JMEPEG (2005) 14:788-791
DOI: 10.1361/105994905X75628

1059-9495/$19.00

Properties of TIMETAL 555 (Ti-5Al-5Mo-5V-3Cr-0.6Fe)

J.C. Fanning

(Submitted August 24, 2005)

TIMETAL 555 is a high-strength near-β titanium alloy that was designed for improved producibility and excellent mechanical property combinations, including deep hardenability. The nominal chemical composition of TIMETAL 555 is Ti-5wt.%Al-5wt.%Mo-5wt.%V-3wt.%Cr. This article provides a summary of the available data for this relatively new alloy.

Keywords forgings, strength, titanium, toughness

1. Background

The concept for the alloy was publicly introduced in 1997 as an improved version of the Russian alloy VT-22 (Ref 1). Since then, TIMET has been manufacturing and evaluating TIMETAL 555 for a variety of aerospace applications.

2. Manufacturing

2.1 Melting

TIMETAL 555 is currently melted by the multiple vacuum arc-remelting process at TIMET in Henderson, NV, and in Savoie, France. The typical ingot sizes produced are 812 mm (32 in.) and 910 mm (36 in.) in diameter. The conversion of ingot to intermediate and final products was performed at TIMET facilities in Toronto, Ohio, the United Kingdom, and France.

2.2 Conversion

Forging is similar to that of TIMETAL 10-2-3, except that the higher β transus enables forging operations to be performed at a temperature approximately 56 °C (100 °F) higher.

2.3 Chemical Composition

The typical chemical composition is provided in Table 1.

3. Physical Properties

- Average β transus (T_β): 856 °C (1572 °F)
- Density: 4.65 g/cm^3 (0.168 lb/in.^{3})
- Thermal expansion: Fig. 1
- Tensile elastic modulus (solution-treated and aged [STA] condition): 112 GPa (16.2 Msi)
- Compressive elastic modulus (STA condition): 113 GPa (16.3 Msi)

This paper was presented at the Beta Titanium Alloys of the 00's Symposium sponsored by the Titanium Committee of TMS, held during the 2005 TMS Annual Meeting & Exhibition, February 13-16, 2005 in San Francisco, CA.

J.C. Fanning, TIMET Henderson Technical Lab. P.O. Box 2128, Henderson, NV 89015. Contact e-mail: john.fanning@TIMET.com.

4. Heat Treatment

4.1 Solution Treated and Aged

Typical solution heat treatment temperatures are subtransus at 28 to 56 °C (50-100 °F) below T_β. Air cooling or fan air cooling is used for sections up to approximately 127 mm (5 in.) thick. Slower cooling rates are sometimes used to improve fracture toughness. Aging is typically performed between 560 and 677 °C (1040 and 1250 °F).

5. Mechanical Properties

5.1 Fastener Stock

Several different sizes of fastener stock have been manufactured. Mechanical property trends for 10.7 mm (0.42 in.) product are summarized in Fig. 2.

5.2 Bar

Tensile, compression, and shear results for the bar are provided in Table 2.

5.3 Billet

The results of a heat treatment study of 178 mm (7 in.) diameter billet are summarized in Fig. 3 and 4. Microstructures and correlative mechanical properties are provided in Fig. 5 and correlative mechanical properties are provided in Table 3. Typical properties for 76 × 152 mm (3 × 5 in.) billet are provided in Table 4.

5.4 Die Forgings

Large die forgings in several configurations (including a Boeing 777 main landing gear truck beam [Ref 2]) have been manufactured and evaluated with satisfactory results. Fatigue life results are provided in Fig. 6.

Table 1 Chemical composition of TIMETAL 555 in weight percent

Element	Minimum	Nominal	Maximum
Aluminum	4.4	5	5.7
Molybdenum	4.0	5	5.5
Vanadium	4.0	5	5.5
Chromium	2.5	3	3.5
Iron	0.3	0.4	0.5

