# 38-6-44 Figures and Tables

- **74 references**
- **231 Tables and Figures**
- **18 pages Text**

**Listing of all the tables and Figures in 38-6-44 Chapter**

SEM photomicrograph (specimen electropolished in an electrolyte of 60 ml perchloric acid, 600 ml methanol, and 360 ml ethylene glycol; unetched) (Ref. 30)

Figure 1.5.12 Absence of silicides in the β matrix of the Beta-C alloy of 1.5.11 upon heat treatment above the silicide solvus (treatment similar to fast cooling of fusion zones of welds) resulting in a transgranular fracture mode: (a) heat treatment cycle, (b) SEM photomicrograph (specimen electropolished in an electrolyte of 60 ml perchloric acid, 600 ml methanol, and 360 ml ethylene glycol; unetched) (Ref. 30)

Figure 1.5.13 Grain boundary silicide precipitation (which led to a loss in ductility) of the Beta-C alloy of 1.5.12 after heat treatment above the silicide solvus followed by reannealing in the β + silicide field at 1144K (1600F) resulting in almost continuous precipitation of grain boundary silicides that reduce ductility and result in an intergranular fracture mode: (a) heat treatment, (b) SEM photomicrograph (specimen electropolished in an electrolyte of 60 ml perchloric acid, 600 ml methanol, and 360 ml ethylene glycol; unetched) (Ref. 30)

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Figure 1.6.14 Average Rockwell Hardness (five readings) as a function of aging time for 3-inch (7.6 cm) diameter Beta-C bar for 1000F (538C) and 1050F (566C) age temperatures with given solution treatments resulting un-recrystallized (UNRX) and recrystallized (RX) microstructures (Ref. 70)

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Figure 1.9.3 Local fracture initiation stress as a function of total H content (see 1.9.2 for charging conditions) for circumferentially notched tensile specimens of Ti-3Al-8V-6Cr-4Mo-4Zr (0.417 cm diameter with a minimum notch root diameter of 0.241 cm and a notch root radius of 0.054 cm) machined with loading axis parallel to the long axis of the bar: (a) ST (1 h at 815C) for stroke rates from 1 x $10^{-6}$ to 1 x $10^{-3}$ cm/s, and (b) STA (ST + 30 h at 500C) for stroke rates ranging from 2 x $10^{-7}$ to 1 x $10^{-4}$ cm/s; beta lattice H content calculated from $C_{H\beta} = 1.7\ C_{Ho}$. Fracture modes are indicated as MV = microvoid processes, F = flutting, IG = intergranular, C = cleavage, and I = process at or near $\alpha/\beta$ interfaces (Ref. 45)

Figure 1.9.4 Local fracture initiation stress as a function of total H content (see 1.9.2 for charging conditions) for circumferentially notched tensile specimens of Ti-3Al-8V-6Cr-4Mo-4Zr (0.417 cm diameter with a minimum notch root diameter of 0.241 cm and a notch root radius of 0.054 cm) machined with loading axis parallel (L) and transverse (T) to the long axis of the bar with specimens ST + CW to 65% reduction in thickness, tested at a stroke rate of 2 x $10^{-5}$ cm/s (see 1.9.3 for comparison) (Ref. 45)

Figure 1.9.5 Local fracture initiation stress as a function of total H content (see 1.9.2 for charging conditions) for circumferentially notched tensile specimens of Ti-3Al-8V-6Cr-4Mo-4Zr (0.417 cm diameter with a minimum notch root diameter of 0.241 cm and a notch root radius of 0.054 cm) machined with loading axis parallel to the long axis of the bar with specimens: RSTU (resolutinized, heat treated and underaged) – ST (1 h at 815C) + 2 h at 830C + 1.5 h at 500C and RSTA (resolutionized, heat treated and peak aged) – ST + 2 h at 830C + 30 h at 500C, tested at a stroke rate of 2 x $10^{-5}$ cm/s (see 1.9.3 for ST and STA comparison) (Ref. 46)

