Table 4 Minimum mechanical properties of aluminum alloy 7005

Temper	Tensile strength, MPa	Tensile strength, ksi	Yield strength, MPa	Yield strength, ksi	Elongation(a), %	Compressive yield strength, MPa	Compressive yield strength, ksi	Shear strength, MPa	Shear strength, ksi	Shear yield Strength, MPa	Shear yield Strength, ksi	Bearing strength, MPa	Bearing strength, ksi	Bearing yield strength, MPa	Bearing yield strength, ksi
Extrusions															
T53															
L direction	345	50	303	44	10	296	43	193	28	172	25	655(b) 496(c)	95(b) 72(c)	503(b) 407(c)	73(b) 59(c)
L-T direction	331	48	290	42	...	303	44	...	...	...	...	...	...	...	...
Sheet and plate															
T6(d), T63(e), T6351(e)	324	47	262	38	...	269	39	186	27	152	22	634(b) 483(c)	92(b) 70(c)	448(b) 365(c)	65(b) 53(c)

(a) In 50 mm (2 in.) or 4*d*, where *d* is diameter of reduced section of tensile test specimen. (b) *e*/*d* = 2.0, where *e* is edge distance and *d* is pin diameter. (c) *e*/*d* = 1.5. (d) Up to 6.35 mm (0.250 in.) thick. (e) 6.35 to 75 mm (0.250 to 3.00 in.) thick.

Table 5 Typical tensile properties at various temperatures for aluminum alloy 7005-T53 extrusions

Temperature, °C	Temperature, °F	Tensile strength(a), MPa	Tensile strength(a), ksi	Yield strength(a), MPa	Yield strength(a), ksi	Elongation, %
−270	−450	641	93	483	70	16
−195	−320	538	78	421	61	16
−80	−110	441	64	379	55	13
−30	−20	421	61	359	52	14
25	75	392	57	345	50	15
100	210	303	44	283	41	20
150	300	165	24	145	21	35
205	400	97	14	83	12	60
260	500	76	11	66	9.5	80

(a) Lowest strength for exposures up to 10,000 h at temperature, no load; test loading applied at 35 MPa/min (5 ksi/min) to yield strength and then at strain rate of 5%/min to fracture.

Fabrication Characteristics

Cold bending and forming capability of 7005 (Table 6) is similar to that of 6061-T6. The alloy is suitable for all methods of brazing including furnace, dip, torch, and vacuum fluxless brazing. It has good brazing characteristics, and high strength after brazing can be obtained by natural and artificial aging. Brazing temperatures are sufficiently high to effectively solution heat treat during brazing. Heat treatments are:

- **Annealing (O-temper)**: Heat at 345 – 400 °C (650 – 750 °F) for several hours, cool slowly in the furnace at a rate of 275 °C (500 °F)/h to about 200 °C (390 °F). This precipitates zinc and magnesium from solid solution and prevents hardening at room temperature.
- **Stabilizing anneal**: Heat at 230 °C (445 °F) for 4 – 6 hours subsequent to the full anneal and air or furnace cool.
- **Solution temperature**: 400 °C (750 °F)

The T53 and T63 tempers provide optimum strength and resistance to stress corrosion cracking. T53 temper is artificial aging following an elevated temperature fabricating process:

- **T53 temper**: Press quench from hot-working temperature, naturally age 72 h at room temperature, then two-stage artificially age 8 h at 100 – 110 °C (210 – 230 °F) plus 16 h at 145 – 155 °C (290 – 310 °F)

REFERENCES

1. R. Reed and A. Clark, *Materials at Low Temperature,* American Society for Metals, 1983, p 399
2. Aluminum X7005: Age Hardenable Alloy, *Alloy Digest:Data on Worldwide Metals and Alloys*, Data Sheet Al-151, ASM International, Jan 1966

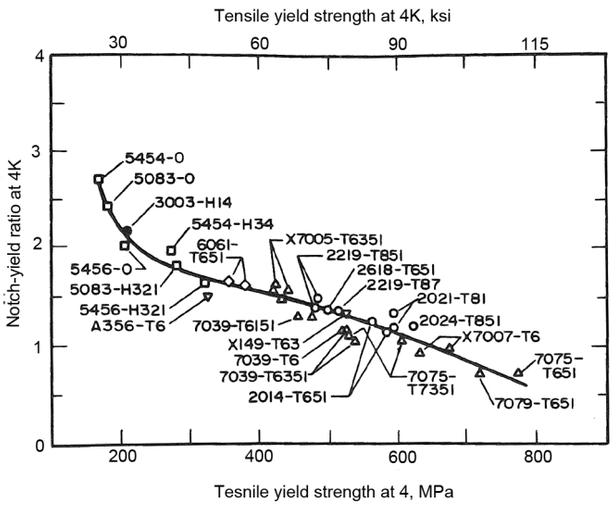

Fig. 1 Notch-yield ratio versus yield strength at a temperature of 4K of alloy 7005 and other aluminum alloys used at cryogenic temperatures

Table 6 Approximate radii for 90-degree cold bending of aluminum alloy 7055 sheet and plate

Thickness, mm (in.)	O temper	T63 temper
1.5 (0.064)	0.5–1.5*t*	1–2*t*
3 (0.125)	1–1.5*t*	1.5–2.5*t*
5 (0.187)	1–2*t*	2–3*t*
6 (0.250)	1–2*t*	2.5–3.5*t*
10 (0.375)	2–3*t*	3–4*t*
13 (0.5)	2–3*t*	3–4*t*

Source: Ref 2

ASM Handbook, Volume 2B, *Properties and Selection of Aluminum Alloys*
Kevin Anderson, John Weritz, and J. Gilbert Kaufman, editors
DOI 10.31399/asm.hb.v02b.a0006729

7020

High-Strength Aerospace Alloy

Alloy 7020 (Table 1) is widely used in aerospace structures generally in the T651 temper to provide maximum strength. A copper content of less than 0.2% makes alloy 7020 weldable. Relatively low formability limits the complexity of the shapes that can be extruded. Specifications equivalents are:

- BS H17
- DIN Werkstoff 3.4335
- A-Z5G

Physical properties are given in Table 2 and mechanical properties in Table 3. Alloy 7020 T651 offers a combination of good ductility and strength levels higher than those of 6*xxx* series alloys. Product specifications are given Table 4.