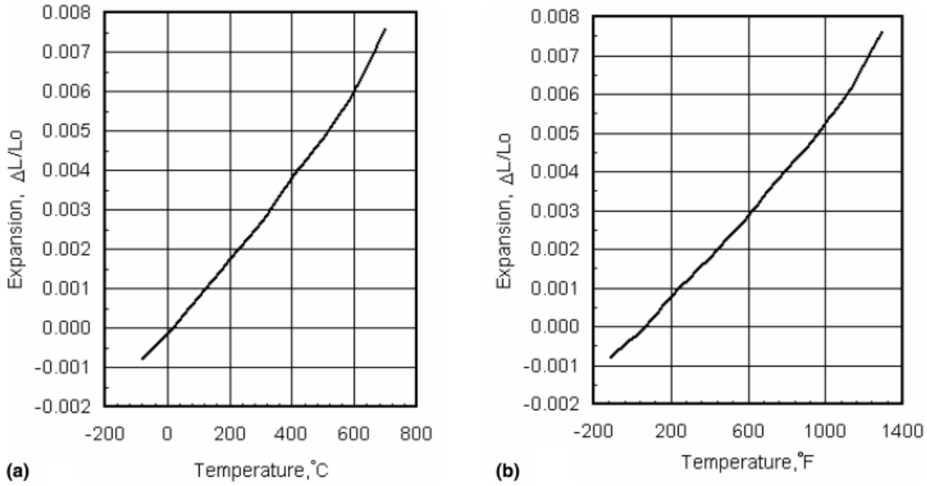

Fig. 1 Effect of test temperature on the thermal expansion of TIMETAL 555 referenced to 20 °C (68 °F). (a) SI units and (b) English units

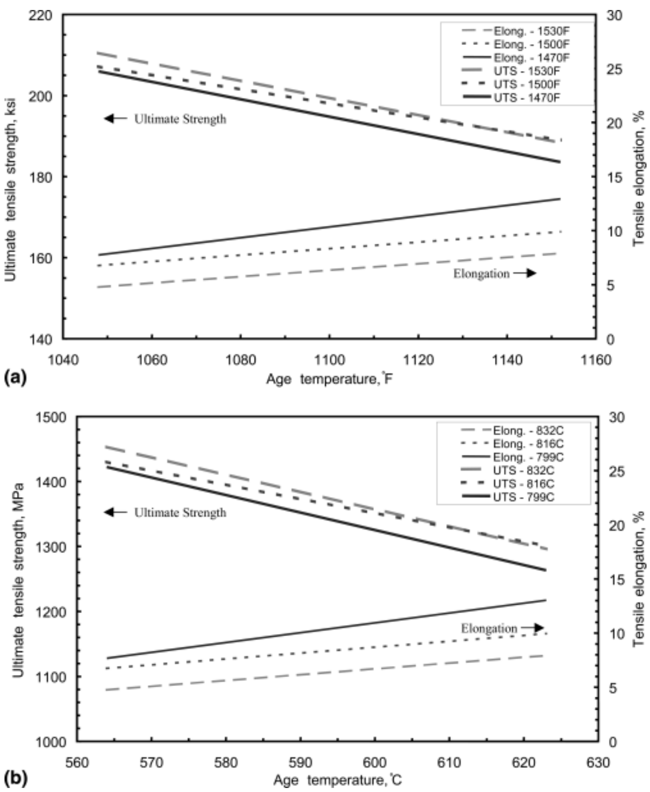

Fig. 2 Ultimate tensile strength (UTS) and tensile elongation (Elong) for TIMETAL 555 10.7 mm (0.42 in.) fastener stock after air-cooling from the noted solution heat treatment temperature then aging for 8 h. (a) English units and (b) SI units)

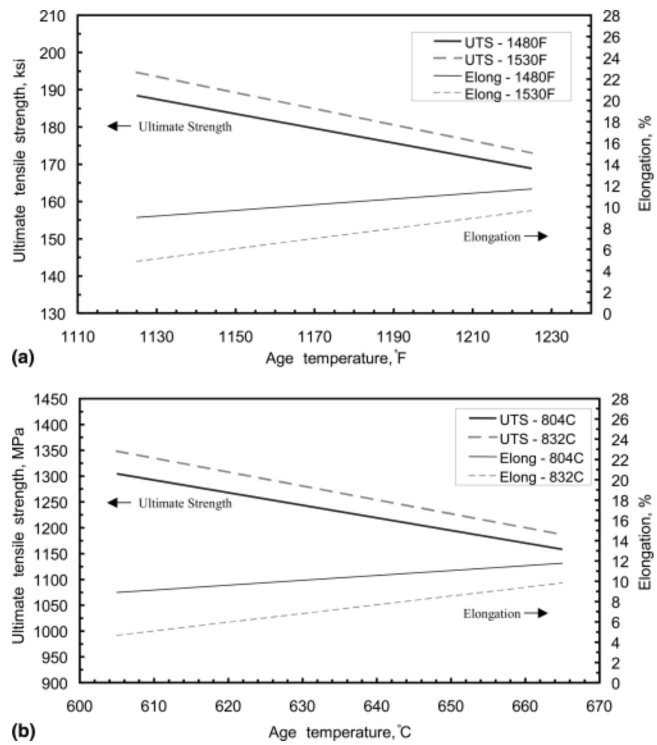

Fig. 3 Ultimate tensile strength (UTS) and tensile elongation (Elong) versus aging temperature (8 h) for 7 in. (178 mm) diameter × 3.5 in. (89 mm) long TIMETAL 555 billet, Heat H2597, solution heat-treated at 1480 °F (804 °C) or 1530 °F (832 °C). Each data point is the average of the results for edge, midradius, and center billet positions. (a) English units and (b) SI units are given.

