

FATIGUE OF WROUGHT AND CAST ANNEALED Ti-5Al-2.5Sn TITANIUM ALLOY (In bending and under axial loading)

1. NOTATION

f_p	0.2 per cent proof stress	N/m ²	lbf/in ²
f_t	tensile strength	N/m ²	lbf/in ²
K_t	elastic stress concentration factor based on net area		
N	endurance		
S_a	alternating stress, based on net area	N/m ²	lbf/in ²
S_m	mean stress, based on net area	N/m ²	lbf/in ²
S'_m	mean stress at stress concentration, $K_t S_m$ or $f_p - K_t S_a$ if $K_t(S_a + S_m) > f_p$	N/m ²	lbf/in ²

Both SI and British units are quoted in the notation but throughout the Item only SI units are used. For convenience the following conversion factors are provided.

$$1 \text{ MN/m}^2 = 145.038 \text{ lbf/in}^2$$

$$1 \text{ m} = 39.37 \text{ in.}$$

2. INTRODUCTION

This Item presents data on the fatigue strength of the 5 per cent aluminium, 2.5 per cent tin, titanium alloy at normal room temperature. Data are presented for this alpha phase alloy (alpha transus temperature 950°C) in the annealed condition for forged bar, forged sheet, rolled sheet and castings. The mechanical properties and details of the specimens are given in Table 6.1. The tensile strength and 0.2 per cent proof stresses quoted in the table have been obtained from tests on specimens cut from the same material as were the fatigue test specimens.

3. NOTES

Fatigue data are provided for forged bar specimens axially loaded and in bending, sheet specimens in bending and cast specimens loaded axially. The curves are presented in terms of $K_t S_a / f_t$, so that comparisons of the fatigue strength of plain and notched specimens can be made. The effect of variations in the value of mean stress, represented by the ratio S'_m / f_t , were available only for the cast material data.

4. PRESENTATION OF DATA

4.1 Forged Bar

Figure 1 presents data for plain and notched ($K_t = 4.2$) forged bar axially loaded. Figure 2 presents data for plain and notched ($K_t = 3.6$) forged bar under rotating bending. On these two figures, the curves for the notched data have been drawn by eye using the logarithmic mean endurance and the curves for the plain specimen data have been drawn by eye through the main body of the data. Comparison of these two figures shows that the axially loaded specimens have lower fatigue endurance for given values of $K_t S_a/f_t$ for both the plain and the notched specimens; the difference between the two sets of curves is largest at very high endurance.

4.2 Flat Specimens Made from Rolled Sheet and Forged Sheet

Figure 3 presents data for flat specimens (4 mm thick) in reverse bending made from both rolled sheet and forged sheet. Plain and notched specimen data are presented for specimens made from forged sheet. The plain specimens were considered to be slightly notched, with a $K_t = 1.2$, obtained from Derivation 1. The notched specimens were of two types, one with symmetrical edge notches ($K_t = 6.7$) and the other with a central hole ($K_t = 2.8$). Only plain specimens were made from the rolled sheets with the longitudinal axis of the test pieces cut parallel to the direction of rolling.

Curves have been drawn by eye using the logarithmic mean of each set of data, except the plain specimen forged sheet data where the curve has been drawn by eye through the main body of the data. These particular data show that there is a very significant difference between the fatigue strengths of plain specimens manufactured from rolled sheet and plain specimens manufactured from forged sheet. The rolled sheet specimens have very much higher fatigue strengths than the forged sheet specimens at high endurance and appear to show a fatigue limit at values of $K_t S_a/f_t$ of about 0.6. The differences in endurance between the forged sheet specimens and the rolled sheet specimens are probably due to the differences in their microstructure, the forged sheet specimens tending to have a coarser grain structure than the rolled sheet specimens.

4.3 Machined Cast Alloy

Figures 4 and 5 present data for axially loaded plain and notched flat bar specimens, approximately 1.8 mm thick. These specimens were cut from investment castings that were produced using a “lost-wax” casting process.

Figure 4 presents data for plain specimens and Figure 5 presents data for specimens with symmetrical edge notches ($K_t = 3.0$). On Figure 4, curves have been drawn by eye using the logarithmic mean endurance of the data for two values of mean stress. The scatter in the test results for mean stress values in the range 0.25 to 0.33 was too large for a reasonable curve to be drawn. The large scatter in these test results may be associated with the differences in the microstructure of the individual test specimens. The figure shows that the fatigue strengths of plain specimens made from casting material are sensitive to changes in the value of mean stress. On Figure 5 there are insufficient data for curves to be drawn to show the effects of variations in the values of mean stress on fatigue endurance and therefore only a curve for zero mean stress is presented.

When predicting fatigue lives of components made from cast alloy, it is recommended that testing of samples manufactured by the particular process to be employed be carried out (see Item No. 77027*, Section 7).

* Data Item No. 77027 “Fatigue of wrought and cast Ti-6Al-4V titanium alloy. (In bending and under axial loading)”.

5. DERIVATION

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