ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

PROGRESS REPORT NO. 6

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

By

L. THOMASSEN
M. J. SINNOTT
A. W. DEMMLER, JR.

Project 2034

WRIGHT AIR DEVELOPMENT CENTER, U. S. AIR FORCE
CONTRACT NO. AF 33(616)-26 SUPPLEMENT S-2(53-582)
E. O. NO. R615-11-SR 3c, PROJECT NO. 53-670A-61

December, 1953

## SUMMARY

The effects of three different types of surface treatments and two types of machined notches on the fatigue strength of an all-alpha type titanium alloy have been determined.

The all-alpha alloy is superior in fatigue properties to the annealed Ti-75A but not as strong as the annealed RC-130B; both of these alloys having been previously tested with similar surfaces and notches.

As was the case with both the annealed Ti-75A and RC-130B, the shot-peening operation improved the fatigue properties while grinding gave inferior properties as compared to a hand-finished surface.

A machined V-notch or square notch decreases the fatigue life of the alloy, as compared to the annealed and hand-finished surface, from 35% to 65% depending on the notch type and the fatigue life level.

## INTRODUCTION

Previous progress reports and the summary report have presented the results of fatigue testing titanium alloys Ti-75A and RC-130B to determine the influence of various types of surface treatments and notches on the resulting fatigue life characteristics. The present progress report deals with the results obtained on an all-alpha alloyed titanium given surface treatments and notches similar to those evaluated for the Ti-75A and RC-130B.

## EXPERIMENTAL PROCEDURES

The all-alpha alloy tested was an experimental heat produced by Rem-Cru Titanium Company. Its nominal composition is 5% aluminum, 2.5% tin and is coded A-110 AT. The actual analysis and tensile properties as reported by Rem-Cru are given in Table I. During the processing of the fatigue test specimens, an annealing operation consisting of heating for one-half hour in argon is performed at some stage prior to fatigue testing. Tensile properties of this alloy given such a treatment are given in Table I.

The work previously carried out on Ti-75A and RC-130B showed that a shot-peened surface or a ground surface produced the greatest change in the fatigue properties of these alloys as compared to the hand-finished surface which was used as a standard surface for comparative purposes. For this reason these three surfaces were investigated in the A-110 AT alloy. Similarly, the studies of the effect of notches on the fatigue properties of Ti-75A and RC-130B showed that the short radius type of notch was not particularly effective in reducing the fatigue properties so it was eliminated in testing the A-110 AT alloy and a 60° V-notch and a square-notch were used. These notches have theoretical notch sensitivities of 3.2 and 2.4 respectively.

The machining operations used to produce the various surfaces and notched specimens were identical with those used and reported in previous reports of this project.

The actual fatigue data are presented in Tables II and III. The stress-log cycles to failure curves derived from these data are given in Figure 1. As was the case in previous testing, a considerable scatter is evident at any given stress level in most cases. There was no evidence of internal heating which was noted in testing the Ti-75A. As was the case in previous work, the shot-peening improves the fatigue life at the higher stress levels but shows no marked improvement over the hand-finished surface at the lower stress levels. Grinding, as before, appears to be deleterious to the fatigue properties, particularly at the lower stress levels. The effect of notches on the fatigue strength is shown in Figure 2 which is a plot of the fatigue strength reduction factor, defined as the ratio of the hand-finished fatigue strength to the notch fatigue strength, as a function of fatigue life. As in the case of the alloys tested previously this reduction factor is less than the theoretically predicted values and shows an increase with increasing fatigue life.

Table IV is the estimated stress-mean fatigue life data for the surface conditions and notches that have been investigated.

## FUTURE WORK

Considerable time and effort has been spent in attempting to produce ground notches of a controlled root radius. These attempts have not been successful when using the usual alundum or silicon carbide types of wheels since the root radius of the notch cannot be maintained. Recent experiments utilizing diamond grinding techniques have been more successful. Work for the next period will consist of investigating the ground notch properties of Ti-75A, RC-130B and A-110 AT. In addition, the rolled V-notch properties of these alloys will be investigated.

