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THE INFLUENCE OF SURFACE TREATMENT ON THE FATIGUE PROPERTIES OF TITANIUM AND TITANIUM ALLOYS

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SUMMARY

Due to the strike in the steel industry the orders which had been placed for titanium on March 20, 1952, have not yet been filled. This has seriously hampered the work of the project since insufficient stock is on hand to fabricate the actual fatigue specimens.

With the limited stock available work is proceeding on developing a technique for measuring surface stresses induced in the preparation of the surfaces of titanium. There is some question as to whether the exact level of residual stress remaining in the surfaces can be measured with x-rays, but work is progressing toward that end. A technique for the determination of the depth of penetration of the working operation below the surface of the metal is being investigated and shows promise of indicating the severity of surface stressing.

EXPERIMENTAL RESULTS

Since the primary purpose of this project is to determine the influence of surface conditions on the fatigue properties of titanium and at least one of its alloys, the major emphasis to date has been placed on the development of techniques for describing these surfaces.

Stress Measurement

For the absolute measurement of the stress remaining in the surface of the titanium samples that have been machined the use of x-rays was indicated. In order to obtain suitable precision in these measurements back reflection parameter techniques must be utilized. These have been used on samples of Ti 75, which had been machined under various controlled conditions, but the results were not satisfactory. The chief difficulty in utilizing this method is traceable to the basic structure of the titanium metal. Since it has a hexagonal close-packed structure the c/a ratio is such that a single exposure of the surface to the more common types of radiation does not produce suitable diffraction lines in the back reflection region to permit an evaluation of the stressed condition. Further complications are the absorption of oxygen and/or nitrogen into the metal at various stages of heat treating and processing, and the presence of preferred orientations. Absorption of both oxygen and nitrogen will change the c/a ratio and contribute to the inaccuracy of the method. Steps to improve the x-ray technique are being taken by fabricating an x-ray target of vanadium. The use of this radiation would permit a back reflection of the 2020 line to give information on the behavior of the a-axis on straining. The change of the c-axis can be obtained from a line with a high order of indices such as 1013.

It is believed that due to the variations in chemical analysis from heat to heat and even within a given heat the lattice parameters "a" and "c" will vary over considerable limits. An indication of this variation has been found in the stock with which we have been working. The average diamond pyramid hardness level is 225 but the actual values vary from 191 to 280 in the annealed state. Other samples of this same material from different heats and sources show values from 160 to 240. In view of this, the use of x-ray diffraction measurements for the determination of the absolute measurement of the stress level will only be qualitative unless a preliminary investigation of the lattice constants of the unstrained metal is carried out in each individual case.

Microhardness and Metallographic Studies

Samples of Ti 75 that have been machined and ground under various conditions to produce different surface conditions have been examined by hardness surveys and metallographically. No regular change in hardness as a function of depth below the surface has been noted, but the overall level of hardness does change as the method of machining is changed. The metallographic studies of these same surfaces indicate no measureable disturbed layer.

Depth of Penetration Measurements

Hardness determinations are usually used to determine the depth of cold-working produced in machining metals and alloys, but this method measures work hardening which will vary in magnitude for the same amount of work from one material to another. A determination of the depth of cold-working by hardness measurments on a material which hardens very little will obviously be inaccurate. This might be the case with Ti 75 since a 40 per cent reduction in area by cold-working changes the hardness by only some 60 points diamond pyramid hardness.

When annealed metals are severely cold-worked the original grains will be deformed and fragmented. This effect will show in an x-ray powder picture by the appearance of continuous rings instead of the separate double lines or spots which are selected from the individual grains and are characteristic of the annealed material. Variations in the degree of cold-working will produce gradations between these two extreme conditions. Figures 1 and 2 are illustrations of this condition in a brass sample which had been lathe-turned under specific conditions. Figure 1 is a picture taken as shown in Figure 3 on the "as-turned" surface. Figure 2 is a picture taken in the same fashion but with 0.025 inches of the surface removed by uniformly etching the surface.

