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

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SUMMARY

A sufficient supply of commercially pure titanium has been received to permit the large-scale investigation originally planned. The material is being processed and tested at the present time, but results are not ready for inclusion in the present report.

Fatigue tests on two random heats of commercially pure titanium indicate that there may be a rather wide variation in fatigue properties of this material from heat to heat even for a fixed surface and subsurface condition.

EXPERIMENTAL RESULTS

The receipt of sufficient stock of Ti75A from one heat has enabled us to lay out part of the originally proposed program. One of the more important factors which must be considered in fatigue testing is the statistical nature of such testing. It is important to determine the variance that can be expected in any given series of tests so that we will be able to assign significance to any differences detected between different types of surface or subsurface treatments. Unfortunately the only data on the statistical nature of fatigue that are available apply to steels, so it will be necessary to do considerable work on titanium and its alloys to determine what type of distribution will be obtained with this material. On the advice of the Statistical Research Group of the University, we will use the stock of Ti75A, which consisted of 60 feet of stock in the form of six bars, to make up six types of surface and subsurface conditions and test each condition at each of five stress levels ranging from 10^3 to 10^7 cycles for failure, using six specimens for testing at each stress level. By allocating stock from each of the six bars to various conditions, it is hoped to determine if significant differences exist between bars while at the same time determining the variance between different surface and subsurface conditions. It is possible that when half of these proposed tests are completed a statistical analysis at that point will enable us to re-evaluate the statistical program and perhaps eliminate some of the extensive testing for a given type of surface. The three types of surface currently under test are (1) annealed followed by hand-polishing, (2) annealed, milled, and hand-polished, and (3) annealed, ground, and hand-polished.

Microradiographic studies of the new heat of titanium currently under test show that very little, if any, tungsten is present, so difficulties from this source should be at a minimum.

Metallographic studies of this heat of material show that the stock is very high in hydrogen. This is indicated by the presence of considerable line markings, which are characteristic of the presence of this gas in solution. The iron content of the heat is reported as 0.18% and this combined with the high hydrogen content has caused the appearance of some beta phase. The work of Battelle Memorial Institute has shown that the hydrogen can be eliminated by heating in vacuum but, except for one set of test specimens, this treatment is not planned for the bulk of the Titanium, since the results desired should be representative of a commercial stock.

An x-ray diffraction study of the as-received stock has shown that the material has a preferred orientation. Annealing at various temperatures to 1450°F has not been effective in changing the condition of the material. Rather than attempt to remove this effect by further treatment, which might result in grain growth, the stock will be annealed at 1450°F to remove strains from machining. Additional stock on order will be used to determine just what effect this preferred orientation has on the fatigue properties for a given type of surface and subsurface finish.

Two random lengths from random heats of Ti75A have been investigated prior to receipt of the present stock. These materials were used in the development of x-ray techniques, heat treatment studies, etc. On the completion of these studies sufficient stock remained for the preparation of a few fatigue specimens from each piece of material. The specimens were prepared identically by lathe turning to within 0.050 inch of the final diameter; then they were annealed in argon at 1200°F for 1/2-hour to remove the effect of the prior machining. They were then placed in a milling machine and machined under controlled speed and feed conditions to within +0.002 inch of the final diameter. Hand-polishing with metallographic paper to the final diameter and same surface finish completed the specimen preparation. The results of the fatigue testing on the two heats is shown in Fig. 1.