Figure 1.9.6 Local fracture initiation stress as a function of total H content (see 1.9.2 for charging conditions) for circumferentially notched tensile specimens of Ti-3Al-8V-6Cr-4Mo-4Zr (0.417 cm diameter with a minimum notch root diameter of 0.241 cm and a notch root radius of 0.054 cm) machined with loading axis parallel to the long axis of the bar with specimens: CW –ST + 65% cold worked, ● – ST + 39% cold work + 0.5 h at 500C, ■ – ST + 12 h at 500C, and ▲ – ST + 100 h at 500C (see 1.9.3 for ST and STA comparison) (Ref. 46)

Figure 1.9.7  Variation in the irreversible hydrogen trapping constant ($k_a$ – determined from apparent diffusivity of hydrogen in the metal) which correlates with hydrogen embrittlement (HE) for various solution treated and aged beta titanium alloys, including Beta-C in various aging condition (1.593 cm diameter Beta-C rod was hot rolled. solution treated, centerless ground, and aged at 510C for 5, 10, and 20 h and denoted as 5A, 10A, and 20A) with $k_a$ determined by a potentiostatic pulse technique for hydrogen entry flux for each alloy in 1 mol $1^{-1}$ acetic acid/1 mol $1^{-1}$ sodium acetate + 15 ppm $As_2O_3$ at room temperature (HE susceptibility measured by $k_a$ was consistent with relative resistance to HE for these alloys) (Ref. 47)

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Figure 2.3.2.1  Effect of test environment on resistance to stress corrosion cracking of

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Figure 2.3.2.3  Yield strength dependence of the lower bound and standardized air fracture toughness compared with the threshold stress intensity factor for side grooved compact tension (CT) specimens* machined from solution treated (815C/1 h/AC) plus aged (STA) Beta-C bar (plane perpendicular to the longitudinal axis of the bar with crack growth in the radial direction) for experiments conducted at 25C in either moist air or 0.6 M (3.5 wt.%) aqueous NaCl (pH = 5-6) solution at a fixed electrode potential of -150 mV SCE (aqueous NaCl fracture modes for each range of $\sigma_{YS}$ are indicated) (Ref. 39)

Figure Note on Figure:  TG – Transgranular,  MVC – Microvoid nucleation, growth and coalescence.

Figure 2.3.2.4  Air fracture toughness and threshold stress as a function of yield strength and cold work reduction for side grooved compact tension (CT) specimens* machined from solution treated (815C/1 h/AC) plus 20-65% cold rolled (ST/CW) Beta-C bar sections for experiments conducted at 25C in either moist air or 0.6 M (3.5 wt.%) aqueous NaCl (pH = 5-6) solution at a fixed electrode potential of -150 mV SCE (the fracture mode for both air and aqueous NaCl exposure is indicated and the dashed trend lines for the STA data in 2.3.2.3 are shown) (Ref. 39)

Figure 2.3.2.5  Rapid crack growth rate (da/dt) as a function of applied stress intensity factor (K) for side grooved CT specimens* machined from solution treated (815C/1 h/AC) plus aged (STA) and ST/CW/A Beta-C bar sections in aqueous NaCl solution with crack growth rates calculated from direct current potential difference based crack length (a) *versus* time (t) (see also 2.3.2.3 and 2.3.2.4) (Ref. 39)

Figure *The ST/CW and ST/CW/A specimens for 2.3.2.3, 2.3.2.4, and 2.3.2.5 were in the T-L orientation with the crack plane perpendicular to the rolling plane and crack growth parallel to the cold rolling direction (the original longitudinal axis). Additional ST/CW (65%) Beta-C specimens were in the LT orientation (crack growth perpendicular to the rolling direction). All specimens except ST/CW had a net thickness ($B_n$) of 5.1 mm and width (W) of 30 mm, except that the ST/CW (65%) specimens had reduced thickness with $B_n$ = 3.8 mm. The CT specimens were fatigue pre-cracked in moist air, terminating with a $K_{max}$ = 15 MPa√m and a crack length-to-width ratio of 0.53. (Ref. 39)

