers reveal the lubricating effect. Further increase in the load should result in the intensification of adhesive wear. It should be noted that similar behavior is the case with low shear strength materials. The reduction in wear is not found to be the characteristic of high shear modulus materials. The reason behind this is that high contact pressures that are needed to form friction layers are accompanied by the intensification of adhesive wear. Fig.3 illustrates the sliding velocity dependencies of friction coefficient and wear. There are also observed the minimums in wear curve that may be correlated with the formation of extremely deformed subsurface layer.

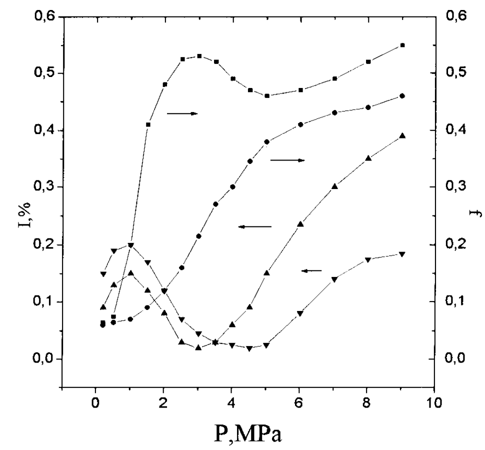

Figure 2. Friction and wear coefficients dependence on the contact pressure

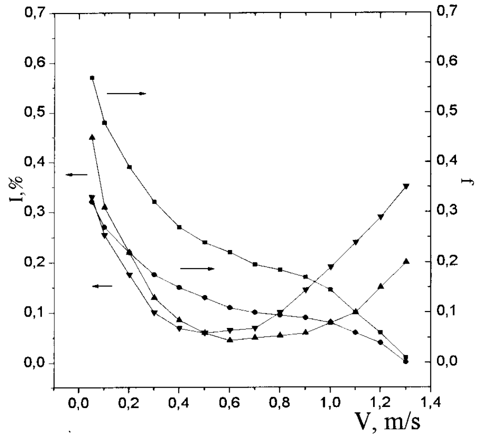

Figure 3. Friction and wear coefficients dependence on the velocity

3 CONCLUSION

The formation of specific surface layers is established to be the result of severe character of friction. It's microstructure is shown to be independent of initial one and may be characterized by high dispersion and misorientations. Anomalous behavior of friction coefficient and wear may be explained in line with this phenomenon.

REFERENCES

1. L.M. Rybakova, L.I. Kuksenova. Struktura i iznosostoikost metalla. Moskva: Mashinostroenie, 1982.

IZUČAVANJA FORMIRANJA I RAZARANJA POVRŠINSKIH SLOJEVA PRI INTENZIVNOJ FRIKCIJI

A.V. Kolubaev, S.Yu. Tarasov

U ovom radu je izloženo proučavanje evolucije početne mikrostrukture metala pri intenzivnoj frikciji sa posebnim osvrtom na uticaj mikrostrukturnih razlika pri formiranju i razaranju površinskih slojeva u toku procesa trenja. U cilju boljeg razumevanja, ovaj proces je analiziran i prikazan kod austenitne legure velike jačine pošto ove legure imaju veliki naučni i praktični značaj.