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

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SUMMARY

Authorization to proceed with this investigation was received March 17, 1952. Orders for titanium were placed immediately, but delivery on the major portion of the necessary stock cannot be obtained before May 20. For preliminary studies a random length of a random heat of Ti-75A was obtained and work has gone forward with this stock.

A heat-treating technique has been developed; preliminary studies on metallography, microradiography, machining and grinding, x-ray diffraction, and fatigue specimen preparation have been made.

A continuing and intensive literature survey preparatory to the compilation of a Bibliography of Fatigue is being made.

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

INTRODUCTION

The primary purpose of this investigation is to determine the influence of surface conditions on the fatigue properties of titanium and at least one of its alloys. The principal factors which will affect the fatigue strength are surface finish, depth and severity of cold working, presence and extent of preferred orientations, possibility of phase transformations induced by surface treatments, surface and/or subsurface contamination by oxidation or nitriding during machining or prior treatment, and nonhomogeniety of the metal.

Certain of these factors are known to vary from heat to heat, so to eliminate spurious and misleading effects an order was placed for sufficient Ti-75A bar stock from the same heat to supply material for all of the projected experimental work. Since immediate delivery could not be obtained on this order, a random length from a random heat of Ti-75A was obtained for preliminary studies. Some of the work that has been done and is currently in progress will have to be repeated on receipt of the single heat stock, but valuable preliminary information is being obtained and techniques are being perfected.

EXPERIMENTAL RESULTS

Heat Treatment

The bar stock supplied was in the form of a rod 5/8 inch in diameter in what is termed the annealed and ground condition. A microhardness traverse of the diameter of this material showed that there was a variation in hardness from surface to center, the center being harder than the surface. Since it is essential that material be as homogeneous as possible, a series of heat treatments was carried out in order to remove this nonhomogeniety in hardness.

The stock was annealed at 1725°F, 1600°F, and 1110°F in an argon atmosphere and in an ambient air atmosphere. In all cases homogenization was obtained, as indicated by a microhardness traverse. Surface oxidation of the samples heated in air to 1600°F and 1700°F occurred, however, and a weight gain due to oxygen and/or nitrogen adsorption was noted. While the amount gained was small, it was felt that future treatments should be in an argon atmosphere at a temperature of 1200-1300°F in order to avoid unnecessary oxygen and nitrogen adsorption. Excessive grain growth was not obtained on the high-temperature anneals, and the hardness level was not noticeably lower than that obtained at the low-temperature anneal.

Hardness traverses in the longitudinal direction of the bar showed that the stock was uniform in this direction.

Metallographic Studies

A suitable electrolytic polishing technique for titanium alloys has been developed. Examination of the bar stock currently under test shows a much improved structure over previous heats examined by the authors. The grain size of both the as-received material and the annealed material is very uniform and equiaxed in structure. There is a very low inclusion count and stringers, which were common in the earlier heats of Ti-75A, are completely absent.

Microradiographic Studies

Other investigations have indicated that the presence of surface or subsurface defects, usually in the form of metallic or nonmetallic stringers, can seriously affect the fatigue strength. Nonhomogeniety in individual grains can also produce undesirable effects. In order to check these factors, microradiographic specimens were prepared and radiographs taken. The results showed that the material was homogeneous and no indication of segregation was found.

Machining and Grinding Studies

Preliminary work on the preparation of machined surfaces for x-ray diffraction analysis has been carried out. Surfaces have been rough machined, fine machined, and surface ground under carefully controlled and supervised conditions of feed, depth of cut, and speed for tools of a predetermined shape. No particular difficulties were encountered in producing the machined surfaces, but the grinding operations were in general unsatisfactory.