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Figure 2.3.2.11  Room temperature fatigue crack growth (*da/dN*) as a function of stress intensity (ΔK) measured in compact tensile (CT) specimens oriented in the L-T direction for as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate for as solution heat treated (SHT) material with tensile properties given in 3.2.1.40 (no noticeable acceleration of crack growth rate occurred in going from air to a salt water environment or when frequency was reduced so data are presented as a single scatterband) (Ref. 71)

Figure 2.3.2.12  Room temperature fatigue crack growth (*da/dN*) as a function of stress intensity (ΔK) measured in compact tensile (CT) specimens oriented in the L-T direction for as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate for as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate solution treated (ST) at 800C (LO – 45 μm grain size and 20 vol % unrecrystallized β grains) and aged in an Ar atmosphere after LO-ST in a single step (Simplex) and in a two-step (Duplex) process, with tensile properties given in 3.2.1.40 (no noticeable acceleration of crack growth rate occurred in going from air to a salt water environment or when frequency was reduced so data are presented as a single scatterband) (compare with 2.3.2.13) (Ref. 71)

Figure 2.3.2.13  Room temperature fatigue crack growth (*da/dN*) as a function of stress intensity (ΔK) measured in compact tensile (CT) specimens oriented in the L-T direction for as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate solution treated (ST) at 927C (HI – 160 μm grain size and fully recrystallized) and aged in an Ar atmosphere after HI ST in a single step (Simplex) and in a two-step (Duplex) process, with tensile properties given in 3.2.1.40 (no noticeable acceleration of crack growth rate occurred in going from air to a salt water environment or when frequency was reduced so data are presented as a single scatterband) (compare with 2.3.1.12) (Ref. 71)

Table 3.1.1  AMS specified minimum (single values) or range of room temperature tensile properties of Grade 19 and 20 alloys in different product forms and conditions (Refs. 5-8)

Table 3.1.2  ASTM specified minimum (single values) or range of room temperature tensile properties of Grade 19 and 20 alloys in different product forms and conditions (Refs. 9-14)

Table 3.2.1.1  Room temperature tensile properties of solution treated and aged (STA) Ti-3Al-8V-6Cr-4Mo-4Zr (Beta-C) in various product forms (Ref. 2)

Table 3.2.1.2  Room temperature tensile properties of Ti-3Al-8V-6Cr-4Mo-4Zr (Beta-C) wire in various conditions (Ref. 2)

Table 3.2.1.3 Effect of solution annealing and aging temperatures on room temperature tensile properties of Beta-C bar (Ref. 20)

Table 3.2.1.4 Tensile properties of solution treated and aged (STA) and preaged and solution treated and aged (PASTA) Beta-C cold pilgered pipe (see 1.5.17) (Ref. 34)

Table 3.2.1.5 Tensile properties of solution treated and aged (STA) and preaged and solution treated and aged (PASTA) Beta-C/Pd cold pilgered pipe (see 3.2.1.4) (Ref. 34)

Figure 3.2.1.6 Room temperature tensile properties of 0.373 in. diameter rod of ATI 38-644 (UNS R58640) titanium alloy after solution treatment, cold drawing, and aging (900F/6 h/air cool) as a function of cold drawing percentage (Ref. 3)

Table 3.2.1.7 Room temperature tensile test results performed on Ti 38-644 (Beta-C) alloy bars extruded at 920C from a 170 mm diameter ingot after solution treatment and single-step aging (A) and duplex aging treatments involving pre-aging (PA) and final aging (FA), and tensile fracture surfaces exhibiting crack propagation as intergranular in the single-step aged material and transgranular in the duplex aged material (see 1.5.20 and 1.5.21 for metallographs, 3.2.1.8 for SEM fractographs, and 3.5.1.4 for fatigue results) (Ref. 36)

