SURFACE AND SUBSURFACE FEATURES OF WORN ALUMINIUM-SILICON BASE ALLOYS.

By

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ABSTRACT

The worn surface of a modified aluminium-silicon eutectic alloy are examined in order to determine the nature of surface damages. Furthermore, an attempt is made to relate the surface features to the mechanism by which the wear particles are formed. Oblique sections of worn materials are used to examine the extent of subsurface changes through both microhardness measurements and metallography observation. The results indicate that both wear features and mechanism are different when the binary eutectic AL/Si alloys are compared to the modified materials.

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I. Introduction:

The microstructure of metals plays an important role in the mechanism by which the material is worn. According to the delamination theory (1), the wear of metal is a result of several and independent processes, such as subsurface deformation, crack nucleation and propagation. Furthermore, it has been reported (2), that other modes such as obrasion and adhesion as well as delamination contribution to wear process. Mutual transfer of material between pin and disc is also an important phenomenon and that the worn surface features can be explained by considering back transfer of material initially deposited on the disc. (3.4) However, it is possible that all such different mechanisms may be operating simulataneously, the worn surface features could be explained by those operating mechanism.

II. EXPERIMENTAL PROCEDURE:

A series of wear tests are carried out on a pin-on-disc type machine for various loading conditions and the sliding speed is maintained constant ~373 m/min. The pin is made of the tested aluminium-Silicon base alloys, the different compositions are shown in table I, and the disc of a surface treated medium carbon steel, ~63 Rc. The various alloys compositions are homogenized at 500°C for five hours after casting.

Wear tests are carried under different loads from 5 to 60 N, for a constant period of time. Microhardness tests are performed after wear tests on a oblique section made on the specimen, in order to measure the depth of hardened layer Microstructure examination of the worn surface and the oblique section after etching, are used to evaluate the changes brought by wear process.

III. EXPERIMENTAL RESULTS AND DISCUSSION:

1. SUBSURFACE CHANGES:

Oblique sections of worn specimens are used to examine the subsurface changes, Fig.(1) shows the microhardness distribution from the interface inwards, from a representative specimens, The presence of a work-hardened layer is clearly noticeable. From the curve in Fig.(1), it is also possible to determine the depth of subsurface damage. However, the resolution capacity of the microhardness being only in the order of 100 um, the depth of the subsurface damage could not be measured accurately.

2. METALLOGRAPHY OBSERVATIONS:

Representative specimens from each composition before wear tests are prepared for optical microscopy observation. No significant differences due to alloying elements additions to the basic eutectic structure can observed in the microstructure, within the limiting power of the microscope, Fig. (2) typical of the observed structure.

The metallographic examination of wear tracks of the worn specimens is conducted in order to investigate the mechanism of particles formation. In general, it is observed that for the high load tested material, above 10 N, a large plastic deformations of the surface took place as a result of sliding, and consequently a "mushrooming" shape are observed around the specimens edges. Figure (3) shows a worn surface at a relative high load _ 40 N, where a shallow surface crater is apparent in one side of the micrograph, indicating that the material had been delaminated from it. Furthermore it is possible to observe the existance of multilyering at the edge of the crater near to the ready for detachment wear particle.

It has been indicated (5) that at some critical stress level the surface fails at a particular point, resulting in a transversal crack on the worn surface. The subsequent load cycling may cause the materials around the crack to be delaminated by adhesive forces. This process is clearly shown in Fig. (4), where a thin layer of the material seem to be ready for detachment around a small crack. An important phenomenon is also observed on both the surface of pin specimens of various compositions under different loads, some of the wear debris of the aluminium alloys are transfered onto the steel disc and adhere to it. On the other hand, some of the deposite then transfer back to the pin surface.

Unlike the multialloying aluminium materials, the binary Al-Si showed a higher wear rate when tested under similar conditions (6). In that case, it is to be expected that the surface wear mechanism would be some what different. The main feature observed is presented in Fig. (5), it shows the presence of strips of overlapping flakes of material. The flake is distinctly seperated from the others and its leading edge is raised with respect to the adjacent flake. Similar observations are made on some binary aluminium-Silicon alloys (7). Examination of the edges of the steps reveals that these are made of a distinct series of layers.

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SUBSURFACE FEATURES:

Observations made on the oblique sections indicated that the presence of subsurface cracks are almost common features and they are oriented nearly parallel to the surface and clsoe to it as shown in Fig.(6). Such cracks may well be responsible for the initial delamination according to delamination theory. (1). The silicon distribution far from the surface did not show any sign of change by regard to the original state, but close to the surface, the silicon phase is fragmented into a relative fine particles in the region close to the sliding interface.

