PRECISION MATCHING OF MATING FRACTURE SURFACES OF WC-Co ALLOYS

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INTRODUCTION

The fracture process in WC-Co alloys is accompanied by a small amount of plastic deformation, which only involves material within a few microns from the fracture surfaces [1] (Figure 1). This microscopic plastic deformation has been extensively studied in recent years [2-6] but all investigations have been limited to single fracture surfaces. The present work is a study of precisely matched areas of pairs of mating fracture surfaces and its aim is to provide a clearer picture of the mechanism of energy dissipation during the fracture process.

The precision matching technique has been described in detail by Meyn and Beachem [7]. In the present work the method has been simplified by using SEM fractographs instead of replicas. The SEM used was a Jeol JSM-35. The "landmarks" necessary to find the microscopic matching areas were abnormally large WC grains crossed by the fracture path. Pictures of matching areas have been left as mirror images of each other, which means that a feature which runs from north-west to south-east in one picture, will run from north-east to south-west in the picture of the matching area.

Although the present investigation has been carried out only on bending and fatigue specimens having low cobalt concentrations (5-10% Co) and relatively large carbide grains (3-4μ average grain size), the present results can be extended to most WC-Co alloys, since the features discussed have been observed on single fracture surfaces of a very wide range of specimens [2-6].

RESULTS

The plastic deformation on fracture surfaces appears in the carbide grains as slip lines and in the cobalt phase as tearing features.

Figure 2 shows an example of a large carbide grain crossed by the fracture path: the fragment in Figure 2a exhibits slip lines while the one in Figure 2b does not. In this and similar cases slip obviously took place after the crack went through the grain and the energy dissipated in the process must have come from stress relaxation. This result could only be achieved by observing mating areas.

The tearing features in the cobalt are of two types: "ridges", when the fracture cuts very thin cobalt layers lying between two carbide grains; "dimples", when the fracture goes through cobalt areas a few microns wide.

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Figure 3 shows many examples of "ridges". By the precision matching technique it was possible to establish that "ridges" on one surface correspond to "ridges" - and not grooves - on the mating surface.

Figure 4 shows examples of "dimples", which are microscopic hollows outlined by ridges. Also in this case, "dimples" on one surface correspond to "dimples" on the mating surface.

CONCLUSIONS

The presence of ridges and dimples indicates that the binder phase within a few microns from the fracture surfaces undergoes plastic deformation during the fracture process. This is in agreement with the observations of Almond and Roebuck, by transmission EM [4].

Ridges must result from a microscopic "necking" process, similar to the necking process occurring in ductile materials subjected to a tensile stress. This would imply that the carbide grains, on the sides of the thin cobalt layers, fracture before the cobalt or that fissures are first formed along the WC-Co boundaries, as was observed in tensile tests at high temperature [8].

Dimples suggest the presence of microvoids, which have also been observed in high temperature tests [8]. At high temperature, the microvoids can coalesce to form fissures, while at room temperature they can only coalesce during the fracture process, by tearing the material between them (hence the ridges outlining them).

The microvoids can have many possible origins: they can come from cavitation during the liquid stage in the manufacturing process; from cavities formed under stress around solute particles (W, C, and possible impurities); or even from the slight change in volume that must accompany the martensitic transformation (f.c.c. → h.c.p.) taking place in the cobalt under stress [9].

The plastic deformation in the cobalt is believed to accompany fracture, and not to follow it as a result of stress relaxation, because of the good matching of ridges and dimples on mating surfaces. A random stress relaxation process would lead to different appearances of the two mating areas, as is the case in the carbide grains.