Figure 3.2.1.8 SEM fractographs of tensile samples of Ti 38-644 (Beta -C) alloy: (a) simplex aged (ST at 815C/1 h + A at 480C/28 h) exhibiting intergranular fracture and (b) duplex aged (ST at 920C/30 min. + PA at 440C/12 h + FA at 500C/24 h) exhibiting transgranular fracture (see 3.2.1.7 for tensile test results and 3.5.1.4 for fatigue results) (Ref. 36)

Figure 3.2.1.9 Room temperature tensile stress-strain curves for Ti Beta-C tensile specimens machined from 19.05 mm diameter rod, annealed at 800C/0.5 h/AQ + solution treated at 850C/1 h/WQ (BC Annealed), and aged at 455C/24 h/AQ (BC AG 455), 495C/24 h/AQ (BC AG 495), and 540C/24 h/AQ (BC AG 540) (Ref. 38)

Figure 3.2.1.10 Room temperature ultimate tensile strength of Ti Beta-C tensile specimens machined from 19.05 mm diameter rod, annealed at 800C/0.5 h/AQ + solution treated at 850C/1 h/WQ (Annealed), and aged at 455C/24 h/AQ (AG 455), 495C/24 h/AQ (AG 495), and 540C/24 h/AQ (AG 540) (see 3.2.1.8) (Ref. 38)

Table 3.2.1.11 Room temperature tensile properties of Ti Beta-C alloy hot rolled and solution annealed sheet (0.065 in. thick, 1600F/30 min/AQ) in the longitudinal (L) and transverse (T) directions as a function of aging treatment (Ref. 50)

Figure 3.2.1.12 Longitudinal Ti-3Al-8V-6Cr-4Mo-4Zr stress-strain curves at room and elevated temperatures for the solution treated plus aged (STA) condition (Ref. 1)

Figure 3.2.1.13 Transverse Ti-3Al-8V-6Cr-4Mo-4Zr stress-strain curves at room and elevated temperatures for the solution treated plus aged *STA) condition (Ref. 1)

Figure 3.2.1.14 Effect of annealing temperature on room temperature tensile properties of 0.312 in. Ti-3Al-8V-6Cr-4Mo-4Zr round cold drawn fastener stock (Ref. 1)

Figure 3.2.1.15 Effect of cold work on room temperature tensile properties of Ti-3Al-8V-6Cr-4Mo-4Zr fastener stock in two solution annealed conditions (Ref. 1)

Figure 3.2.1.16 Effect of aging on room temperature mechanical properties of Ti-3Al-8V-6Cr-4Mo-4Zr fastener stock cold drawn various percentages (Ref. 1)

Figure 3.2.1.17 Effect of aging temperature on room temperature tensile properties of cold worked Ti-3Al-8V-6Cr-4Mo-4Zr tubing (Ref. 1)

Figure 3.2.1.18 Effect of annealing temperature on room temperature tensile properties of cold worked Ti-3Al-8V-6Cr-4Mo-4Zr tubing (Ref. 1)

Figure 3.2.1.19 Effect of aging temperature on the room temperature tensile properties of annealed Ti-3Al-8V-6Cr-4Mo-4Zr tubing (Ref. 1)

Table 3.2.1.20 Room temperature tensile properties of as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate solution treated (ST) at 800C (LO – 45 μm grain size and 20 vol % unrecrystallized β grains) and at 927C (HI – 160 μm grain size and fully recrystallized) and aged in an Ar atmosphere after LO and HI ST in a single step (Simplex) and in a two-step (Duplex) process (Ref. 71)

grain structure, as a function of aging temperature (see 1.6.14-1.6.15 and 3.2.1.39) (Ref. 70)