Table 2 Average longitudinal mechanical properties of TIMETAL 555 22 mm (0.87 in.) bar in solution heat treated plus aged condition

Tensile mechanical properties					
Ultimate, ksi (MPa)	Yield @ 0.2%, ksi (MPa)	El (4D), %	RA %	Compression yield @ 0.2%, ksi (MPa)	Shear ultimate, ksi (MPa)
179.2 (1236)	170.3 (1174)	13	25.4	…	…
…	…	…	…	170.1 (1173)	…
…	…	…	…	…	99.5 (686)

5.5 Sheet and Plate

Although primarily intended as a forging alloy, developmental quantities of sheet and plate have also been manufactured. Properties from these initial trials are provided in Tables 5 and 6.

6. Machinability

The alloy is reportedly more difficult to machine than Ti-6Al-4V or Ti-10V-2Fe-3Al. The main difficulty with machining in the STA condition is tool wear. The as-forged

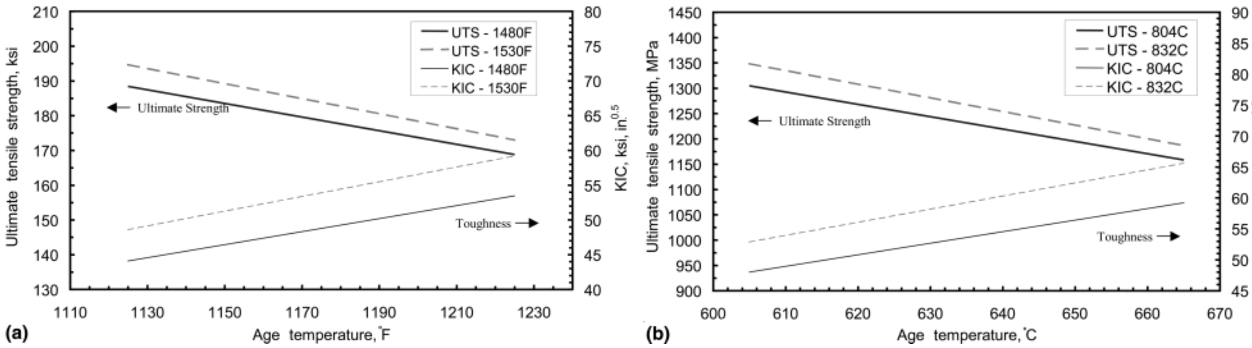

Fig. 4 Ultimate tensile strength (UTS) and fracture toughness (K_{Ic}) versus aging temperature (8 h) for 7 in. (178 mm) diameter × 3.5 in. (89 mm) long TIMETAL 555 billet, Heat H2597, solution heat-treated at 1480 °F (804 °C) or 1530 °F (832 °C). Each data point for strength is the average of results for edge, midradius, and center billet positions. Each data point for fracture toughness is a single value from the midradius billet position. (a) English units and (b) SI units are given.