The above-described technique has been utilized on a rough-machined sample of Ti 75. Figures 4, 5, and 6 are surfaces of titanium which have been treated in 10 per cent HF solution to remove successive layers of disturbed metal. From these photographs the depth of penetration of the rough-machining has been determined to be approximately 0.0125 inches. For comparative purposes a piece of 66-34 Cu-Zn brass bar stock which had been machined under approximately the same conditions was examined by removing successive layers in a 35 per cent HNO_3 solution. Figures 2, 7, and 8 are photographs of these surfaces. It appears that the depth of penetration in this material is approximately 0.020 inches.

The titanium pictures are not quite as sharp and clear as those of the brass because of its structure and condition. It is believed however that this method of analysis will enable the qualitative determination of the surface stress condition.

FUTURE WORK

For the next period work will continue on the development of an x-ray technique for the measurement of the actual stresses in various titanium surfaces.

The technique described for the measurement of the depth of penetration will be extended to other types of machining and on other heats of Ti 75A.

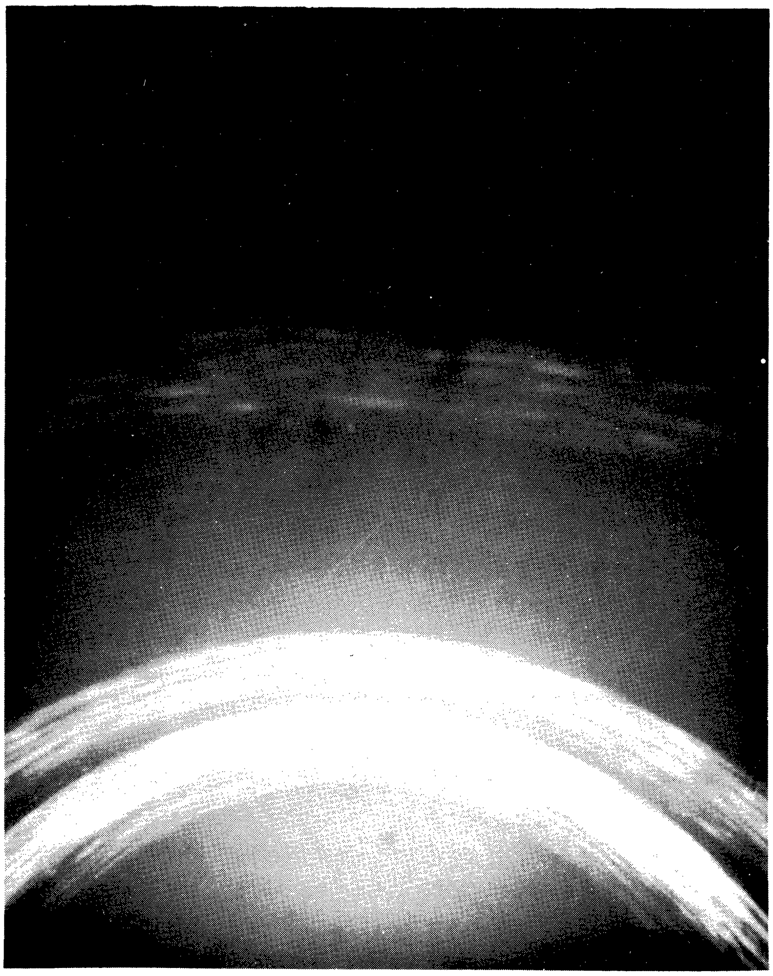


Figure 1. Lathe turned 66-34 Cu-Zn Etched 0.0024"