Figure 3.2.1.39 Room temperature longitudinal (a) and transverse (b) tensile strength and ductility for hot rolled 3-inch (7.6 cm) diameter Beta-C bar solution treated at 1550F (842C), which resulted in a recrystallized (RX) grain structure, as a function of aging temperature (see 1.6.14-1.6.12.1.38) (Ref. 70)

Figure 3.2.2.1 (see Figure 3.3.2.1) Typical Ti-3Al-8V-6Cr-4Mo-4Zr longitudinal compressive stress-strain curves at room and elevated temperature for the solution treated plus aged (STA) condition (Ref. 1)

Figure 3.2.2.2 (see Figure 3.3.2.2) Typical Ti-3Al-8V-6Cr-4Mo-4Zr transverse compressive stress-strain curves at room and elevated temperature for the solution treated plus aged (STA) condition (Ref. 1)

Table 3.2.2.3 Room temperature compressive properties of Ti Beta-C alloy hot rolled and solution annealed sheet (0.065 in. thick, 1600F/30 min/AQ) in the longitudinal (L) and transverse (T) directions as a function of aging treatment (Ref. 50)

Table 3.2.2.4 Room temperature compressive properties of hot rolled Beta-C alloy sheet (0.065 in. thick) with different processing cycles (Ref. 50)

Table 3.2.3.1 Effect of solution treatment conditions on the dynamic fracture toughness ($K_d$) and average grain size ($L_{avg}$) of RMI 38644 plate (1.59 cm thick) for conventional unprecracked Charpy V-notch specimens determined in the L-S direction at an initial impact velocity of 130 in./s (Fracture Load – $P_F$ and General Yield Load – $P_{GY}$) (Ref. 66)

Table 3.2.5.1 Effect of solution treatment temperature on room temperature torsion, modulus, longitudinal and 45° tensile properties of fine grained Ti-38-6-44 bar (Refs. 1, 52)

Table 3.2.5.2 Effect of aging treatment after production annealing at 1,700F/30 min./AC followed by laboratory annealing at 1,500/30 min/AC on torsion and tension properties of 2.625 in. diameter Ti-3Al-8V-6Cr-4Mo-4Zr bar (Ref. 1)

Table 3.2.5.3 Tensile and double shear test results for Beta-C 3/8-24 bolts in the solution treated (1,500F) plus aged (950F) condition (Ref. 52)

Figure 3.2.5.4 Double shear strength of Beta-C bar (0.6 in. diameter) produced from double vacuum arc remelted (VAR) and the more economical single melt plasma arc melted (PAM) ingots (see 1.8.1 and 3.2.1.28) (Ref. 55)

Table 3.2.5.5 Double shear strength of direct aged Beta-C and Ti-185 wire both produced from single melt plasma arc melted (PAM) ingot hot rolled from 120 to 35 mm diameter on a two-high reversing mill, reheated and further processed to 12 mm hot rolled coil, then further processed to by wire drawing to finished size ranging from 7.4 to 8 mm diameter (Beta-C was finished in as cold worked condition per AMS 4957 and Ti-185 was finished in the annealed condition) (Ref. 32)

Table 3.2.5.6 Double shear strength as a function of ultimate tensile strength for Beta-C and candidate titanium alloys for high strength fastener applications (Ref. 60)

Table 3.2.5.7 Room temperature shear strength of Beta-C alloy fastener stock (0.312 in diameter) heat treated as indicated and before exposure to high temperature (see 3.2.5.8 for data after exposure) (Ref. 57)

Table 3.2.5.8 Room temperature shear strength of Beta-C alloy fastener stock (0.312 in diameter) heat treated as indicated and after exposure to to 285C (550F) temperature for 500 h (see 3.2.5.7 for pre-exposure data) (Ref. 57)

Table 3.2.7.1.1 Notch strength ($K_t$ = 3.5) of Beta-C and Ti-185 wire both produced from single melt plasma arc melted (PAM) ingot hot rolled from 120 to 35 mm diameter on a two-high reversing mill, reheated and further processed to 12 mm hot rolled coil, then further processed to by wire drawing to finished size ranging from 7.4 to 8 mm diameter (Beta-C was finished in as cold worked condition per AMS 4957 and Ti-185 was finished in the annealed condition) (Ref. 32)