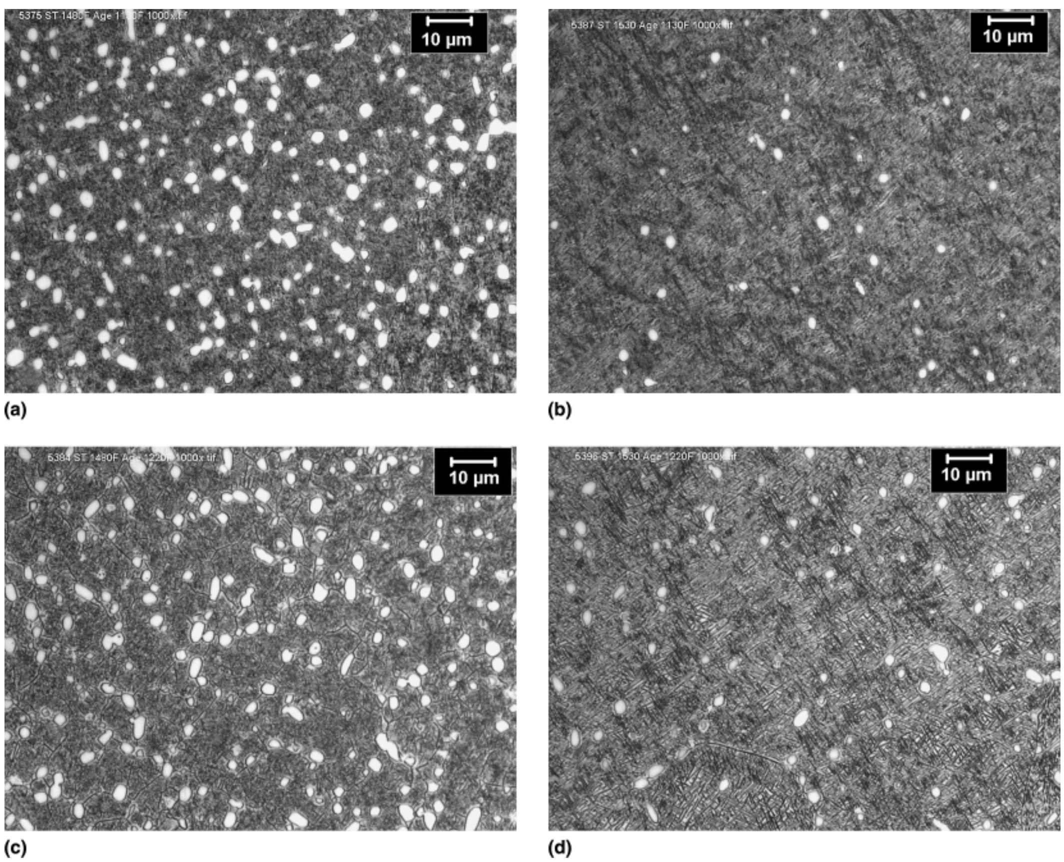

Fig. 5 Photomicrographs of 178 mm (7 in.) TIMETAL 555 billet in several different STA conditions

Table 3 Correlative mechanical properties for TIMETAL 555 billet microstructures shown in Fig. 5

	Heat treat		L tensile properties				Toughness	Shear and compression	
Fig.	ST(1), C	Age(2), C	UTS, MPa	TYS, MPa	Elong, %	RA, %	L-T K_{Ic}, MPa $m^{0.5}$	L SUS, MPa	L CYS, MPa
5(a)	804	610	1294	1218	7	21	48.8	729.5	1274
5(b)	804	660	1163	1100	13	32	58.4	698.5	1159
5(c)	832	610	1332	1218	5	9	52.1	733.6	1328
5(d)	832	660	1189	1104	9	21	65.1	710.9	1191

(1) Soaked 3 h then air cooled. Minimum section size of 89 mm (3.5 in.)
(2) Soaked 8 h then air cooled

Table 4 Tensile mechanical properties of TIMETAL 555 76 × 152 mm (3 × 6 in.) billet in solution heat treated plus aged condition

	Tensile mechanical properties					
	Ultimate		Yield @ 0.2%			
Orientation	ksi	MPa	ksi	MPa	Elongation (4D), %	RA, %
L	184	1269	176	1214	14	35.0
T	189	1303	180	1241	11	29.0
ST	189	1304	182	1255	11	30.2