Receipt of an all-alpha alloy (6% Al) and an all-beta alloy (30% Mo) is expected in February and the determination of the fatigue properties of these materials under the test conditions previously used will complete the scope of the program.

TABLE I

Analyses and Mechanical Properties
Heat R-30314

| Carbon | Nitrogen | Aluminum | Tin | Titanium |
|---|---|---|---|---|
| 0.1% | 0.05% | 4.13% | 2.58% | Balance |

| | | |
|---|---|---|
| Yield Strength | 130,800 Psi | (Manufacturer's Rpt.) |
| Tensile Strength | 140,100 Psi | |
| Percent Elongation (2") | 17.8 | |

Annealed 1450°F, 1/2 HR in Argon*

| | |
|---|---|
| Proportional Limit | 124,000 |
| Tensile Strength | 138,100 |
| Percent Elongation (2") | 16.0% |
| Percent Reduction in Area | 40.0% |

*Duplicate specimens

TABLE II

Fatigue Data
Rem-Cru All-Alpha Alloy, Ht R-30314
1000 cycles of stress

Surface

| RM, A, HF* | RM, A, HF, SP* | RM, HF, A, G* |
|---|---|---|
| **100,000 psi** | **95,000 psi** | **90,000 psi** |
| 44 | 206 | 32 |
| 17 | 208 | 23 |
| 75 | 203 | 76 |
| **90,000 psi** | **90,000 psi** | **85,000 psi** |
| 68 | 280 | 76 |
| 225 | 586 | 72 |
| 50 | 448 | 90 |
| **85,000 psi** | **85,000 psi** | **80,000 psi** |
| 55 | 3,036 | 241 |
| 89 | 254 | 60 |
| 129 | 1,077 | |
| **80,000 psi** | **80,000 psi** | **75,000 psi** |
| 768 | 948 | 129 |
| 133 | 3,686 | 103 |
| | 6,917 | 190 |
| **75,000 psi** | **77,500 psi** | **60,000 psi** |
| 10,041 ** | 3,457 | 10,234 ** |
| 10.735 ** | 9,876 | 11,297 ** |
| | 4,009 | 10,189 ** |

* RM = Rough Machine; A = Anneal; HF = Hand Finish; SP = Shot Peen
G = Grind

** Did not fail.

## TABLE III

Fatigue Data, Notched Rotating Beam
Rem-Cru All-Alpha Alloy, Ht R-30314
1000 cycles of stress

| 60° V-Notch | Square Notch |
|---|---|
| **70,000 psi** | **60,000 psi** |
| 6 | 41 |
| | 81 |
| | 47 |
| **60,000 psi** | **55,000 psi** |
| 11 | 151 |
| | 162 |
| **50,000 psi** | **50,000 psi** |
| 29 | 234 |
| | 327 |
| | 174 |
| **40,000 psi** | **45,000 psi** |
| 249 | 11,262 * |
| 84 | 955 |
| 123 | 682 |
| **35,000 psi** | **40,000 psi** |
| 431 | 10,350 * |
| 310 | 10,167 * |
| 343 | 10,877 * |
| **30,000 psi** | |
| 715 | |
| 1,167 | |
| 732 | |
| **25,000 psi** | |
| 10,061 * | |
| 10,298 * | |
| 11,763 * | |

*Did not fail

TABLE IV

Estimated Stress-Mean Fatigue Life Data

| | Cycles | | | |
|---|---|---|---|---|
| | $10^4$ | $10^5$ | $10^6$ | $10^7$ |
| Treatment | | Stress, 1000 psi | | |
| Hand Finished | 120.0 | 84.5 | 77.5 | 76.0 |
| Shot Peened | 125.0 | 103.0 | 83.0 | 76.5 |
| Ground | 108.0 | 77.5 | 64.0 | 62.0 |
| V-Notch | 63.0 | 39.0 | 31.0 | 27.0 |
| Square Notch | 78.0 | 56.5 | 45.5 | 42.5 |