Table 1 Composition limits for aluminum alloy 7020

Element	Composition, wt%	Element	Composition, wt%
Si	0.35 max	Cr	0.10–0.35
Fe	0.40 max	Ti	0.08–0.25 Zr + Ti
Cu	0.20 max	Zn	4.0–5.0
Mn	0.05–0.50	Other (each), max	0.05
Mg	1.0–1.4	Other (total), max	0.15
Zr	0.08–0.20	Al	bal

Table 2 Physical properties of aluminum alloy 7020

Property	Value
Poisson's ratio at 20 °C (68 °F)	0.33
Elastic modulus at 20 °C (68 °F), GPa (× 10^6 psi)	72 (10)
Density at 20 °C (68 °F), g/cm^3 (lb/in.^{3})	2.78 (0.10)
Melting range, °C (°F)	485–630 (905–1165)
Thermal conductivity at 20 °C (68 °F), W/m · K	130–160
Electrical resistivity at 20 °C (68 °F), nΩ · m	46
Average coefficient of linear thermal expansion, μm/m · °C	20 to 100 °C, 23.5

Table 3 Mechanical properties of aluminum alloy 7020

Temper	Dimensions, mm (in.)		R_m, MPa		$R_{p0.2}$, MPa		A, %	$A_{50\ mm}$, %	Hardness, typical, HB
	D(a)	S(b)	Min	Max	Min	Max	Min	Min	
Extruded rod and bar									
T6(c)	≤50 (≤2)	≤50 (≤2)	350	···	290	···	10	8	110
	50–200 (2–8)	50–200 (2–8)	340	,,,	275	···	10	···	110
Extruded tube									
	Wall thickness (t), mm (in.)								
T6(c)	≤15 (≤0.6)		350	···	290	···	10	8	110
Extruded profile									
T6	≤40 (≤1.5)		350	···	290	···	10	8	110

(a) D = diameter round bar. (b) S = width across flats for square and hexagonal bar, thickness for regular bar. (c) Properties may be obtained by press quenching. Source: Ref 1

The alloy is used in machined components and in load-bearing structures such as cargo containers. Typical applications are highly loaded construction parts, such as in rail transport, aircraft storage containers, pontoon bridges, and mobile cranes containers. With excellent machinability and wear resistance, alloy 7020 also is widely used for mold applications and is produced as ring-rolled components in spacecraft applications.

A hot-working processing map of alloy 7020 in a prior hot-forged condition is shown in Fig 1. Flow stress values of alloy 7020 at different temperatures and strain rates are given in Table 5 for various strains. Optimum hot-working processing conditions (forgings) are a temperature of 500 °C (930 °F) and a strain rate of 10 per second. The material exhibits flow instability in the temperature range of 300 – 425 °C (570 – 800 °F) when the strain rate is above 1.0 per second. Adiabatic shear band formation occurs in this region. Other processing conditions are:

- Superplastic deformation in the temperature range 425 – 550 °C (800 – 1020 °F) at a strain rate range of 0.001 – 0.01 per second with a maximum efficiency of 44% occurring at 500 °C (930 °F) with a strain rate of 0.001 per second.
- Dynamic recrystallization in the temperature range of 425 – 550 °C (800 – 1020 °F) with a strain rate range of 1 to 10 per second with a maximum efficiency of 33% occurring at 500 °C (930 °F) with a strain rate of 10 per second. This domain can extend to higher strain rates.
- Dynamic recovery occurs in the temperature range of 325 – 425 C (620 – 800 °F) within a strain rate range of 0.01 – 0.5 per second with a maximum efficiency of 26% occurring at 400 °C (750 °F) and 0.1 per second.

The heat-affected zone from welding recovers part of the fully heat-treated strength through natural aging. Good-quality welded joints can only be achieved with close control of the welding technique and good joint design. Post-weld corrosion protection could be required. Weldability is very good using gas metal-arc welding (GMAW) and gas tungsten-arc welding (GTAW). Typical fillers metals are EN ISO18273, SG-AlMg5Cr(A), SG-Al4.5Mn0.7(A), and SG-Al4.5MnZr. The alloy is unsuitable for resistance welding, but weldability is fair for spot welding.

Table 4 Product specifications for aluminum alloy 7020

Standard number	Product form
ISO 6361	Sheet, strip, and plate
ISO 6362	Extruded rods/bars, tubes, and profiles
ISO 6363	Cold-drawn rods/bars, tubes, and wire
EN 485-1	Sheet, strip, and plate
EN 754	Cold drawn rod/bar and tube
EN 755	Extruded rod/bar, tube, and profiles
JIS H 4040	Bar and wire
JIS H 4080	Extruded tubes and cold-drawn tubes
JIS H 4100	Extruded profiles

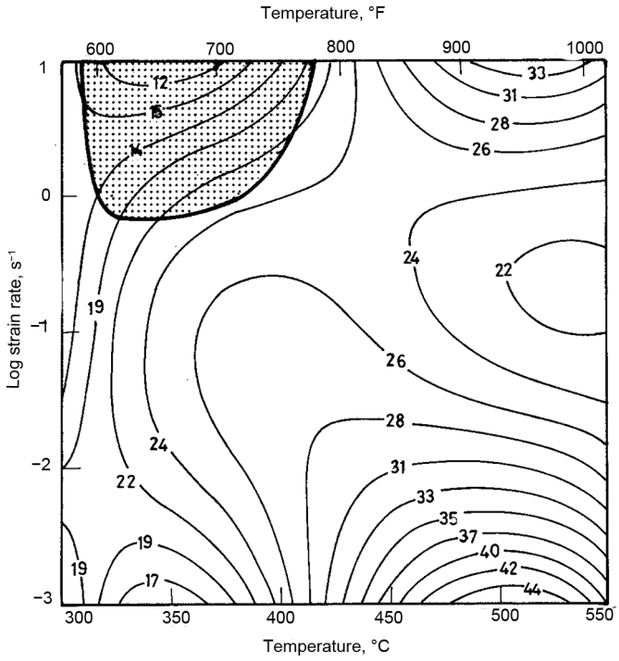

Fig. 1 Processing map of aluminum alloy 7020 at a strain of 0.3. Contour numbers represent percent efficiency of power dissipation. Shaded region corresponds to flow instability. Source: Ref 2

