

AFGROW User Workshop 2016

Development of a Compendium of Mechanical Properties of USAF ASIP Materials

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Presentation By:

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*Benefiting government, industry and
the public through innovative science
and technology*



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- Luciano Smith, SwRI
- Heidi Reid, SwRI turned USAF A-10 ASIP
- Loretta Mesa, SwRI



- The What
- The Why
- The How





The What: A Collection of Material Properties from Test

- **The What:** “a collection of concise but detailed information about a particular subject, especially in a book or other publication.”

Compendium of Mechanical Properties of USAF T-38 ASIP Materials

Prepared for:

Hill AFB
Ogden, UT

Prepared by:

Dallen L. Andrew
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March 2016

APPROVED:

Ben H. Thacker, Ph.D., Director
Materials Engineering Department

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Compendium of Mechanical Properties of USAF A-10 ASIP Materials

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The What: A Collection of Material Properties from Test

■ The What

- 21 different materials

Compendium of Mechanical Properties
of USAF T-38 ASIP Materials

Material	Reference Source		
	Tensile	Fracture Toughness	Fatigue Crack Growth
7050-T74 Forging	[4]	[4,6]	[4,6]
7075-T6 Sheet	[3]	[3]	[3,6]
7075-T73 Forging	[6]	[5,6]	[5,6]
7075-T7351 Plate	[1,2,3,6]	[1,2,6]	[1,2,3,6]
7075-T73511 Extrusion	[1,2,3]	[1,2]	[1,2,3]
7075-T74 Forging	[6]	---	---
7175-T74 Forging	[1,2,3]	[1,2,3]	[1,2,3]
7475-T7351 Plate	[4]	[4,6]	[4,6]
4330M Bar	[1,2]	[1,2]	[1]
4130 Bar	[1,2,3,5]	[2,5]	[1,2,3,5]
4340 Bar	[3]	[3]	[3]
A356-T6	---	---	[7]

Compendium of Mechanical Properties
of USAF A-10 ASIP Materials

Material	Reference Source		
	Tensile	Fracture Toughness	Fatigue Crack Growth
2024-T351 plate	[6, 7, 8, 9]	---	[8, 9]
2024-T3511 extrusion	[6, 7, 9]	---	[8]
2024-T42 sheet	[6]	---	[6, 7]
2224-T3511 extrusion	[7]	[6, 7]	[6, 7]
7075-T6 sheet	[1, 7, 9]	[1]	[9]
7075-T76 plate	[9]	---	[9]
7075-T76511 extrusion	---	---	[8]
7175-T74 forging	[1, 2, 3, 4, 9]	[1, 2, 3, 9]	[9]
AMS 6526 forging	[9]	[9]	[9]
17-7PH RH1000 sheet	[9]	[9]	[9]
15-5PH H1025 plate	[5]	---	[5]



The What: A Collection of Material Properties from Test

■ The What

Data ID	7075-T73-1	7075-T73-2	7075-T73-8	7075-T73-3
Stress Ratio	0.1	0.1	0.1	0.5
Alloy	7075	7075	7075	7075
Heat Treat Condition	T73	T73	T73	T73
Form	Forging	Forging	Forging	Forging
Environment	LA	LA	LA	LA
Specimen	ESE(T)	ESE(T)	ESE(T)	ESE(T)
Orientation	T-L	T-L	T-L	T-L
Thickness	0.25	0.25	0.25	0.25
Width	1.5	1.5	1.5	1.5
Yield Strength	62.7	62.7	62.7	62.7
Reference	[6]	[6]	[6]	[6]