Table 3.2.7.1.2 Comparison of standard room temperature tensile and notched tensile data for Beta-C and candidate titanium alloys for high strength fastener applications (Ref. 60)

Table 3.2.7.2.1 Plane strain fracture toughness properties at room temperature of Ti-3Al-8V-6Cr-4Mo-4Zr for specimens solution annealed at 1500F/15 min/AC plus aged at 1050F/12 h/AC (Ref. 1)

Figure 3.2.7.2.2 Fracture toughness of Ti Beta-C at room temperature as a function of yield strength compared with other titanium alloys (Ref. 2)

Figure 3.2.7.2.3 Effect of solution treatment temperature on room temperature strength-toughness (a) and strength-ductility (b) trends of extruded and heat treated Beta-C alloy showing that the best combination of strength and fracture toughness is achieved using a relatively high temperature beta solution heat treatment at 1700F (strength on horizontal axis is given in ksi) (Ref. 20)

Table 3.2.7.2.4 Room temperature fracture toughness of specimens taken from a 75 mm (3 in.) heat treated Beta-C bar (Ref. 57)

Table 3.2.7.2.5 Room temperature fracture toughness of heat treated Beta-C billet, forging, and plate (Ref. 57)

Table 3.2.7.2.6 Room temperature fracture toughness ($K_{Ic}$) measured on duplicate compact tension specimens machined from hot rolled 3-inch (7.6 cm) diameter Beta-C bar in the solution treated and aged (STA) condition and oriented in C-R and R-L directions (ST at 1450F and 1550F resulted in an unrecrystallized (UNRX) and recrystallized (RX) grain structure respectively) (see 3.3.3.1) (Ref. 70)

Figure 3.2.7.2.7 Values of room temperature J-integral ($J_{0.2}$ for STA material or upper and lower bounds for ST material) for as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate solution treated (ST) at 800C (LO – 45 µm grain size and 20 vol % unrecrystallized β grains) and at 927C (HI – 160 µm grain size and fully recrystallized) and aged (STA) in an Ar atmosphere after LO and HI ST in a single step (Simplex) and in a two-step (Duplex) process (tensile properties given in 3.2.1.40) (Ref. 71)

Table 3.2.7.2.8 Room temperature fracture toughness ($K_J$ calculated from $J_{0.2}$ per ASTM E813), tearing modulus (T = dJ/da from 3.2.7.2.7), and plastic zone size ($r_p$) results from compact tensile (CT) specimens oriented in the L-T direction for as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate solution treated (ST) at 800C (LO – 45 µm grain size and 20 vol % unrecrystallized β grains) and at 927C (HI – 160 µm grain size and fully recrystallized) and aged (STA) in an Ar atmosphere after LO and HI ST in a single step (Simplex) and in a two-step (Duplex) process (tensile properties given in 3.2.1.40 and $J_{0.2}$ values in 3.2.7.2.7) (Ref. 71)

Figure 3.2.7.2.9 Fracture toughness ($J_{0.2}$) results as a function of yield stress measured in compact tensile (CT) specimens oriented in the L-T direction for as-received hot rolled (3.5 mm thick) Ti-3Al-8V-6Cr-4Mo-4Zr plate solution treated (ST) at 800C (LO – 45 µm grain size and 20 vol % unrecrystallized β grains) and at 927C (HI – 160 µm grain size and fully recrystallized) and aged (STA) in an Ar atmosphere after LO and HI ST in a single step (Simplex) and in a two-step (Duplex) process (tensile properties given in 3.2.1.40 and $J_{0.2}$ values in 3.2.7.2.7) (Ref. 71)

Figure 3.3.1.1 Yield strength/density ratio as a function of temperature for Ti Beta-C and competitive metals and alloys (Ref. 2)