Table 5 Flow stress values (in MPa) of 7020 aluminum alloy at different temperatures and strain rates for various strains

		Temperature, °C (°F)					
Strain	Strain rate, s^{-1}	300 (570)	350 (660)	400 (750)	450 (840)	500 (930)	550 (1020)
0.1	10^{-3}	54.4	48.0	24.7	16.0	14.8	11.5
	10^{-2}	77.3	54.6	36.9	31.9	21.7	17.3
	10^{-1}	91.2	71.6	51.9	46.2	31.9	24.3
	1	114.8	96.8	75.9	62.5	38.9	31.6
	10	131.4	110.6	102.3	81.8	61.0	45.6
0.2	10^{-3}	53.2	46.0	25.4	16.1	15.3	11.3
	10^{-2}	77.3	53.7	35.9	31.1	22.4	18.0
	10^{-1}	89.9	70.3	53.3	44.9	32.5	25.1
	1	114.9	98.2	74.3	62.5	39.6	32.3
	10	133.8	113.1	103.8	83.7	62.1	47.0
0.3	10^{-3}	53.0	44.4	24.6	16.3	15.3	10.9
	10^{-2}	76.7	53.3	35.2	29.8	22.0	17.7
	10^{-1}	87.7	68.3	53.7	44.5	32.3	25.5
	1	115.7	96.9	72.3	62.4	39.2	32.5
	10	134.7	112.5	102.1	82.1	61.2	47.2
0.4	10^{-3}	52.8	43.9	24.1	15.7	15.4	10.5
	10^{-2}	76.3	53.1	35.0	29.3	21.3	18.2
	10^{-1}	89.8	66.5	53.7	43.7	31.7	25.6
	1	116.7	96.4	70.7	61.5	38.8	32.0
	10	136.3	113.7	102.7	82.1	60.9	47.4
0.5	10^{-3}	56.4	43.5	24.1	15.9	15.6	11.3
	10^{-2}	78.3	54.7	34.7	29.0	21.3	19.0
	10^{-1}	89.6	66.3	55.6	43.7	31.3	27.2
	1	122.5	97.7	71.3	60.5	38.2	31.9
	10	137.5	117.9	104.6	83.7	61.3	48.4

Source: Ref 2

REFERENCES

1. "Aluminium and aluminium alloys – Extruded rod/bar, tube and profiles – Part 2: Mechanical properties," European Standard DIN EN 755-2, German Institute for Standardization, 2016
2. 7020 Al Alloy, *Hot Working Guide – A Compendium of Processing Maps,* 2nd ed., Y.V.R.K. Prasad, K.P. Rao, and S. Sasidhara, Eds., ASM International, 2015

ASM Handbook, Volume 2B, *Properties and Selection of Aluminum Alloys*
Kevin Anderson, John Weritz, and J. Gilbert Kaufman, editors
DOI 10.31399/asm.hb.v02b.a0006730

7039

Armor Plate

Alloy 7039 (Table 1) contains about 4% Zn and 2.8% Mg with small additions of Cr and Mn. Its high tensile strength provides high resistance to penetration by projectiles, and it's primary application is armor plate, although other uses include cryogenic storage tanks, unfired pressure vessels, ordnance tanks, missile structures, and low-temperature processing equipment. Available forms include plate, forgings, extrusions, and sheet.

Physical properties of alloy 7039 are given in Table 2 and mechanical properties in Tables 3 and 4. The general corrosion resistance characteristics of 7039-T64 are comparable to such highly resistant Al-Mg alloys as 5052, 5086, and 5083. Resistance to general corrosion is superior to that of most heat-treatable alloys. Under standard 6% NaCl immersion test for 6 months or 5% NaCl salt fog, only slight superficial staining and a mild, shallow pitting attack with no measurable loss in strength are observed. In a NaCl-H_2O_2 test, no evidence of intergranular corrosion is observed. However, a major drawback of alloy 7039 is susceptibility to stress corrosion cracking originating at exposed end grains of welded plates. "Buttering" welds to cover exposed end grains is done in armored vehicles operating in humid environments.

Heat Treatment

Typical heat treatments for alloy 7039 include:

- **Solution treatment**: Heat to 460 – 500 °C (860 – 930 °F), soak 2 h, quench in cold water. Sheet stock should be quenched from 490 – 500 °C (915 – 930 °F), while extruded stock should be quenched from 460 – 470 °C (860 – 880 °F).
- **Aging treatment (T6 temper)**: Reheat to 120 °C (250 °F), hold at temperature for 20 – 24 h, air cool.
- **Annealing treatment (O temper)**: Heat to 415 – 455 °C (780 – 850 °F), soak for 2–3 h, air cool, reheat at 230 °C (445 °F), hold at temperature for 4 h, air cool. Alternatively, heat to 355 – 370 °C (670 – 700 °F), air cool.
- **Stress-relief anneal**: Heat to 355 – 370 °C (670 – 700 °F), soak for 2 h, air cool to room temperature.