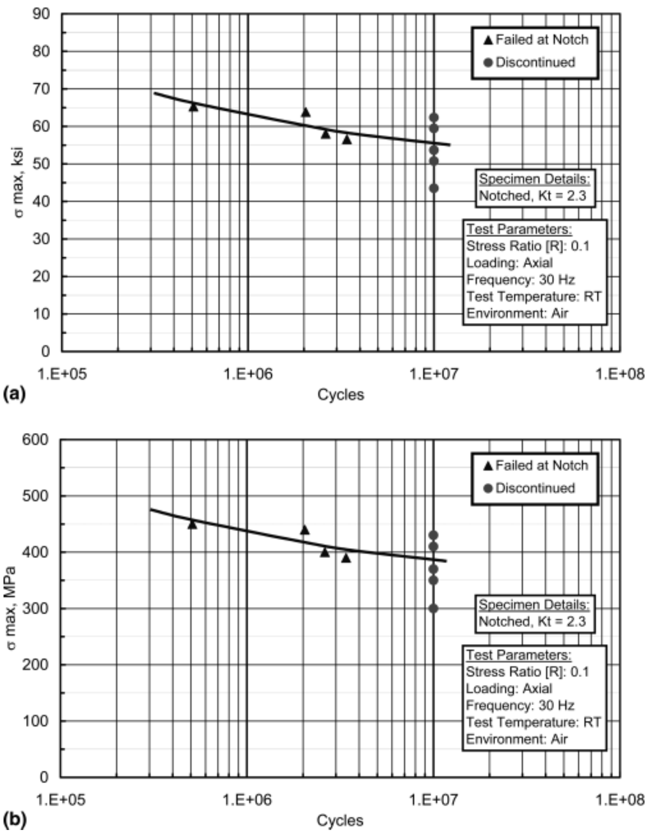

Fig. 6 Notched (Kt = 2.3) axial fatigue data at $R = 0.1$ for TIMETAL 555 large-die forging in the STA condition. English units (top) and SI units (bottom) are given. Tensile mechanical properties of product tested: ultimate tensile strength 1177 MPa (169 ksi); tensile yield stress 1117 MPa (160 ksi); elongation 11%

plus stress-relieved condition (704-732 °C [1300-1350 °F] for 2-4 h) appears to result in the best overall machinability. As illustrated by the results for drilling tests (Fig. 7 and Table 7), machining parameters (including tool material, speed, and feed rate) for a particular situation can have a major effect on machinability.

7. Summary

TIMETAL 555-forged products have shown combinations of mechanical properties that should be useful for a variety of airframe and other structural applications.

Table 5 Tensile mechanical properties of TIMETAL 555 2.3 mm (0.090 in.) sheet in solution heat-treated plus aged condition

	Tensile mechanical properties				
	Ultimate		Yield @ 0.2%		
Orientation	ksi	MPa	ksi	MPa	Elongation (4D), %
L	194	1338	183	1261	5
L	197	1358	186	1281	5
T	201	1386	189	1303	6
T	201	1386	189	1302	6
Average	198	1367	187	1287	6

Table 6 Tensile mechanical properties of TIMETAL 555 11.4 mm (0.45 in.) plate in solution heat treated plus aged condition

	Tensile mechanical properties				
	Ultimate		Yield @ 0.2%		
Orientation	ksi	MPa	ksi	MPa	Elongation (4D), %
L	171	1179	160	1102	16
L	174	1199	162	1117	15
T	176	1214	165	1138	16
T	175	1205	164	1131	16
Average	174	1199	163	1122	16

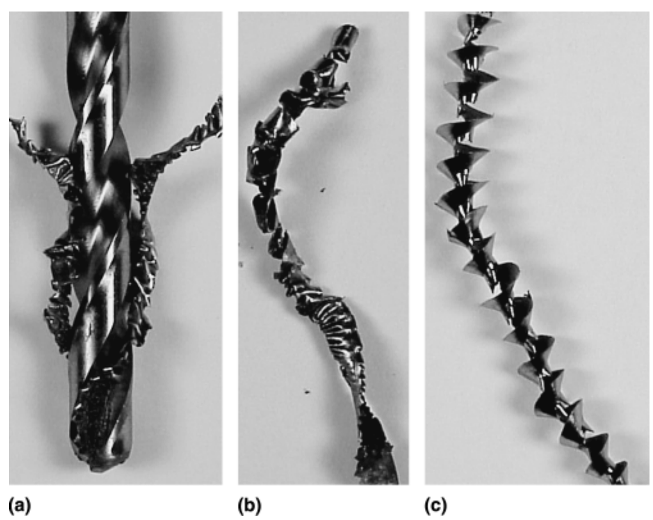

Fig. 7 Effect of drilling parameters on chip morphology and the number of holes-to-failure for TIMETAL 555 in high-strength (STA) condition

Table 7 Correlative drilling parameters and results for machining chip morphologies shown in Fig. 7

Figure	7(a)	7(b)	7(c)
Drill speed, RPM	475	370	370
Feed rate, mm [in.]	0.19 mm (0.0075 in.)	0.19 mm (0.0075 in.)	0.13 mm (0.005 in.)
Number of holes before failure	1.5	1.5	>50

References

1. V.V. Tetyukhin, Current State of Russian Titanium Industry and VSMPO: Development of New High Strength Alloys for Aircraft and Civil Engineering, *Proceedings of 13th Annual Titanium Conference* (San Francisco, CA), ITA, 1997, p 37-54
2. J.C. Fanning and R.R. Boyer, Properties of TIMETAL 555 – A New Near-Beta Alloy for Airframe Components, *Proceedings of the 10th World Conference on Titanium,* July 13-18, 2003 (Germany), Vol IV, DGM, 2003, p 2643-2650