Furthermore, Fig.(7) shows a dark and unresolved region at one end of the photomicrograph in which presumably, surface wear tracks are produced. This hard formed layer does not have a homogeneous width throughout its length and is been fragented at its end towards the specimen centre. This layer could well be responsible for the observed increase in hardening near the worn surface, as shown in Fig.(1).

DISCUSSION:

A proposed mechanism for wear, must explain the important features of the worn surface. It is reasonable to assume that the wear particles originate from asperities interactions owing to the severe surface stress. Moreover, the adheren of the pin wear particles on the disc surface and its back transfter is an evident mechanism which are observed in the present work. The hard surface, counterface, also takes part in this transfer process and most probably wear in time. Cracks formation inside this deposited layers by mutual transfer, could be due to surface forces or because of interlayer zones failure during sliding under load (8), and the material is likely to detached from the pin surface by an adhesive force.

A subsurface cracks formation and the subsequence delamination of the surface area are not excluded as an mechanism acting simultaneously with the above proposed suggestion for wear particles formation.Suh (1) has indicated that the rate of cracks nucleation may be increased when a hard particles are present in the material. Where mobile dislocations generated by the applied load are blocked by silicon particles mainly, and dislocations pile-up occurs. Therefore, small cracks can form when these hard particles break-up under dislocations pile-up stress and, wear particles are form only when those cracks join, or reach the surface, by a propagation mechanism.

It is possible to summarize the mechanism by which the wear particles are formed in the present materials where two possible delamination modes exist. The first type of delamination occurs when the initial surface is ruptured due to subsurface cracks formation and the second by the surface rupture due to surface forces.

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Table (1): Nominal Composition of Aluminium-Silicon Based Alloys.

Alloy designation	Si %	Cu %	Mg %	Ni %
A_0	11.5	-	-	-
A_1	11.5	1	1	1
A_2	11.5	2	1	1
A_3	11.5	3	1	1