Table 1 Composition limits of aluminum alloy 7039

Element	Composition, wt%	Element	Composition, wt%
Si	0.30 max	Ti	0.10 max
Fe	0.40 max	Zn	3.5–4.5
Cu	0.10 max	Other (each), max	0,05
Mn	0.10–0.40	Other (total), max	0.15
Mg	2.3–3.3	Al	bal
Cr	0.15–0.25		

Table 2 Physical properties of aluminum alloy 7039

Property	Value
Density at 20 °C (68 °F), g/cm^3 (lb/in.^{3})	2.73 (0.0988)
Liquidus temperature, °C (°F)	638 (1180)
Solidus temperature, °C (°F)	482 (900)
Thermal conductivity at 20 °C (68 °F), W/m · °C (Btu/h · ft · °F)	125–155 (72.2–89.5)
Electrical conductivity (equal volume) at 20 °C (68 °F)	32–40% IACS

Table 3 Typical mechanical properties of aluminum alloy 7039

	Value(a) at temper		
Property	T64	T61	O
Tensile strength, MPa (ksi)			
Longitudinal	450 (65)	400 (58)	227 (33)
Transverse	450 (65)	400 (58)	227 (33)
0.2% tensile yield strength, MPa (ksi)			
Longitudinal	380 (55)	330 (48)	103 (15)
Transverse	380 (55)	330 (48)	103 (15)
Elongation in 50 mm (2 in.), %			
Longitudinal	13	14	22
Transverse	13	14	22
0.2% compressive yield strength, MPa (ksi)			
Longitudinal	400 (58)	380 (55)	···
Transverse	415 (60)	407 (59)	···
Shear strength, MPa (ksi)			
Longitudinal	270 (39)	···	···
Transverse	255 (37)	235 (34)	···
Bearing strength(b), MPa (ksi)			
Longitudinal	910 (132)	···	···
Transverse	910 (132)	827 (120)	···
Brinell hardness (1500 kg), HB	133	123	61

(a) Property values for 6 to 75 mm (0.25 to 3.0 in.) thick plate. (b) $e/d = 2$, where e is the edge distance and d is the pin diameter. Source: Ref 1

Table 4 Transverse impact toughness of aluminum alloy 7039-T64 plate

Plate thickness		Test temperature		Elongation in 50 mm (2 in.), %	Unnotched impact toughness,		Notched impact toughness,	
mm	in.	°C	°F		J	ft · lbf	J	ft · lbf
45	1.75	25	75	12	66.2	48.8	7.6	5.6
		−195	−320	12	87.5	64.5	6.5	4.8
38	1.50	25	75	11	75.3	55.5	7.5	5.5
		−195	−320	11	96.7	71.3	8.3	6.1

Source: Ref 1

Weldability

Alloy 7039 is readily weldable to alloy 5083-H131 plate, which is used in areas where protection against fragments are required, while the high strength of 7039-T64 provides increased ballistic protection against armor-piercing projectiles. It is readily weldable using gas metal-arc welding (GMAW) and gas tungsten-arc welding (GTAW) processes, using aluminum alloy X5039 or 5183 filler rod. Alloy 7039 has considerably better weld strength and ductility than alloy 5083, and is readily welded over a wide range of thicknesses with no decrease in weld ductility. It has very good crack resistance in restrained plate weldments when joined using X5039 filler wire. Room temperature weld strength averages 360 MPa (52 ksi) and increases to 448 MPa (65 ksi) at −195 °C (−320 °F). No special preweld or post-weld heat treatment is required.

Workability

Alloy 7039 is best formed in the freshly quenched condition. In the soft temper, the alloy can be successfully formed on all types of equipment. Because of its higher strength, it requires a greater allowance for springback than when working with other aluminum alloys. Heating up to 120 °C (250 °F) during forming in the annealed condition is beneficial in certain swaging, spinning, and drop-hammer operations. In the solution treated condition, properties are intermediate between those of O and T6 temper, but higher than the O temper condition during the first few hours after quenching. Formability gradually diminishes as age hardening increases. In the solution treated and aged T6 temper condition, the material exhibits very poor forming qualities. Due to the elaborate annealing and stabilizing treatment required, severe forming in its annealed O temper condition is impractical. Rubber forming or streaking is usually conducted at a temperature between 120 and 230 °C (250 and 450 °F).

REFERENCE

1. Aluminum 7039: Heat Treatable Wrought Alloy, *Alloy Digest: Data on Worldwide Metals and Alloys*, Data Sheet Al-154, ASM International, April 1966

ASM Handbook, Volume 2B, *Properties and Selection of Aluminum Alloys*
Kevin Anderson, John Weritz, and J. Gilbert Kaufman, editors
DOI 10.31399/asm.hb.v02b.a0006731

7040 and 7140

High-Strength Plate

Alloy 7040 (Table 1) is a variation of 7050, where Zr additions prevent recrystallization of hot-worked products during solution heat treatment without the quench sensitivity from additions of Cr. Alloy 7040 provides higher static strength and toughness compared with previous alloys 7010- and 7050-T74. Lower Cu and Mg limits (substantially lower than the solubility limits) and high purity contribute to the higher strength/fracture toughness of the alloy.

The 7040 plate alloy was introduced by Pechiney for use in fuselage applications, such as integrally machined main frames, cockpit window frames, beams, and fittings (Ref 1). The over-aged T7651 temper was designed for similar strength as 7010/7050, with significantly improved toughness (Table 2). The over-aged T7451 temper is obtained through a conventional two-stage aging treatment, as defined in AMS 2772 (Ref 3). Alloy 7040-T7651 is covered by AMS 4211 (Ref 4) and MMPDS and is available in the thickness range of 75 to 230 mm (3.0 to 9.0 in).

Alloy 7040-T7451 has been produced in European and North American facilities using a technology that results in low residual stress and lower machining distortion in thickness up to 220 mm (8.5 in.). In 2005, alloy 7140 (Table 1) was introduced as adaptation of 7040-T7651 plate. The aim of alloy 7140 is higher strength (Table 3). Alloy 7140-T7651 plate is available in the thickness range of 100 to 250 mm (4.0 to 10.0 in) and is covered in AMS 4408 (Ref 6) and has MMPDS design values.