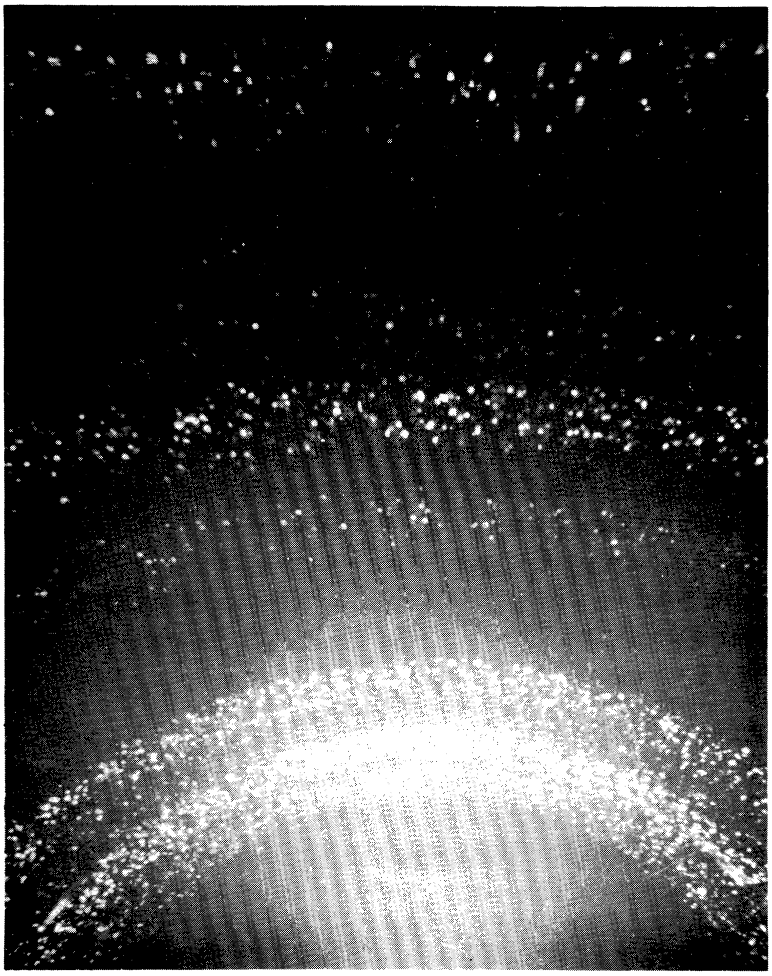


Figure 2. Annealed 66-34 Cu-Zn Etched 0.025"