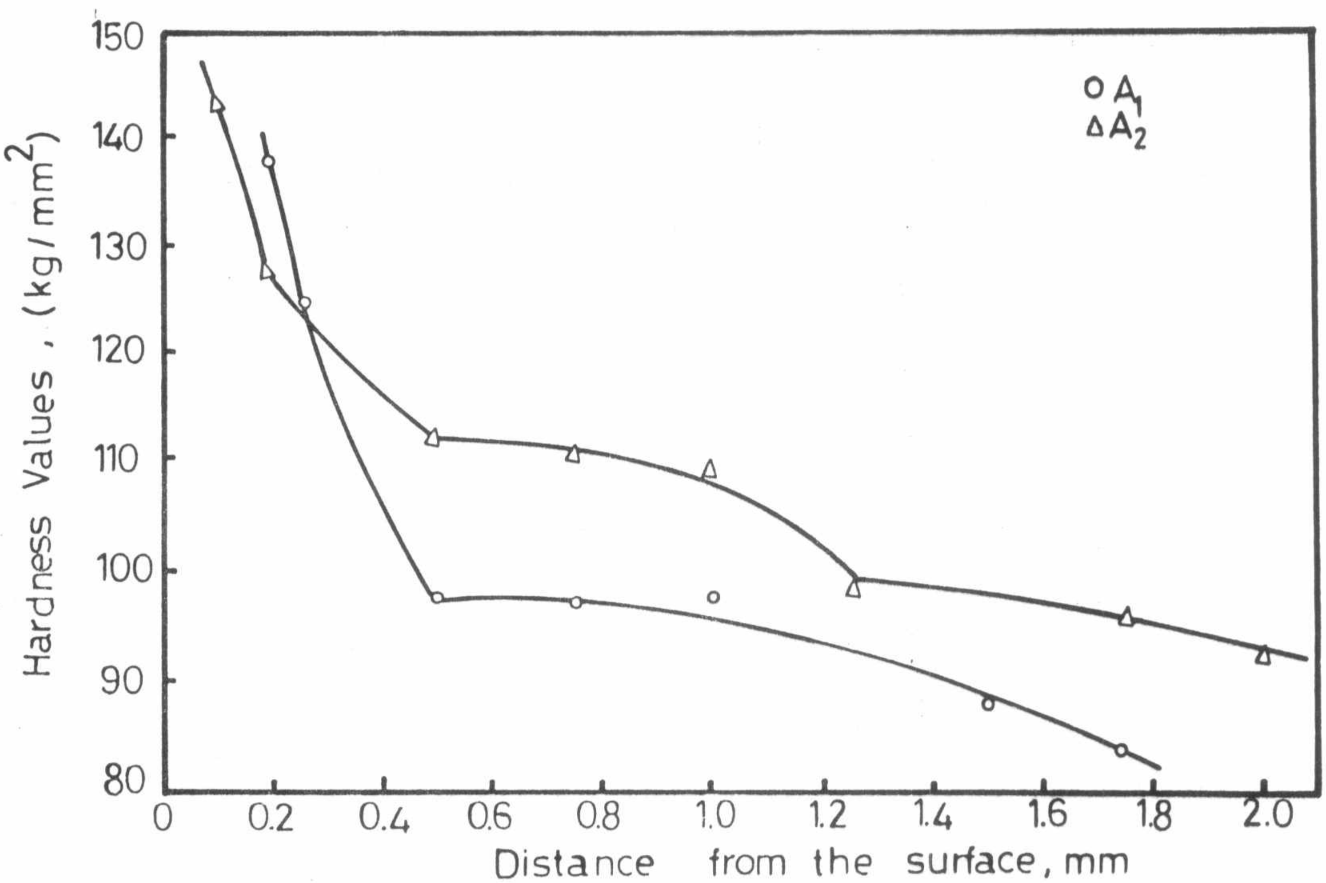

Figure 1. The change in hardness values below the worn surface for the alloys A_1 and A_2.

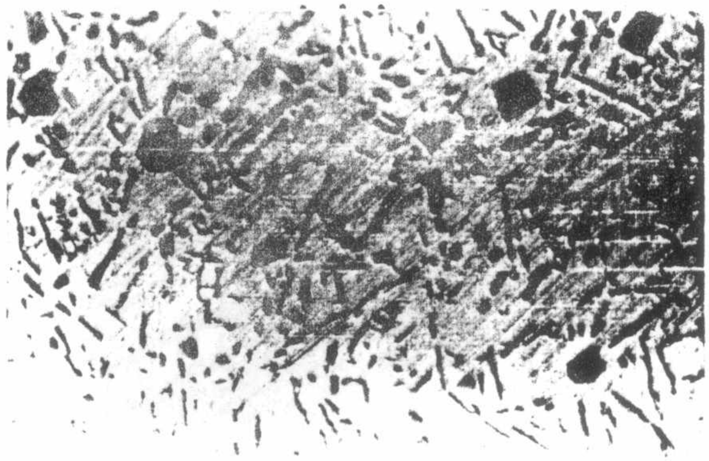

Figure 2. Typical of the microstructure of Allais base alloys, before wear test. (A_3).

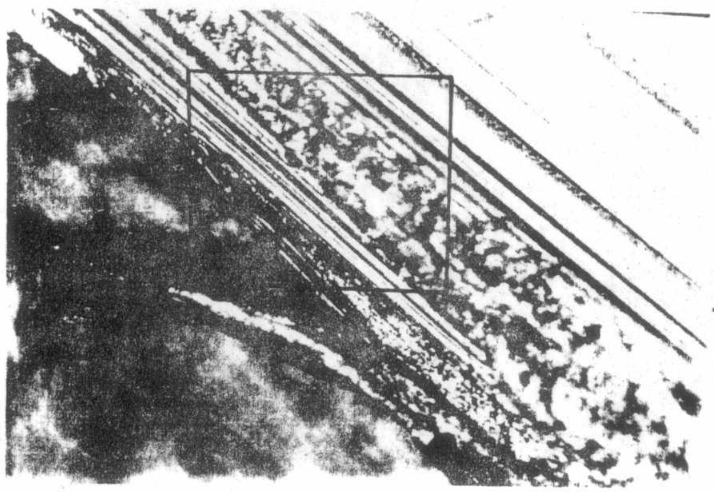

Figure 3. The micrograph shows the worn surface and to the left the shallow surface, the multilayer can be observed near to the detach wear particle, P = 40 N, (A_1).