Table 1 Composition limits of aluminum alloys 7040 and 7140

	Composition, wt%	
Element	7040 (France, 1996)	7140 (France, 2005)
Si	0.10 max	0.10 max
Fe	0.13 max	0.13 max
Cu	1.5–2.3	1.3–2.3
Mn	0.04 max	0.04 max
Mg	1.7–2.4	1.5–2.4
Zr	0.05–0.12	0.05–0.12
Cr	0.04 max	0.04 max
Ti	0.06 max	0.06 max
Zn	5.7–6.7	6.2–7.0
Other (each), max	0.05	0.05
Other (total), max	0.15	0.15
Al	bal	bal

REFERENCES

1. P. Lequeu and T. Warner, Aluminum Alloy Development for the Airbus A380, Advanced Matls. and Process., July 2007, p 41–44.
2. 7040-T7451 Plates Datasheet, Constellium, May 2017
3. "Heat Treatment of Aluminum Alloy Raw Materials" AMS 2772G, Society of Automotive Engineers, 2016
4. "Aluminum Alloy, Plate 6.2Zn – 1.9Cu – 2.1Mg – 0.10Zr (7040-T7451) Solution Heat Treated, Stress Relieved, and Overaged," AMS 4211C, Society of Automotive Engineers, 2018
5. 7140-T7651 Plates Datasheet, Constellium, June 2018
6. "Aluminum Alloy, Plate (7140-T7651) 6.6Zn – 1.8Cu – 2.0Mg – 0.10Zr Solution Heat Treated, Stress Relieved, and Overaged," AMS 4408A, Society of Automotive Engineers, 2018

Table 2 Mechanical properties of aluminum alloy 7040-T7651 plate

		Thickness range, mm (in.)					
Property	Direction	75–100 (3–4)	100–125 (4–5)	125–150 (5–6)	150–175 (6–7)	175–200 (7–8)	200–230 (8–9)
Tensile strength, min, MPa (ksi)	L	483 (70)	483 (70)	483 (70)	476 (69)	469 (68)	469 (68)
Yield strength, min, MPa (ksi)	L	427 (62)	427 (62)	427 (62)	427 (62)	421 (61)	412 (61)
Elongation, min, %	L	8 (9)	8 (9)	7 (8)	6 (7)	5 (6)	5 (6)
Toughness, K_{Ic}, min, MPa$\sqrt{m}$ (ksi$\sqrt{in.}$)	L-T	34 (31)	33 (30)	32 (29)	30 (27)	28 (26)	28 (26)
EXCO rating ASTM G34				Better or equal to EB			
Stress corrosion cracking (max -ASTM G47), MPa (ksi)	S-T			241 (35)			
Density, typical, g/cm^3 (lb/in.^{3})				2.82 (0.102)			

Source: Ref 2

Table 3 Mechanical properties of aluminum alloy 7140-T7651 plate

		Thickness range, mm (in.)					
Property	Direction	100–125 (4–5)	125–150 (5–6)	150–175 (6–7)	175–200 (7–8)	200–230 (8–9)	230–250 (9–10)
Tensile strength, min, MPa (ksi)	L	510 (74)	510 (74)	503 (73)	496 (72)	496 (72)	490 (71)
Yield strength, min, MPa (ksi)	L	483 (70)	483 (70)	476 (69)	469 (68)	469 (68)	462 (67)
Elongation, min, %	L	6 (7)	6 (7)	6 (7)	6 (6)	4 (5)	4 (5)
Toughness, K_{Ic}, min, MPa$\sqrt{m}$ (ksi$\sqrt{in.}$)	L-T	30 (27)	28 (25)	26 (24)	24 (22)	22 (20)	20 (18)
EXCO rating ASTM G34				Better or equal to EB			
Stress corrosion cracking (max -ASTM G47), MPa (ksi)	S-T			179 (26)			
Density, typical, g/cm^3 (lb/in.^{3})				2.82 (0.102)			

Source: Ref 5

ASM Handbook, Volume 2B, *Properties and Selection of Aluminum Alloys*
Kevin Anderson, John Weritz, and J. Gilbert Kaufman, editors
DOI 10.31399/asm.hb.v02b.a0006732

7049 and 7049A

Extrusion and Forging Alloy

Alloy 7049 (Table 1) is the earliest version of the 7*x*49 family of alloys, which include 7149, 7249, 7349, and 7449. Alloy 7249 was introduced by Universal Alloys for use in extrusion applications in 1992. Pechiney introduced alloys 7349 and 7449 in 1994 for high-strength T79 temper aerospace components. Alloy 7349 contained Cr and was used only for thin extruded products. Alloy 7449 was formulated without Cr, using Zr instead, making it more amenable to production of thicker wrought products.

Alloy 7049 contains chromium and is more highly alloyed (Zn + Mg + Cu) than alloy 7075. It has been used where static strengths are approximately the same as forged 7079-T6 and where high resistance to stress corrosion cracking are required in components such as forged aircraft and missile fittings, landing-gear cylinders, and extruded sections. It does not have a clear advantage compared with other alloys such as 7178 and 7050. In 1975, Kaiser introduced a lower Fe and Si version of the alloy as 7149.

The alloy still sees some application and is still produced occasionally for forgings and extrusions. Physical properties of alloy 7049 are given in Table 2 and mechanical properties in Tables 3 and 4. The alloy has very high tensile strength and good machinability. Extruded sections are used where static strengths approximating those of forged 7079-T6 and high corrosion resistance to stress corrosion cracking are required. Product specifications of 7049 include forgings, extrusions, and plate:

- **Forgings:** ASTM B 247 and AMS 4111, 4321, and 4247
- **Extrusions** AMS 4157 and 4159
- **Plate:** AMS 4200

Product specifications that also cover the European version (alloy 7049A) include:

- **ISO 6362:** Extruded rods/bars, tubes, and profiles
- **ISO 6363:** Cold-drawn rods/bars, tubes, and wire
- **EN 754:** Cold drawn rod/bar and tube
- **EN 755:** Extruded rod/bar, tube, and profiles
- **JIS H 4040:** Bar and wire