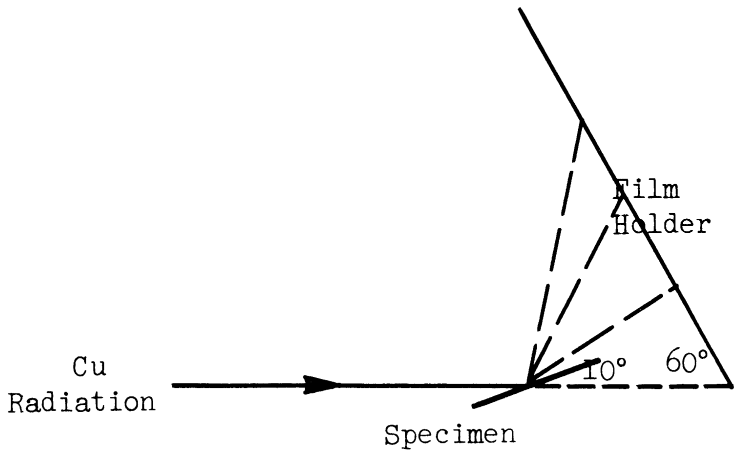


Figure 3. Schematic Diagram of X-Ray Set-Up

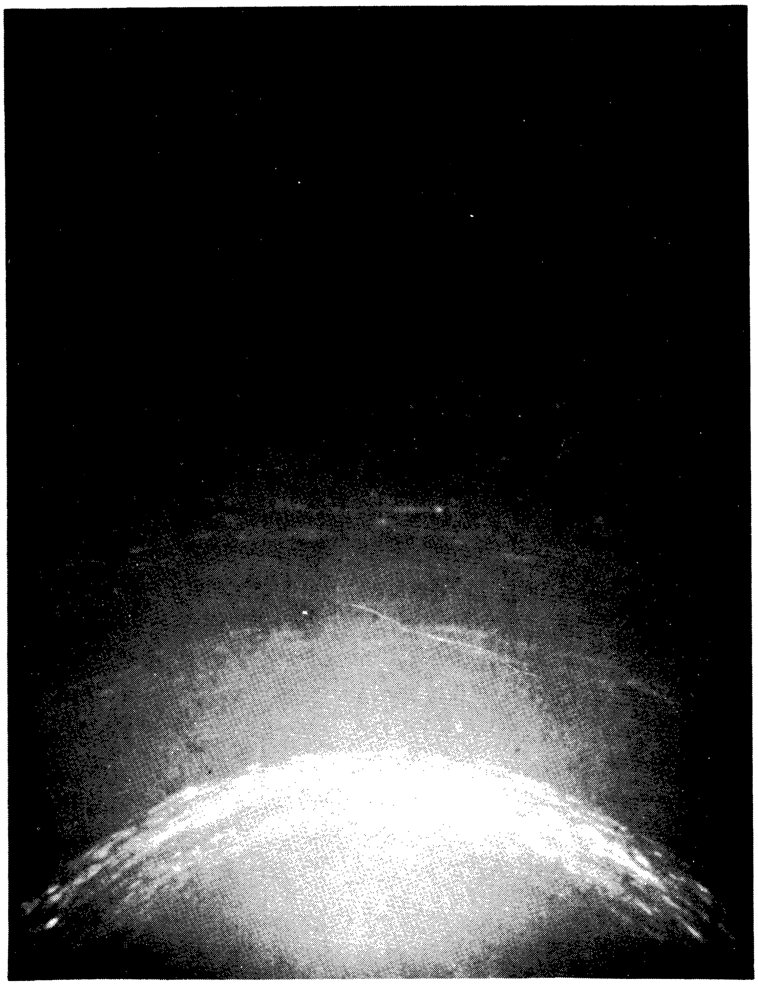
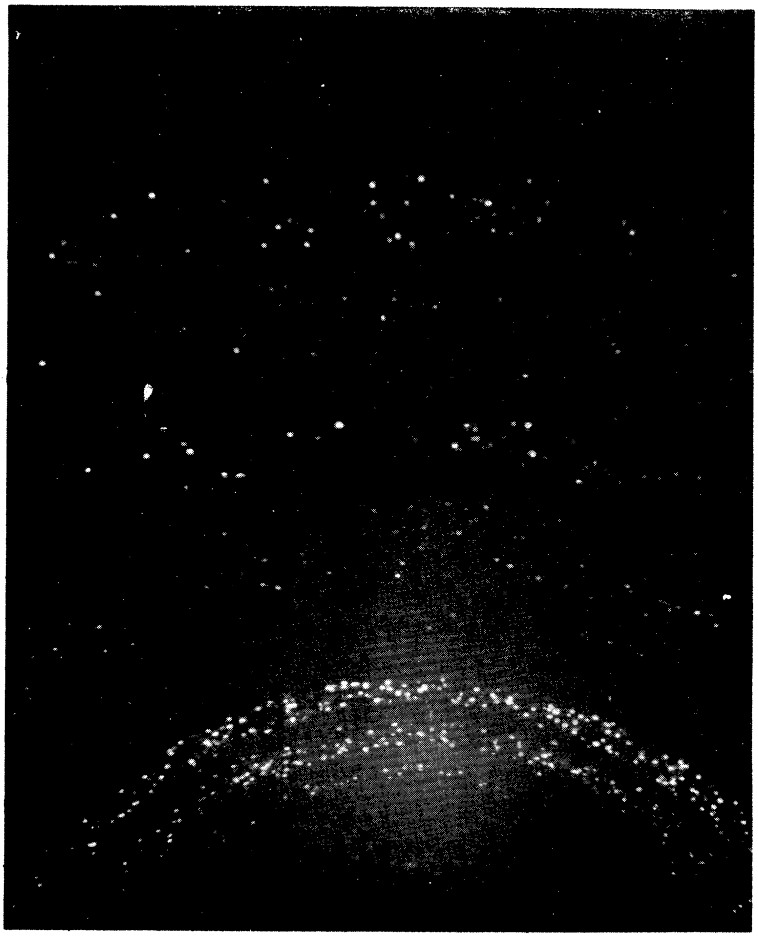


Figure 4. Lathe turned Ti 75 Etched 0.00055"