Data	da/dN	DK	da/dN	DK	da/dN	DK	da/dN	DK
	1.19E-06	5.583	6.17E-07	5.019	6.81E-07	4.794	1.46E-07	2.29
	1.20E-06	5.629	6.02E-07	4.909	7.08E-07	4.897	1.12E-07	2.243
	1.26E-06	5.689	5.78E-07	4.863	7.08E-07	4.862	1.16E-07	2.262
	1.28E-06	5.753	5.45E-07	4.817	7.05E-07	4.815	1.19E-07	2.289
	1.28E-06	5.818	5.45E-07	4.771	6.83E-07	4.77	1.23E-07	2.316
	1.30E-06	5.883	5.47E-07	4.727	6.45E-07	4.725	1.24E-07	2.343
	1.38E-06	5.949	5.25E-07	4.682	6.24E-07	4.68	1.24E-07	2.37
	1.43E-06	6.015	4.86E-07	4.639	6.14E-07	4.637	1.28E-07	2.397
	1.47E-06	6.083	4.63E-07	4.595	6.04E-07	4.592	1.34E-07	2.424
	1.60E-06	6.151	4.51E-07	4.552	5.85E-07	4.549	1.38E-07	2.452
	1.75E-06	6.219	4.22E-07	4.51	5.55E-07	4.506	1.39E-07	2.479
	1.83E-06	6.287	4.01E-07	4.467	5.29E-07	4.464	1.42E-07	2.508
	1.86E-06	6.356	3.98E-07	4.426	5.10E-07	4.422	1.48E-07	2.536
	1.88E-06	6.425	4.01E-07	4.385	5.02E-07	4.379	1.51E-07	2.564
	2.00E-06	6.497	4.10E-07	4.343	4.86E-07	4.338	1.58E-07	2.594
	2.12E-06	6.567	4.05E-07	4.302	4.72E-07	4.296	1.66E-07	2.622
	2.23E-06	6.641	3.73E-07	4.262	4.62E-07	4.255	1.67E-07	2.652
	2.36E-06	6.712	3.54E-07	4.221	4.41E-07	4.216	1.72E-07	2.682
	2.45E-06	6.785	3.49E-07	4.181	4.24E-07	4.176	1.83E-07	2.713
	2.51E-06	6.858	3.39E-07	4.142	4.08E-07	4.137	1.93E-07	2.744
	2.64E-06	6.934	3.37E-07	4.102	4.02E-07	4.097	1.96E-07	2.774
	2.84E-06	7.011	3.37E-07	4.064	4.00E-07	4.058	1.97E-07	2.806
	2.96E-06	7.087	3.36E-07	4.025	3.87E-07	4.019	1.94E-07	2.836
	3.08E-06	7.164	3.33E-07	3.988	3.66E-07	3.98	1.88E-07	2.868
	3.24E-06	7.24	3.26E-07	3.949	3.45E-07	3.943	1.98E-07	2.9
	3.31E-06	7.317	3.17E-07	3.913	3.25E-07	3.905	2.10E-07	2.931
	3.42E-06	7.398	3.06E-07	3.878	3.15E-07	3.868	2.18E-07	2.965

A.5 7075-T73511 Extrusion

Material	Product Thickness (in.)	Orientation	Yield (ksi)	UTS (ksi)	RA (%)	ϵ_f (%)	E (Msi)	Ref.
7075-T73511 Extrusion	1.25	Long	65.7	74.87	33.4	11.5		[1]
			63.93	74.36	32.1	11.4		
			63.15	73.85	32.1	11.8		
			63.66	73.42	31.6	11.4		
			65.96	75.38	33.4	11.8		
			68.7	79.2	27.2	11.0	11.0	
			68.2	78.5	27.2	12.5	10.8	
			68.2	78.6	22.0	11.0	10.7	
	1.25	Trans	68.6	78.8	26.5	11.5	10.5	[2]
			69.8	78.3	24.5	11.0	10.5	
			69.6	78.1	23.0	10.0	10.4	
			73.0	80.3	26.9	10.5	10.8	
			59.11	69.48	23.2	10.5		
			60.61	70.79	21.9	11.1		
1.25	Trans	60.10	69.77	21.9	10.9		[1]	
		59.59	69.26	21.2	10.0			

B.3 7075-T73 Forging

Material	Orient.	Spec.	Thick (in.)	Width (in.)	K_{Ic} (ksi $\sqrt{in.}$)	Ref.
7075-T73 Forging	L-T	C(T)	1	2	32.3	[5]
			1	2	38.18	
			1	2	29.97	
	T-L	C(T)	1.001	2.000	20.0	[6]
			1.000	1.996	20.0 ^(a)	
			0.999	1.996	22.2	
			1.000	2.001	20.6	
			0.999	1.999	21.3	

(a) Did not meet a/W crack length requirements



The Why: “Just here to help”

■ The Why: Origin



<http://www.a-listinternational.com/motivation-monday-how-to-be-a-great-team-player/>