Table 1 Composition limits of aluminum alloy 7049 and 7*x*49 family

	Composition, wt%					
Element	**7049**	**7049A**	**7149**	**7249**	**7349**	**7449**
Si	0.25 max	0.40 max	0.15 max	0.10 max	0.12 max	0.12 max
Fe	0.35 max	0.50 max	0.20 max	0.12 max	0.15 max	0.15 max
Cu	1.2–1.9	1.2–1.9	1.2–1.9	1.3–1.9	1.4–2.1	1.4–2.1
Mn	0.20 max	0.50 max	0.20 max	0.10 max	0.20 max	0.20 max
Mg	2.0–2.9	2.1–3.1	2.0–2.9	2.0–2.4	1.8–2.7	1.8–2.7
Cr	0.10–0.22	0.05–0.25	0.10–0.22	0.12–0.18	0.10–0.22	...
Ti	0.10 max	0.25 Zr + Ti max	0.10 max	0.06 max	0.25 Zr + Ti max	0.25 Zr + Ti max
Zn	7.2–8.2	7.2–8.4	7.2–8.2	7.5–8.2	7.5–8.7	7.5–8.7
Other (each), max	0.05	0.05	0.05	0.05	0.05	0.05
Other (total), max	0.15	0.15	0.15	0.15	0.15	0.15
Al	bal	bal	bal	bal	bal	bal

Table 2 Physical properties of aluminum alloy 7049

Property	**Value**
Poisson's ratio at 20 °C (68 °F)	0.33
Elastic modulus at 20 °C (68 °F), GPa (× 10^6 psi)	70 (10.2), forgings 72.5 (10.5), extusions
Compressive modulus, GPa (× 10^6 psi)	76 (11)
Modulus of rigidity (shear), GPa (× 10^6 psi)	27.6 (4.0)
Density at 20 °C (68 °F), g/cm^3 (lb/in.^{3})	2.82 (0.102)
Liquidus temperature, °C (°F)	627 (1160)
Solidus temperature, °C (°F)	477 (890)
Specific heat at 100 °C (212 °F), J/kg · K (Btu/lb · °F)	960 (0.23)
Thermal conductivity at 25 °C (77 °F), W/m · K (Btu/ft · h · °F)	154 (89)
Electrical conductivity (equal volume) at 20 °C (68 °F)	40% IACS min
Electrical resistivity at 20 °C (68 °F), nΩ · m	43
Average coefficient of linear thermal expansion, μm/m · °C	20 to 100 °C, 23.4

Heat Treatment

Precipitation heat treatment following solution heat treatment and quenching produces T6-type tempers. Alloys in T6-type tempers generally have the highest strengths practical without sacrificing minimum levels of other properties and characteristics found by experience to be satisfactory and useful for engineering applications. Alloys in T7-type tempers are overaged, which means that some degree of strength has been sacrificed to improve one or more other characteristics. Strength may be sacrificed to improve dimensional stability, particularly in products intended for service at elevated temperatures, or to lower residual stresses to reduce warpage and distortion in machining. Precipitation heat-treating temperatures used to produce these tempers generally are higher than those used to produce T6-type tempers in the same alloys.

Two important groups of T7-type tempers, T73 and T76, were developed for 7*xxx*-series wrought alloys, which contain more than about 1.25% copper. These tempers are intended to improve resistance to exfoliation corrosion and stress corrosion cracking, but as a result of overaging, they also increase fracture toughness and, under some conditions, reduce rates of fatigue crack propagation. The T73 temper has greatly minimized stress corrosion cracking of large, complex machined parts made of these alloys, a phenomenon that occasionally occurred with T6-type tempers.

The precipitation heat treatment used to produce T73 and T76 tempers consists either of a two-stage isothermal precipitation heat treatment or of heating at a controlled rate to a single treatment temperature. The microstructural-electrochemical relationships required to achieve the desired corrosion-resistance characteristics can be developed by using only a single-stage or slow-controlled heat up. Extended natural aging can provide the same results, but the times required at room temperature are impractical.

Table 3 Mechanical properties of aluminum alloy 7049

Size (mm, or in.) and direction	Tensile strength(a), MPa	Tensile strength(a), ksi	Yield strength, 0.2% offset(a), MPa	Yield strength, 0.2% offset(a), ksi	Elongation(a)(b), %	Compressive yield strength, MPa	Compressive yield strength, ksi	Shear strength, MPa	Shear strength, ksi	Bearing strength(c), MPa	Bearing strength(c), ksi	Bearing yield strength(a), MPa	Bearing yield strength(a), ksi
Die forgings (AMS 4111), T73 temper(d)													
Parallel to grain flow													
Up to 50 (2)	496	72	427	62	7	441	64	283	41	917	133	662	96
Over 50–100 (2–4)	490	71	421	61	7	434	63	276	40	903	131	655	95
Over 100–125 (4–5)	483	70	414	60	7	427	62	269	39	890	129	641	93
Across grain flow													
Up to 25 (1), incl	490	71	421	61	3	434	63	283	41	917	133	662	96
Over 25–100 (1–4), incl	483	70	414	60	3–2	427	62	276	40	903	131	655	95
Over 100–125 (4–5), incl	469	68	400	58	2	414	60	269	39	890	129	641	93
Extrusions (AMS 4157), T73511 temper													
Up to 75 (2.999)													
Longitudinal	510	74	441	64	7	448	65	276	40	758	110	···	···
Long transverse	483	70	414	60	5	420	61	276	40	993	144	···	···
Over 75–125 (2.999–5.000)													
Longitudinal	496	72	427	62	7	435	63	269	39	738	107	···	···
Long transverse	469	68	400	58	5	407	59	269	39	965	140	···	···
Extrusions (AMS 4159), T75511 temper													
Up to 75 (2.999)													
Longitudinal	538	78	483	70	7	490	71	290	42	···	···	586	85
Long transverse	524	76	469	68	5	475	69	290	42	···	···	724	105
Over 75–125 (2.999–5.000)													
Longitudinal	524	76	469	68	7	475	69	283	41	···	···	572	83
Long transverse	510	74	455	66	5	462	67	283	41	···	···	696	101

(a) Single values are minimum values. (b) In 50 mm (2 in.) or 4*d*, where *d* is diameter of reduced section of tensile test specimen. Where a range appears in this column, the specified minimum elongation varies with thickness of mill product. (c) *e*/*d* = 2.0, where *e* is edge distance and *d* is pin diameter. (d) Data from Ref 1