In the grinding operation the localized heating of the surface evidently caused phase changes in the material and produced localized hard spots and oxidized or burned sections. Several conditions of feed, speed, and depth of cut were tried, but no satisfactory surface was produced. The same type of grinding wheel was used for this work, and it is now believed that this is the cause of the difficulty. From other work that has been done on the grinding of titanium and its alloys it is known that such factors as the type of abrasive, its grain size, grade, structure, and bonding have to be carefully controlled. Further work is planned on grinding, using the information available in regard to the correct choice of grinding wheels and grinding procedures.

The problem of localized overheating encountered in the grinding operation may be a serious factor in the machining operations. It may be argued that the transformation temperature will probably never be reached during the machining operations, but on the other hand it is generally agreed that the temperature of the parting surfaces on the breaking of a chip is very high, even approaching the melting point. If this actually does occur with titanium then there is, in addition to the danger of phase changes, the possibility of chemical reaction with the oxygen and nitrogen of the air. This behavior has been partially verified by studies on tool wear in machining titanium.

Fatigue Specimen Preparation

Since fatigue testing is to be done on R. R. Moore rotating-beam machines, a modified test specimen for the testing program has been designed. Fig. 1 is a sketch of the specimen that will be used. It differs from the tentative ASTM standard specimen in that it is much easier to machine and finish. Test results obtained in previous work on fatigue have been comparable to the results obtained with the ASTM tentative standard specimen.

A specimen of this modified design has been machined and finished using the same techniques that have been used on steel specimens tested in the past, and no particular difficulties were encountered. The tapping operation has to be done more carefully and the hand finishing on 000 metallographic paper does not remove as much stock from the titanium as it does in the comparable finishing operation on steel specimens.

X-Ray Diffraction Studies

The surface condition of the actual fatigue specimens is to be investigated by x-ray diffraction techniques. In order to do this accurately, a special diffraction camera has been designed and constructed, and work is just starting on the determination of the surface characteristics of the previously described machined samples. It is hoped that this information will permit the determination of the stress condition of the surface, but these measurements may be complicated by the occurrence of oxygen and nitrogen adsorption by the surface. Such a reaction will expand the titanium lattice, particularly along the c axis, and may interfere with the stress measurements.

BIBLIOGRAPHY

In the early stages of the work a bibliography on fatigue was started; compilation is still in progress. This bibliography will be extensive and probably will not be submitted until the final summary report.

FUTURE WORK

Upon the receipt of the single heat of Ti-75A, much of the preliminary work will have to be repeated in order to define completely the condition of the metal. Groups of test specimens of known s rface characteristics will then be prepared, and fatigue properties will be evaluated as functions of variations in surface characteristics.

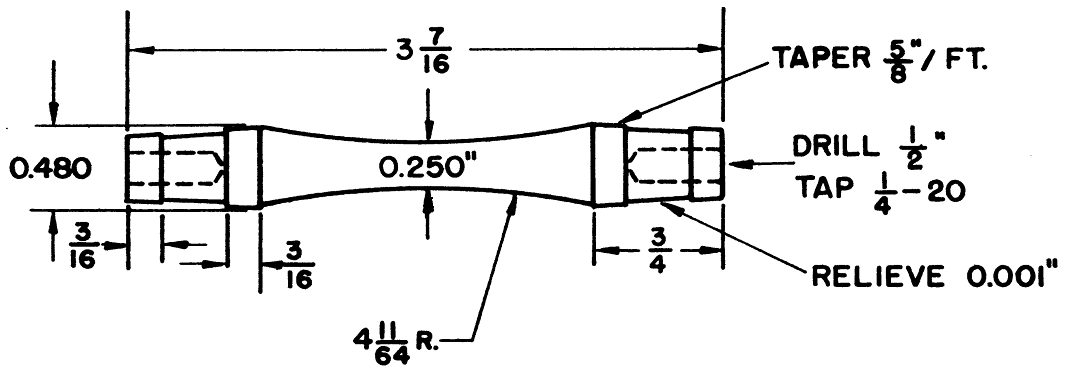

FIG. 1
FATIGUE TEST SPECIMEN