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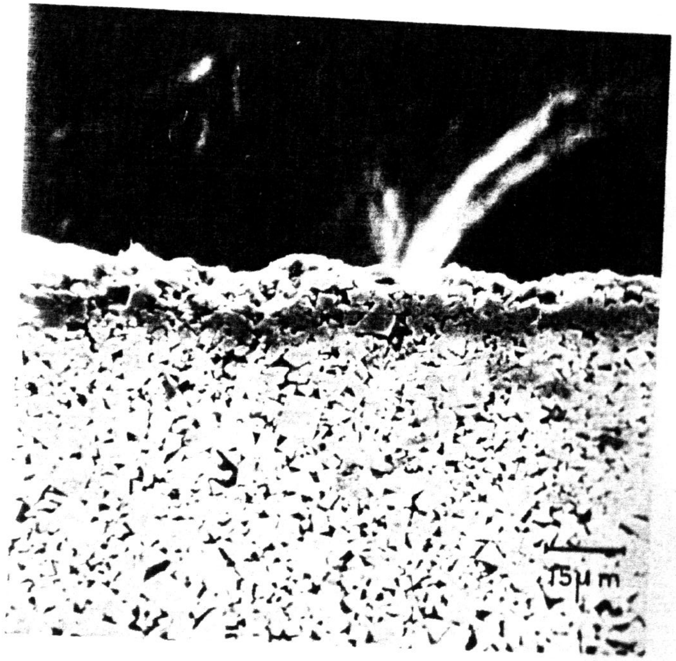

Figure 1 S.E. Micrograph of the Fracture Outcrop of a WC-10% Co Fatigue Specimen. The Thickness of the Layer Involved in the Plastic Deformation Accompanying Fracture (Which Appears as a Deformed "Lip" Outlining the Fracture Surface) is about 10 μ

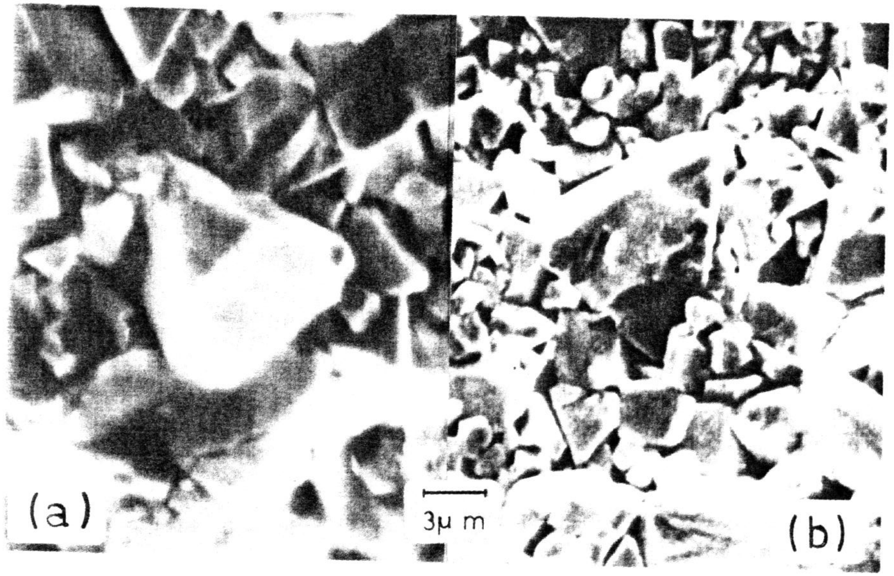

Figure 2 S.E. Micrographs from Matching Areas of Mating Fracture Surfaces in a WC-10% Co Fatigue Specimen. The Triangular Large Carbide Grain in the Centre of Each Micrograph was Crossed by the Fracture Path. The Fragment in Picture (a) Exhibits Slip Lines, While the Fragment in Picture (b) Does Not