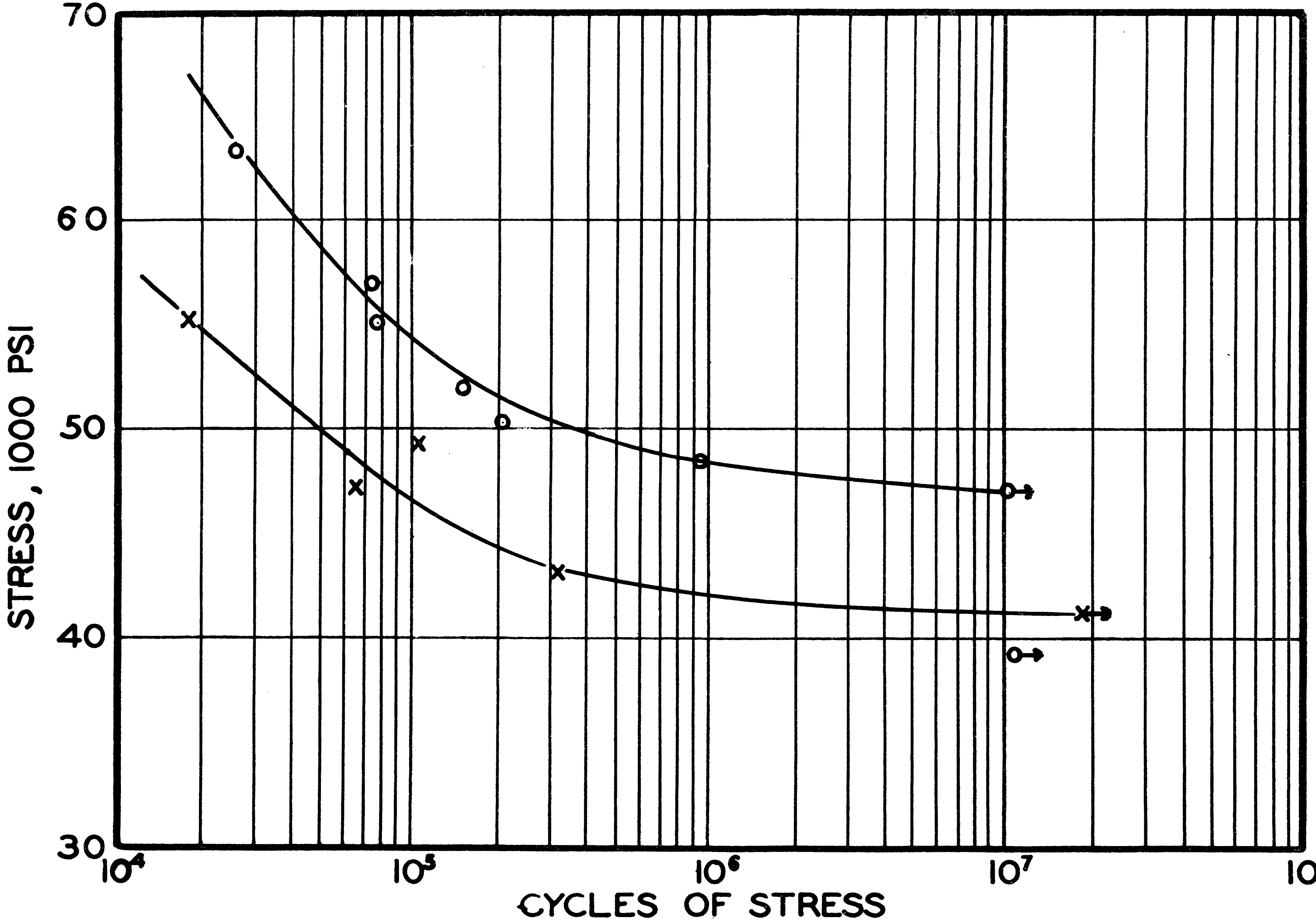
70
60
50
40
30
STRESS, 1000 PSI
10^4
10^5
10^6
10^7
10^8
CYCLES OF STRESS

Fig. 1

It is apparent that there is a marked difference between the two heats, although the surface and subsurface preparation in both cases was identical. One possible answer appears in the microstructure. The heat with the superior fatigue properties was a simple solid solution, while the metal with the lower strength showed line markings and the presence of a trace of beta phase; due again presumably to the presence of hydrogen and iron. On the other hand, hardness studies showed that there was a considerable difference between the two heats. The material with the better fatigue properties had an average hardness of 240 DPH, while the other heat averaged 190 DPH. This difference is probably due to the quality of the sponge used in the manufacturing process or possibly to oxygen absorption in later processing. Tensile data on the two heats showed that the proportional limit and ultimate strength of the material with the greater fatigue strength were higher. The values for the two heats were 57,400 psi and 53,400 psi for the proportional limits and 96,400 psi and 84,200 psi for the ultimate strengths. The per cent elongations in a one-inch section were identical at a value of 33%, as were the percentage reduction in areas at a value of 44%.

These variables will probably be minimized by the use of stock from the one heat of material and the use of statistical methods will enable us to determine significant changes in the fatigue properties as induced by changes in processing.