Project	PM	Enl Rpt Date	Material	Tensile	Toughnes	FCG
5990	Fohn	Nov-03	13-8MO steel forging	y	y	0.8
15992	Feiger	Sep-12	4130 steel	y	y	0.1, 0.5, 0.7
12457	Popelar	Jun-09	4130 steel	y		0.1, 0.8
5990	Fohn	Nov-03	4130 steel	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	4130 steel	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	4130 steel	y		0.1, 0.5, 0.8
5990	Fohn	Nov-03	4330M steel	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	4330M steel	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	4330M steel	y	y	0.1, 0.5, 0.8
12457	Popelar	Jun-09	4340 steel	y	y	0.1, 0.8, 0.5
20403	Hickey	Sep-14	7050-T74 forging	Y	Y	0.1,0.5,0.8,-0.1
15288	Popelar	Mar-11	7050-T74 forging	y	y	0.1, 0.5, 0.8, -0.1
20403	Hickey	Sep-14	7075-T6			0.1,0.5,0.8
5990	Fohn	Nov-03	7075-T6 plate	y	y	0.1, 0.5, 0.8
12457	Popelar	Jun-09	7075-T6 sheet	y	y	0.1, 0.8, 0.5
20403	Hickey	Sep-14	7075-T73 forging	Y	Y	0.1,0.5,0.8,-0.1
15992	Feiger	Sep-12	7075-T73 forging	y	y	0.1, 0.5, 0.8
20403	Hickey	Sep-14	7075-T7351 plate	Y	Y	0.1,0.5,0.8,-0.1
12457	Popelar	Jun-09	7075-T7351 plate	y		0.1, 0.8
5990	Fohn	Nov-03	7075-T7351 plate	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	7075-T7351 plate	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	7075-T7351 plate	y		0.1, 0.5, 0.8
12457	Popelar	Jun-09	7075-T73511 extrusion	y		0.1, 0.8
5990	Fohn	Nov-03	7075-T73511 extrusion	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	7075-T73511 extrusion	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	7075-T73511 extrusion	y	y	0.1, 0.5, 0.8
5990	Fohn	Nov-03	7075-T76 forging	y	y	0.1, 0.33, 0.5
12457	Popelar	Jun-09	7175-T74 forging	y	y	0.1, 0.8
5990	Fohn	Nov-03	7175-T74 forging	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	7175-T74 forging	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	7175-T74 forging	y	y	0.1, 0.5, 0.8
20403	Hickey	Sep-14	7475-T7351 plate	Y	Y	0.1,0.5,0.8,-0.1
15288	Popelar	Mar-11	7475-T7351 plate	y	y	0.1, 0.5, 0.8, -0.1
18074.10.106	Popelar	Dec-10	A356-T6 casting			0.1, 0.5, 0.8, -0.3



The Why: “Just here to help”

■ The Why: Beneficiaries



NORTHROP GRUMMAN



U.S. AIR FORCE



- The How
 - Record keeping



<https://worldtransportarchives.wordpress.com/2012/11/05/searching-the-archives/>

Project	PM	Enl Rpt Date	Material	Tensile	Toughnes	FCG
5990	Fohn	Nov-03	13-8MO steel forging	y	y	0.8
15992	Feiger	Sep-12	4130 steel	y	y	0.1, 0.5, 0.7
12457	Popelar	Jun-09	4130 steel	y		0.1, 0.8
5990	Fohn	Nov-03	4130 steel	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	4130 steel	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	4130 steel	y		0.1, 0.5, 0.8
5990	Fohn	Nov-03	4330M steel	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	4330M steel	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	4330M steel	y	y	0.1, 0.5, 0.8
12457	Popelar	Jun-09	4340 steel	y	y	0.1, 0.8, 0.5
20403	Hickey	Sep-14	7050-T74 forging	Y	Y	0.1,0.5,0.8,-0.1
15288	Popelar	Mar-11	7050-T74 forging	y	y	0.1, 0.5, 0.8, -0.1
20403	Hickey	Sep-14	7075-T6			0.1,0.5,0.8
5990	Fohn	Nov-03	7075-T6 plate	y	y	0.1, 0.5, 0.8
12457	Popelar	Jun-09	7075-T6 sheet	y	y	0.1, 0.8, 0.5
20403	Hickey	Sep-14	7075-T73 forging	Y	Y	0.1,0.5,0.8,-0.1
15992	Feiger	Sep-12	7075-T73 forging	y	y	0.1, 0.5, 0.8
20403	Hickey	Sep-14	7075-T7351 plate	Y	Y	0.1,0.5,0.8,-0.1
12457	Popelar	Jun-09	7075-T7351 plate	y		0.1, 0.8
5990	Fohn	Nov-03	7075-T7351 plate	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	7075-T7351 plate	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	7075-T7351 plate	y		0.1, 0.5, 0.8
12457	Popelar	Jun-09	7075-T73511 extrusion	y		0.1, 0.8
5990	Fohn	Nov-03	7075-T73511 extrusion	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	7075-T73511 extrusion	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	7075-T73511 extrusion	y	y	0.1, 0.5, 0.8
5990	Fohn	Nov-03	7075-T76 forging	y	y	0.1, 0.33, 0.5
12457	Popelar	Jun-09	7175-T74 forging	y	y	0.1, 0.8
5990	Fohn	Nov-03	7175-T74 forging	y	y	0.1, 0.5, 0.8
1334	McMaster	Dec-99	7175-T74 forging	y	y	0.1, 0.8, -0.2
06-5906	FitzGerald	Jun-95	7175-T74 forging	y	y	0.1, 0.5, 0.8
20403	Hickey	Sep-14	7475-T7351 plate	Y	Y	0.1,0.5,0.8,-0.1
15288	Popelar	Mar-11	7475-T7351 plate	y	y	0.1, 0.5, 0.8, -0.1
18074.10.106	Popelar	Dec-10	A356-T6 casting			0.1, 0.5, 0.8, -0.3