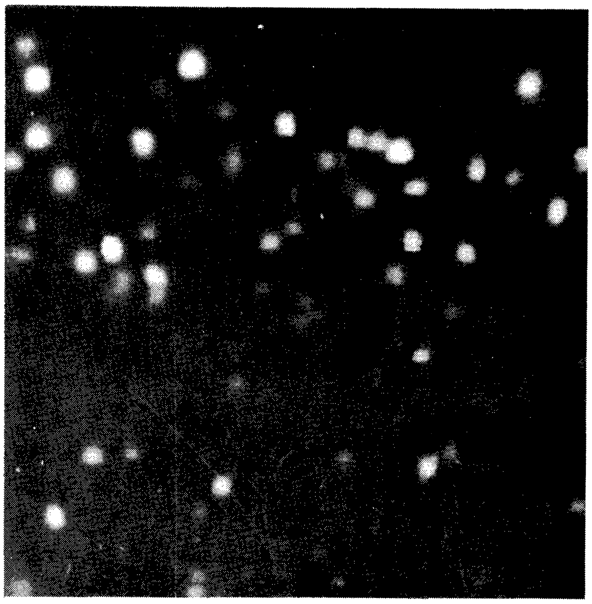


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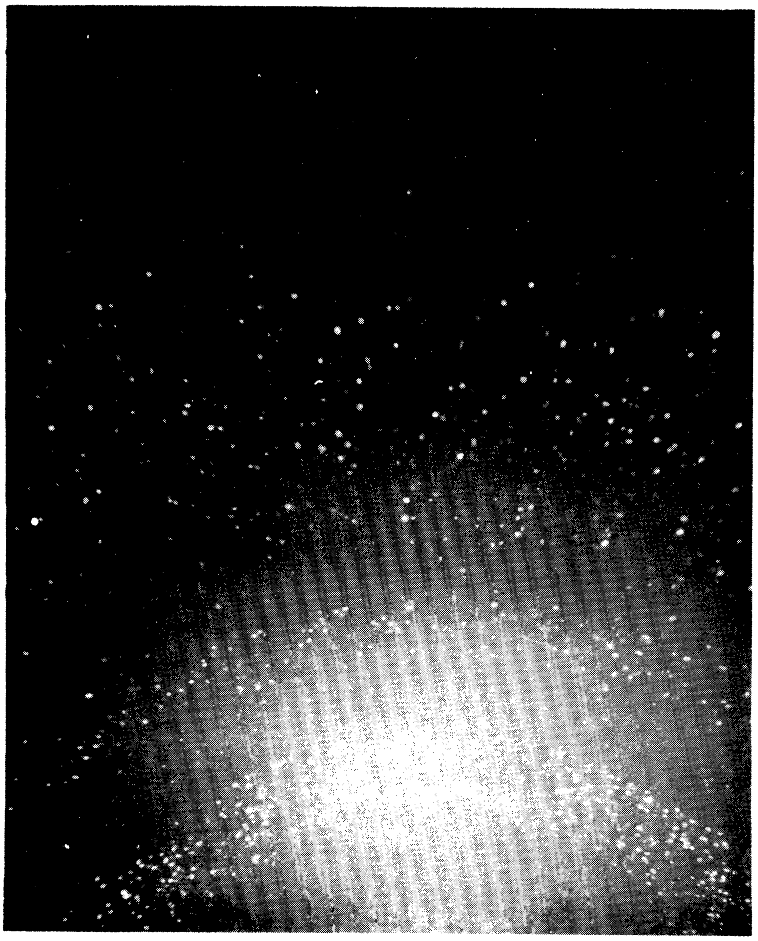
Figure 5. Lathe turned Ti 75 Etched 0.0076"