Table 3.3.1.2 Typical elevated temperature properties of grade 19 (Ti Beta-C) and 20 (Ti Beta-C/Pd) alloys in the solution treated (ST) and solution treated and aged (STA) conditions (Ref. 2)

Figure 3.3.1.3 Elevated tensile properties of 0.500 in. diameter bar of ATI 38-644 beta Ti alloy (UNS R58640) in the STA condition: solution treated (1,500F) and aged (1,050F/6 h/air cool) (Ref. 3)

Table 3.3.1.4 Short-time tensile test results at 600F of Ti Beta-C alloy hot rolled and solution annealed sheet (0.065 in. thick, 1600F/30 min/AQ) tested in the longitudinal direction as a function of aging treatment (Ref. 50)

Table 3.3.1.5 Tensile test results at -65F of hot rolled Beta-C alloy sheet (0.065 in. thick) with different processing cycles (Ref. 50)

Table 3.3.1.6 Tensile test results at 600F of hot rolled Beta-C alloy sheet (0.065 in. thick) with different processing cycles (Ref. 50)

Table 3.3.1.7 Tensile properties at 600F of induction melted and investment cast Ti-38644 test bars (six 0.250 in. diameter test bars bottom poured from in a cluster in molds coated with pyrolytic graphite), heat treated at 1350F/15 min/rapid cool + 1100F/8 h/rapid cool, and sand blasted before testing (see 3.2.1.26 for room temperature tensile properties) (Ref. 51)

Figure 3.3.1.8 Tensile properties at 600F of induction melted and investment cast test bars of various titanium alloys including Ti-38644 (six 0.250 in. diameter test bars bottom poured from in a cluster in molds coated with pyrolytic graphite) in the solution treated and aged condition after sand blasting before testing (see 3.3.1.27 for room temperature tensile properties) (Ref. 51)

Figure 3.3.1.9 Effect of test temperature on tensile properties of Ti-3Al-8V-6Cr-4Mo-4Zr bar in the solution annealed condition (Ref. 1)

Beta-C under tension-compression equal to 700 MPa and under rotating bending equal to 745 MPa (see 3.2.1.7 for tensile test results and 3.2.1.8 for SEM fractographs) (Ref. 36)

Figure 3.5.1.5 Crack propagation curves da/dN as a function of ΔK obtained at R = 0.1 in fully recrystallized (solution annealed at 920C/30 min), direct aged to intermediate strength, and duplex aged (solution annealed 920C/30 min + 440C/12 h + 500C/24 h) Beta-C alloy, with inserts illustrating fatigue crack propagation profiles in relation to microstructural features in (a) duplex aged and (b) solution annealed Beta-C (see 3.2.1.7 for tensile results and 3.5.1.4 for fatigue data) (Ref. 36)

Table 3.5.1.6 Long crack propagation threshold $\Delta K_{th}$-values determined by the indirect electric potential method for Beta-C specimens in 3.5.1.6 (Ref. 36)

Table 3.5.1.7 Fatigue limit at $10^7$ cycles of Beta-C alloy (beta transus, $\beta_t$ = 732C) in various conditions with different microstructures (Ref. 49)

Figure 3.5.1.8 S-N curves for Ti-3Al-8V-6Cr-4Mo-4Zr at elevated temperatures for smooth and notched specimens in the solution treated plus aged (STA) condition at a stress ratio of R = 0.1 (Ref. 1)

Table 3.5.1.9 Room temperature smooth tension-tension fatigue tests performed at 60 Hz (R = 0.1) on samples machined from coil per ASTM E-466 for Beta-C and candidate titanium alloys for high strength fastener applications (duplicate samples run at 724 MPa or 48-53% of UTS and tests terminated after 1 million cycles) (Ref. 60)