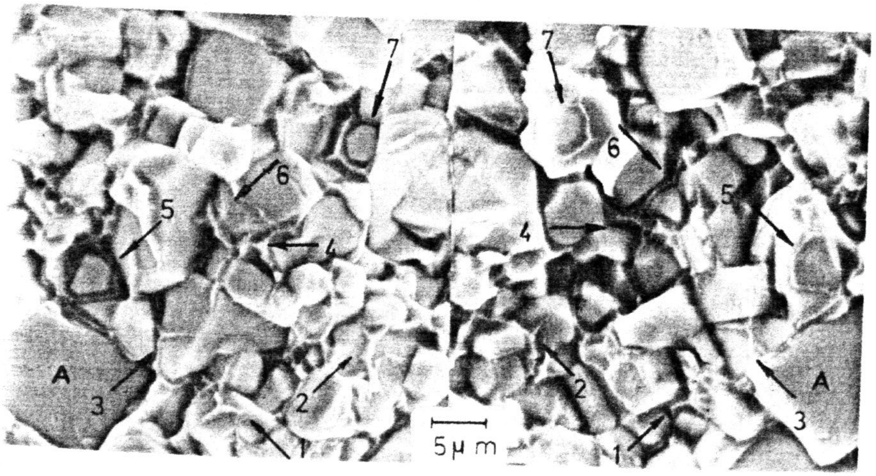

Figure 3 S.E. Micrographs from Matching Areas of Mating Fracture Surface in a WC-5% Co Bending Specimen. The Grain Indicated as A was Used as "Landmark" in the Study of These Areas. The Ridges Appear as White "Veins" All Over the Surfaces. Some of the Matching Ridges are Indicated by Numbered Arrows

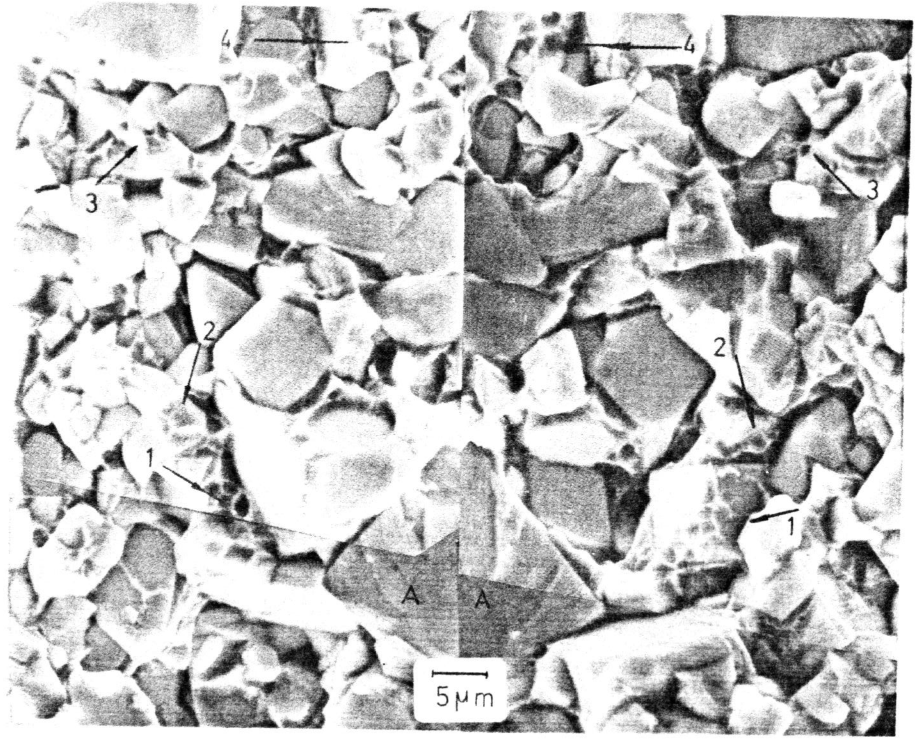

Figure 4 S.E. Micrographs from Matching Areas of Mating Fracture Surfaces in a WC-5% Co Bending Specimen. The Grain Indicated as A was the "Landmark" in these Areas. Matching Dimples are Indicated by Numbered Arrows