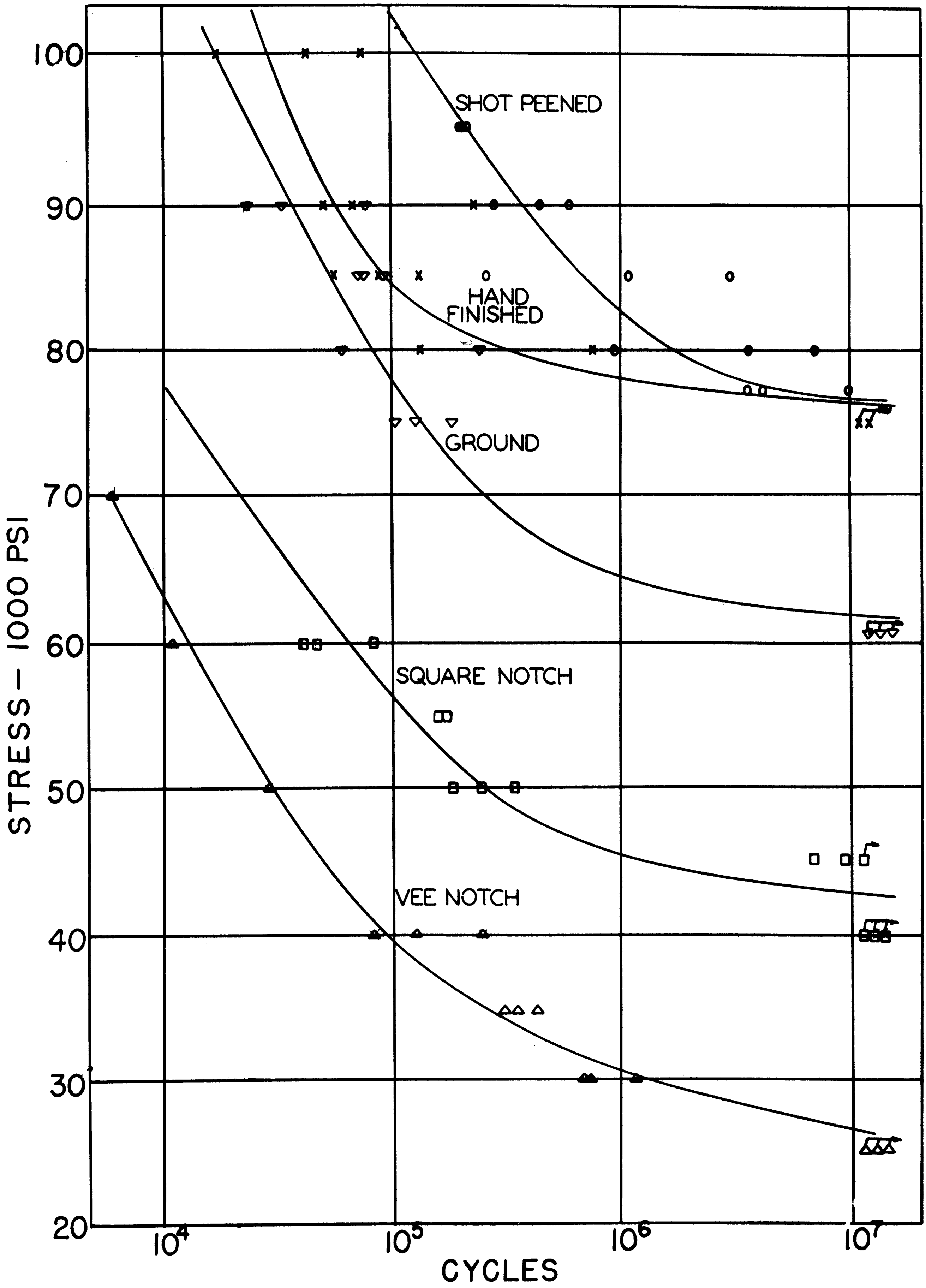


**FIGURE 1. STRESS-CYCLES OF STRESS PLOTS. ANNEALED A-110 AT TITANIUM ALLOY.