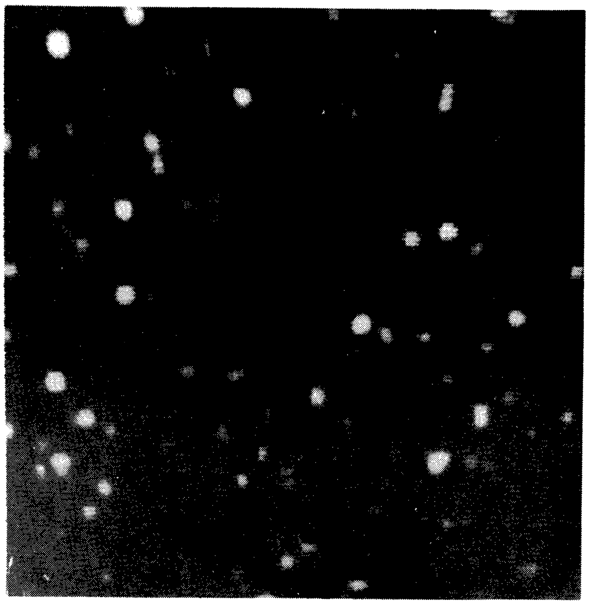


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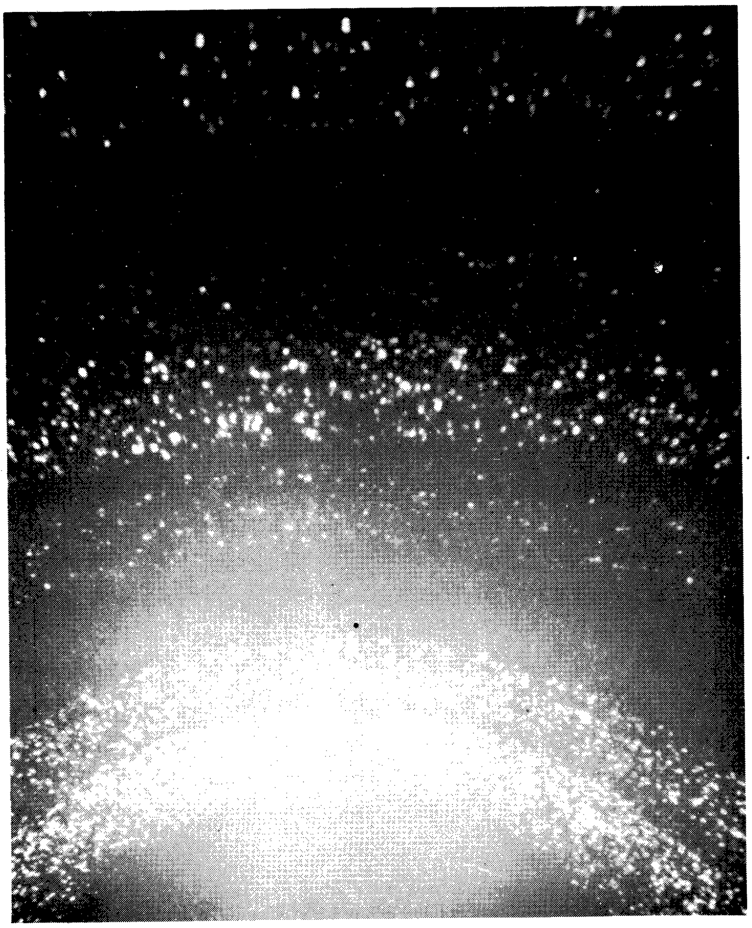
Figure 6. Lathe turned Ti 75 Etched 0.0125"