- The How
 - Not just copy/paste

TABLE 4.2
FRACTURE TOUGHNESS TEST RESULTS FROM 7075-T73511 EXTRUSION

Specimen ID	Orientation	Thickness "B" (inch)	Width "W" (inch)	Average Crack Length (inch)	Fracture Toughness K_{Ic} (ksi \sqrt{in})
EF-LT-1	L-T	1.001	2.000	1.032	33.72
EF-LT-2	L-T	1.001	2.000	1.027	33.40
EF-LT-3	L-T	1.001	1.999	1.027	33.87
Average -----					33.66
EF-TL-1	T-L	1.001	1.997	1.036	23.56
EF-TL-2	T-L	1.001	1.999	1.035	23.83
EF-TL-3	T-L	1.001	1.998	1.033	23.49
Average -----					23.63



<http://temo.dvrlists.com/treasure-trove/>

CRACK PROPAGATION RATE DATA FOR
SPECIMEN PD-LT-1 7075-T7351 PLATE

SPEC. TYPE = C(T) DIR. = L-T ENVIRON. = LA
 TEST TEMP = 78F B = .351 IN W = 2.004 IN
 PMAX = 340 LBS R = .1 FREQ = 20 HZ
 FTY = 63240 PSI

POINT NO.	N (CYCLES)	A (IN)	DA/DN (IN/CYCLE)	DELTA K (KSI SQRTIN)	VALID PER ASTM
1	0	0.8558			
2	40000	0.8730	4.31E-07	4.88	Y
3	82000	0.8905	4.17E-07	4.99	Y
4	120850	0.9095	4.89E-07	5.12	Y
5	163580	0.9350	5.97E-07	5.29	Y
6	210000	0.9663	6.73E-07	5.51	Y
7	235000	0.9873	8.40E-07	5.73	Y
8	261000	1.0120	9.52E-07	5.93	Y
9	282000	1.0365	1.17E-06	6.16	Y
10	300000	1.0640	1.53E-06	6.42	Y
11	314000	1.0895	1.82E-06	6.70	Y
12	324000	1.1140	2.45E-06	6.99	Y
13	347026	1.1850	3.08E-06	7.62	Y
14	352682	1.2095	4.33E-06	8.33	Y
15	359000	1.2415	5.06E-06	8.81	Y
16	361977	1.2595	6.05E-06	9.27	Y
17	366000	1.2855	6.48E-06	9.71	Y
18	369322	1.3108	7.60E-06	10.28	Y
19	372122	1.3360	9.02E-06	10.89	Y
20	374479	1.3615	1.08E-05	11.57	Y
21	376669	1.3890	1.28E-05	12.36	Y
22	378082	1.4115	1.59E-05	13.19	Y
23	379272	1.4358	2.04E-05	14.05	Y
24	380273	1.4620	2.62E-05	15.08	Y
25	381051	1.4860	3.08E-05	16.25	Y
26	381692	1.5110	3.90E-05	17.53	Y
27	382209	1.5365	4.93E-05	19.02	Y
28	382532	1.5605	7.43E-05	20.70	Y
29	382797	1.5845	9.06E-05	22.57	Y
30	382952	1.6095	1.61E-04	24.78	Y
31	383037	1.6350	3.00E-04	27.43	Y

- The How
- Time well spent
 - November 2014 – June 2016
- Key players
 - Carl Popelar
 - Luciano Smith
 - Heidi Reid
 - Loretta Mesa



<http://dailyplateofcrazy.com/2010/10/08/timing-is-everything/>



<http://karetuschooltgc.blogspot.com/2012/08/many-hands-make-light-work.html>



The End.



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