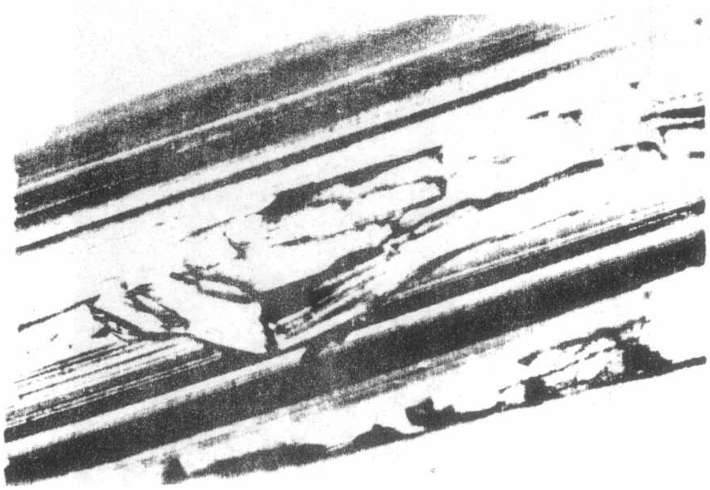

Figure 4. The worn surface of (A_3) alloys composition, showing the effect of adhesive force on removing the wear particle around a surface crack, P=60 N.

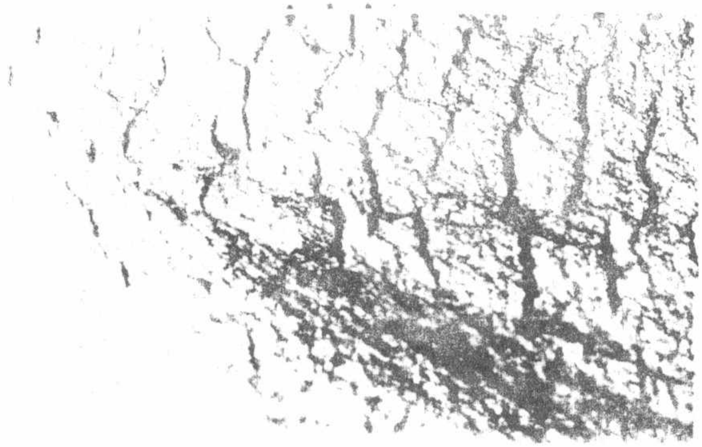

Figure 5. Typical of the worn surface of the binary Allsi eutectic alloy, P = 20 N.

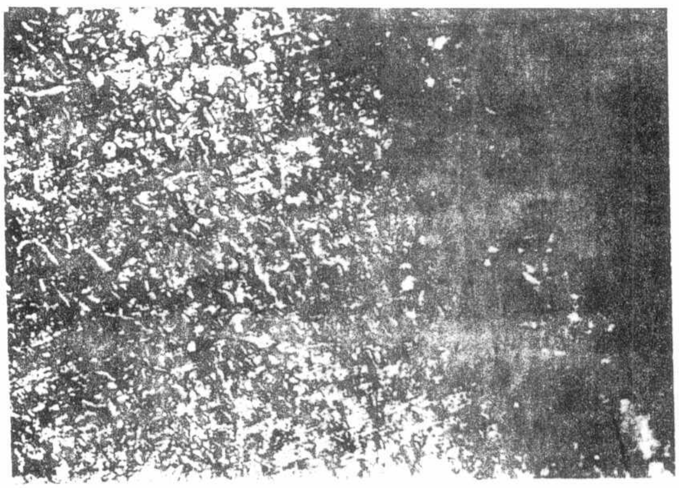

Figure 6. Micrograph of the oblique section of the worn specimen showing the subsurface crack, nearly parallel to the surface.P = 10 N, (A_1).

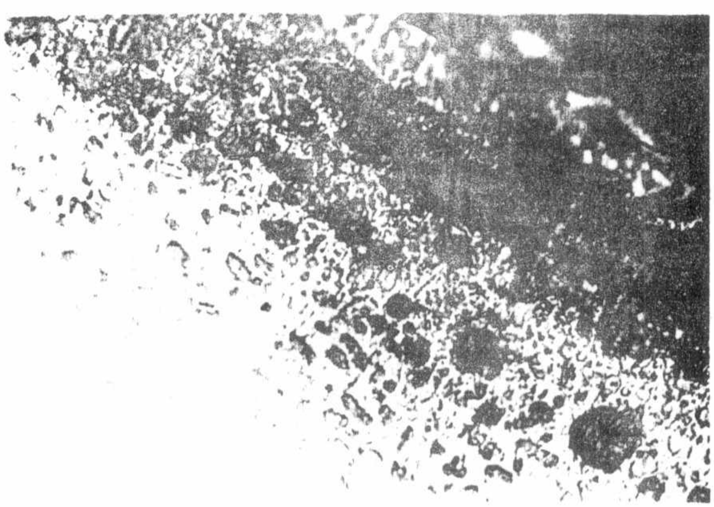

Figure 7. The subsurface area showing the effect of deformation on the microstructure of Allsi base alloy.P = 10 N, (A_1).