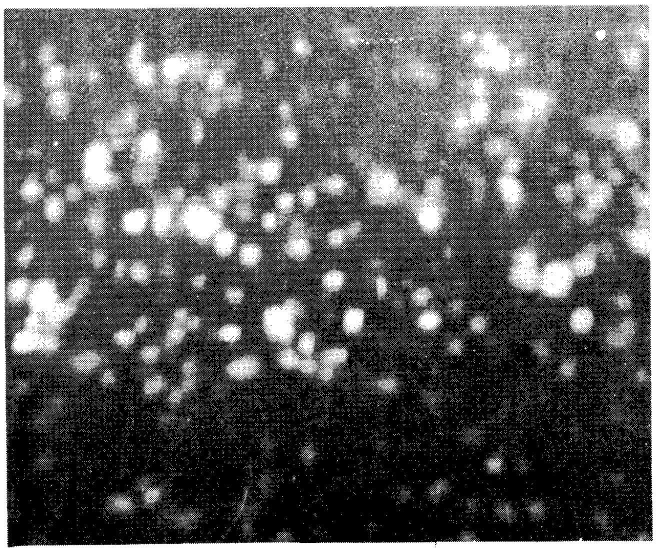


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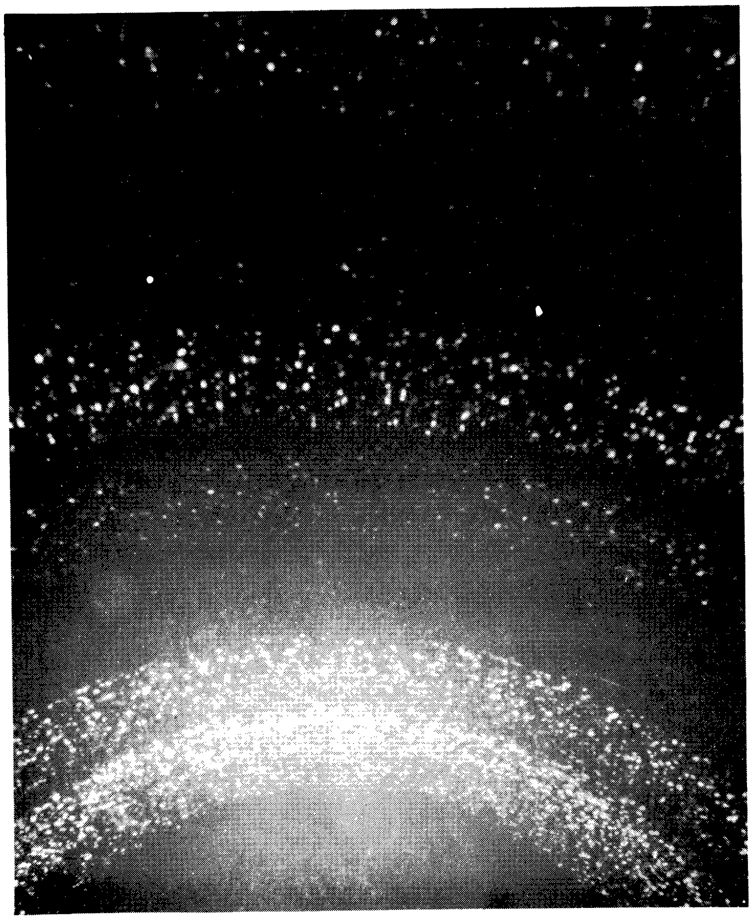
Figure 7. 66-34 Cu-Zn Etched 0.01675"



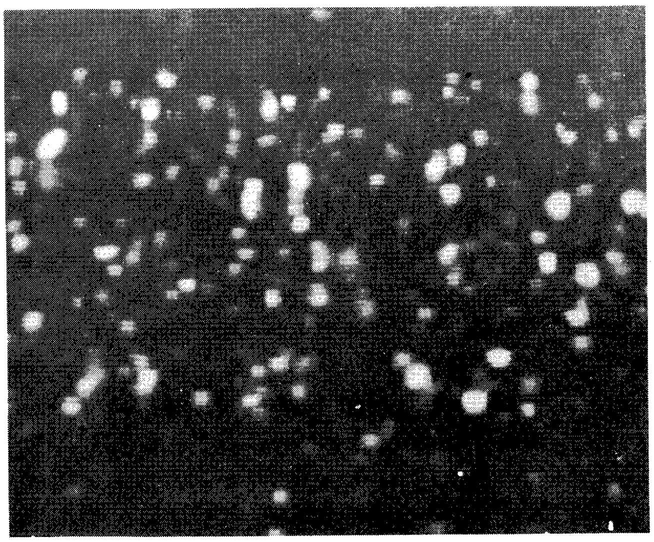


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Figure 8. 66-34 Cu-Zn Etched 0.0195"

A stock of alloy 130B has been ordered and a sufficient supply is on hand to permit some preliminary work on this material similar to that done on 75A.

Sufficient stock is on hand to make one set of fatigue tests on one heat of 75A, and there is stock from another heat to make up an additional set of specimens. Tentatively these tests are planned for the usual type of surface finish and for a ground type of finish. All samples are to be machined under carefully controlled and reproducible conditions.

On the receipt of the originally ordered material work can proceed more rapidly on the actual evaluation of surface effects on the fatigue strength.