**

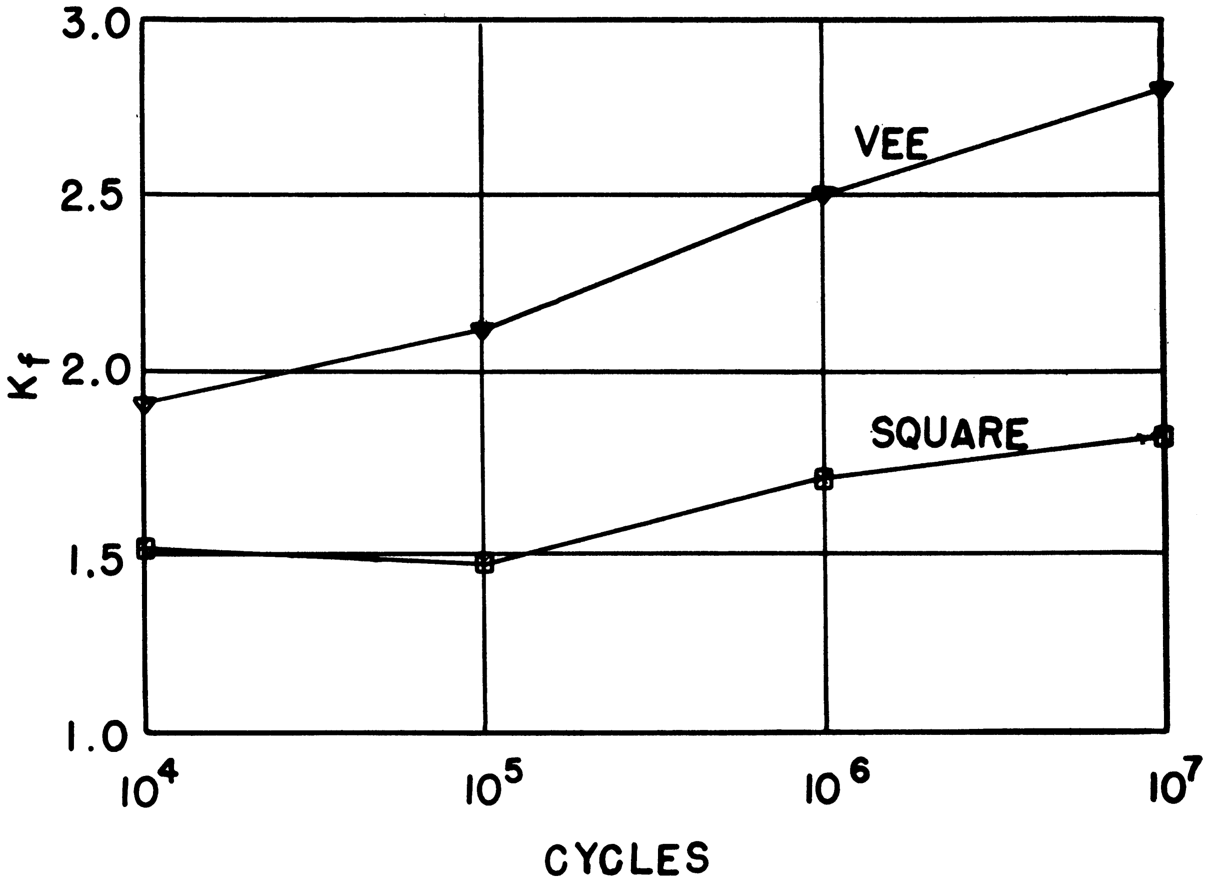


FIGURE 2. FATIGUE STRENGTH REDUCTION FACTOR VERSUS FATIGUE LIFE. A- 110 AT TITANIUM ALLOY.