Figure 3.5.1.10 Effects of cold work and tensile strength on the log average fatigue life of Ti-3Al-8V-6Cr-4Mo-4Zr wire of 0.392 in. (10 mm) diameter, shot peened to 0.016-0.018A Almen intensity, with each data point representing the log average of six tests conducted using 3-point bend specimens (Ti-13V-11Cr-3Al data points included for comparison) (Ref. 54)

Figure 3.5.1.11 Effect of surface finish prior to shot peening to 0.016-0.018A Almen intensity on fatigue life at two stress levels for 0.353 in. (9 mm) diameter Ti-3Al-8V-6Cr-4Mo-4Zr wire, with each data point representing the log average of six tests conducted using 3-point bend specimens (Ref. 54)

Figure 3.5.1.12 Fatigue life as a function of tensile strength for recrystallized and unrecrystallized Ti-3Al-8V-6Cr-4Mo-4Zr wire shot peened to 0.016-0.018A Almen intensity, with each data point representing the log average of six tests conducted using 3-point bend specimens (Ref. 54)

Table 3.5.1.13 *[Table}* Fatigues test results on rigid prototype production springs fabricated from Ti 38-6-44 wire that was cold worked, heat treated, and shot peened (Ref. 54)

Figure 3.5.1.14 Fatigue crack growth as a function of stress intensity range for compact tension specimens of Beta-C alloy solution treated at 900C/30 min/WQ and aged at 350 and 500C with a comparison with data for Ti-6-4 (Ref. 62)

Figure 3.5.2.1 Room temperature fatigue data generated at 1034 MPa (150 ksi) maximum strength, R = 0.1, and a cyclic rate of 30 Hz for Beta-C alloy bar in the heat treated condition (see 3.2.1.28 for STA conditions) from VAR and single melt PAM ingots (initial PAM data generated at the topmost or low cycle region of the fatigue curve seem to lie within the portion of the curve that would be predicted based on STA bar from VAR ingot) (Ref. 55)

Figure 3.5.2.2 Cyclic stress response behavior of solution treated (ST – 925C/WQ) and aged (see 1.6.12) Beta-C alloy cylindrical specimens (gage = 0.120 in. diameter by 0.32 in. length) tested in completely reversed strain cycling tested under constant plastic strain ($\varepsilon_p$) and constant total strain ($\varepsilon_T$) on an Instron machine at 2 x $10^{-3}$ $sec^{-1}$ strain rate (Ref. 65)

Figure 3.5.2.3 Monotonic and cyclic stress-strain curves of solution treated (ST – 925C/WQ) and solution treated and aged Beta C (cyclic flow stress is appreciable lower than the monotonic flow stress due to cyclic softening of the alloy exhibited in 3.5.2.2 at which the cyclic work hardening exponent (defined as n′ = dlnσ/dln*c*, where σ is cyclic stress and *c* is cyclic strain) has a value of 0.07 (Ref. 65)

Figure 3.6.2.1 Elastic modulus of ATI 38-644 (UNS R58640) at room temperature as a function of tensile strength (composite modulus line was estimated using results from various degrees of cold drawing + aging process routes) (Ref. 3)

Figure 3.6.2.2 Elastic modulus as a function of tensile yield strength of Beta-C alloy at room temperature (Ref. 57)

Figure 3.6.2.3 Room temperature tensile modulus of elasticity of RMI 38-6-44 sheet (0.5 cm thick) as a function of aging time at 538C for material solution treated at 816C for 1 h in a vacuum furnace, argon quenched, and cold worked 40 and 80% (Ref. 61)

for 24 h resulted in a high ultimate tensile strength (UTS) of 200 ksi and a low elongation of 2.5%, while the increased aging temperature of 1100F for 8 h promoted coarser α-phase precipitation with a UTS of only 163 ksi with an increased elongation of 8%) (Ref. 74)

Figure 4.4.1 Effectiveness of an aluminum-based oxidation protective coating on titanium (coating was developed for titanium by Nippon Steel and consists of aluminum flakes coated with stearic acid) (Ref. 59)