Table 4 Damage tolerance properties of 7049-T73 die forgings

Property	Value
K_Q values from compact tension tests, MPa$\sqrt{m}$ (ksi$\sqrt{in.}$)	• L-S orientation, 32–36 (29–33)
	• L-T orientation, 31–40 (28–37)
	• S-L orientation, 21–27 (19–25)
Axial fatigue at 10^7 cycles with stress ratio *R* of 1.0 for smooth specimens from 125 mm (5 in.) thick forgings, MPa (ksi)	275–315 (40–46), from room temperature to 175 °C (350 °F)
Axial fatigue at 10^7 cycles with stress ratio *R* of 1.0 for notched specimens from 75 mm (3 in.) thick forgings, MPa (ksi)	390 (56), for K_t of 1.0 115 (17), for K_t of 3.0

Recommended treatments to produce T5-type and T6-type tempers, and those of the T7-type used for dimensional and property stabilization, provide adequate tolerance for normal variations encountered with good operating practices. By comparison, T73, T74, and T76 tempers for alloy 7049 involve changes in strength, which occur significantly more rapidly at the temperatures used in the second stage of the T7*x* precipitation heat treatment cycle compared with changes occurring at the temperatures used to produce the T6 temper.

Addendum

Alloy 7249 was introduced by Universal Alloys for extrusion applications in 1992. Pechiney introduced alloys 7349 and 7449 in 1994 for high strength T79 temper aerospace components (Ref 154). The 7349 alloy contained Cr and was used only for thin extruded products. The 7449 alloy was formulated without Cr, using Zr instead, making it more amenable to production of thicker wrought products.

REFERENCE

1. Aluminum 7049-T73: Aluminum Forging Alloy, *Alloy Digest: Data on Worldwide Metals and Alloys*, Data Sheet Al-201, ASM International, Mar 1971

ASM Handbook, Volume 2B, *Properties and Selection of Aluminum Alloys*
Kevin Anderson, John Weritz, and J. Gilbert Kaufman, editors
DOI 10.31399/asm.hb.v02b.a0006733

7050

High-Strength Structural Alloy

Alloy 7050 (Table 1) contains higher levels of Cu than alloy 7075 (2.5% vs 1.6%), which develops a more attractive combination of strength, corrosion resistance characteristics including stress-corrosion cracking resistance. The higher copper content modifies the relative differences in electrochemical potential between matrix and grain boundary regions by the diffusion of copper into the η phase and η′ phase particles during the over-aging step and reduces resolved stress on grain boundaries, because the incoherent η phase particles minimize strain concentration. The alloy also replaces Cr with additions of Zr to prevent recrystallization of hot-worked products during solution heat treatment. Additions of 0.1% Zr are nearly as effective as 0.25% Cr in preventing recrystallization, and Zr additions do not affect quench sensitivity to the extent of Cr additions, where Cr-bearing dispersoids function as nucleation sites for precipitation during a slow quench.

Physical properties of alloy 7050 are given in Table 2, and typical mechanical properties of plate, forgings, and extrusions are given in Tables 3 and 4. Typical products are plate, extrusions, bar, wire, rod,

Table 1 Composition limits of aluminum alloy 705

Element	Composition, wt%	Element	Composition, wt%
Si	0.12 max	Cr	0.04 max
Fe	0.15 max	Ti	0.06 max
Cu	2.0–2.6	Zn	5.7–6.7
Mn	0.10 max	Other (each), max	0.05
Mg	1.9–2.6	Other (total), max	0.15
Zr	0.08–0.15	Al	bal

Table 2 Physical properties of aluminum alloy 7050

Property	Value
Poisson's ratio at 20 °C (68 °F)	0.33
Elastic modulus at 20 °C (68 °F), GPa (× 10^6 psi)	70.3 (10.2)
Compressive modulus, GPa (× 10^6 psi)	73.8 (10.7)
Modulus of rigidity (shear), GPa (× 10^6 psi)	26.9 (3.9)
Density at 20 °C (68 °F), g/cm^3 (lb/in.^{3})	2.83 g/cm^3 (0.102 lb/in.^{3})
Liquidus temperature, °C (°F)	635 (1175)
Solidus temperature, °C (°F)	465 (870)
Incipient melting temperature for solution treated material, °C (°F)	488 (910)
Eutectic temperature for unhomogenized wrought or as-cast material, °C (°F)	465 (870)
Specific heat at 20 °C (68 °F), J/kg · K (Btu/lb · °F)	860 (0.206)
Thermal conductivity at 20 °C (68 °F), W/m · K	O temper, 180 T76, T7651 tempers, 154 T736, T 73651 tempers, 157
Electrical conductivity (equal volume) at 20 °C (68 °F)	O temper, 47% IACS T76, T7651 tempers, 39.5% IACS T736, T73651 temper, 40.5% IACS
Electrical resistivity at 20 °C (68 °F), nΩ · m	O temper, 36.7 T76 tempers, 43.6 T736, T73651 tempers, 42.6 Temperature coefficient, all tempers: 0.1 nΩ · m/ K at 20 °C (68 °F)
Average coefficient of linear thermal expansion, μm/m · °C	−50 to 20 °C, 21.7 20 to 100 °C, 23.5 20 to 200 °C, 24.4 20 to 300 °C, 25.4

Table 3 Typical tensile properties of aluminum alloy 7050 plate and forging

Temperature, °C	Temperature, °F	Time at temp, h	At indicated temperature: Tensile strength, MPa	Tensile strength, ksi	Yield strength, MPa	Yield strength, ksi	Elongation (a),%	At room temperature after heating: Tensile strength, MPa	Tensile strength, ksi	Yield strength, MPa	Yield strength, ksi	Elongation (a),%
T73651 plate												
24	75	···	510	74	455	66	11	510	74	455	66	11
100	210	0.1–10	441	64	427	62	13	510	74	455	66	11
		100	448	65	434	63	13	510	74	462	67	12
		1,000	441	64	427	62	14	510	74	455	66	12
		10,000	441	64	421	61	15	510	74	441	64	12
150	300	0.1	393	57	386	56	16	510	74	455	66	11
		0.5	393	57	386	56	17	510	74	448	65	12
		10	393	57	386	56	18	503	74	441	64	12
		100	359	52	332	51	19	483	70	407	59	13
		1,000	290	42	276	40	21	407	59	317	46	13
		10,000	221	32	193	28	29	331	48	228	33	14
175	350	0.1	359	52	345	50	19	510	74	448	65	12
		0.5	352	51	345	50	20	496	72	441	64	12
		10	324	47	310	45	22	469	68	400	58	13
		100	248	36	234	34	25	386	56	296	43	13
		1000	193	28	172	25	31	317	46	214	31	14
		10,000	159	23	124	18	40	248	36	152	22	15
205	400	0.1	303	44	290	42	22	490	71	434	63	12
		0.5	290	42	276	40	23	469	68	421	61	12
		10	221	32	207	30	27	386	56	283	41	13
		100	165	24	152	22	32	317	46	200	29	14
		1000	131	19	110	16	45	262	38	138	20	16
		10,000	117	17	90	13	54	234	34	117	17	19
T73652 forgings												
−195	−320	···	662	96	572	83	13	···	···	···	···	
−80	−110	···	586	85	503	73	14	···	···	···	···	
−30	−20	···	552	80	476	69	15	···	···	···	···	
25	75	···	524	76	455	66	15	524	76	455	66	15
100	210	0.1–10	462	67	427	62	16	524	76	455	66	15
		100	469	68	434	63	16	524	76	462	67	15
		1000	462	67	427	62	17	524	76	524	76	16
		10,000	462	67	421	61	17	517	75	517	75	16
150	300	0.1	414	60	386	56	17	517	75	455	66	15
		0.5	414	60	386	56	17	510	74	448	65	15
		10	407	59	386	56	18	503	73	441	64	16
		100	365	53	352	51	20	483	70	407	59	16
		1000	290	42	276	40	23	407	59	317	46	17
		10,000	221	32	193	28	29	331	48	228	33	17
175	350	0.1	379	55	345	50	19	510	74	448	65	15
		0.5	365	53	345	50	20	496	72	441	64	15
		10	324	47	310	45	22	469	68	400	58	16
		100	248	36	234	34	25	386	56	296	43	17
		1000	193	28	172	25	31	317	46	214	31	17
		10,000	159	23	124	18	40	248	36	152	22	18
205	400	0.1	324	47	290	42	22	503	73	434	63	15
		0.5	296	43	276	40	23	483	70	421	61	15
		10	221	32	207	30	27	386	56	283	41	16
		100	165	24	152	22	32	317	46	200	29	17
		1,000	131	19	110	16	45	262	38	138	20	19
		10,000	117	17	90	13	54	234	34	117	17	22

(a) In 50 mm (2 in.). Source: Ref 1

and hand and die forgings (Table 5) in various product tempers (Table 6). Minimum properties of forgings are given in Tables 7 and 8.

Heat Treatment

The annealing temperature is 415 °C (780 °F). Generally, solution treating is performed at a temperature between 470 and 480 °C (880 and 895 °F), followed by water quenching. Plate, extrusions, and die and hand forgings are solution treated at 475 °C (885 °F) for W, W51, W52, W510, and W511 tempers. Parts can be quenched directly from the extrusion press if the extrusion temperature is properly controlled.

Alloy 7050 is quench sensitive, but not as sensitive as 7075 (Fig. 1). Plate is generally spray quenched. Forgings are sometimes quenched in a mixture of water and polyalkylene glycol (PAG). When quenching alloy 7050 using PAG solution, guidelines indicate a maximum PAG concentration of 12%, a maximum quench temperature of 30 °C (90 °F) with mechanical agitation, and a quench time of 2 min/25 mm (2 min/1 in.) of thickness for product up to 75 mm (3 in.) thick (Ref 4). Relief of quenching stresses for all products except die forgings, wire, rod, and rivets is accomplished by plastic deformation of 1 to 5%, depending on the product form.

Like the other 7*xxx* heat-treatable alloys, 7050 naturally ages, but this is usually not performed, because products are not stable if aged at room temperature; that is, their strength gradually increases with increasing time and can continue to do so for years. Therefore, 7050, like other

Table 4 Typical longitudinal properties of aluminum alloy 7050 extrusions

Temper	Tensile strength, MPa (ksi)	Yield strength, MPa (ksi)	Elong., 4*D*, %	Hardness (500 kg, 10 mm), HB	Shear strength, MPa (ksi)
T76, T76511	552 (80)	489 (71)	11	150	324 (47)
T74, T74511	524 (76)	469 (68)	11	140	303 (44)

Specimen diameter = 13 mm (0.5 in.). Source: Ref 2

Table 5 Product specifications for aluminum alloy 7050

Product	ASTM	AMS	ISO	EN	JIS
Plate	···	**4050**	6361	3982 3983	H 4000
Sheet	···	···	···	4449 4450F	···
Extruded rods/bars, tubes, and profiles	···	**4340, 4341, 4342**	6362	3338 (bar with peripheral coarse grain control)	H 4040 H 4080 H 4100
Rivet wire and rod (including U.S. federal specification QQ-A-430)	**B 316**	···	···	···	···
Forgings	**B 247**	**4107, 4201, 4108, 4333**	···	···	H 4140

Table 6 Aluminum alloy 7050 product tempers

Temper	Description	Product
T7	Solution heat treated and artificially overaged/stabilizcd to control important properties (rarely used without second digit as below)	Rivets
T73510	Solution heat treated, stretched a controlled amount (product dependent) for stress relief, and artificially overaged to achieve best corrosion resistance with a greater reduction in strength than T74 (no further straightening after stretching)	Extruded wire, rod, bar, and profiles
T73511	Same as T73510 except minor straightening allowed after stretching to comply with standard tolerances	Extruded wire, rod, bar, and profiles
T74	Solution heat treated and artificially overaged to achieve corrosion resistance and strength levels between the T73 and T76 tempers, (T74-type tempers, although not previously registered, have appeared in various literature and specifications as T736-type tempers)	Forgings and forging stock
T7451	Solutions heat treated, stretched a controlled amount for stress relief (product dependent), then artificially overaged to achieve corrosion resistance and strength level between the T73 and T76 tempers (no further straightening after stretching)	Plate
T74510	Solution heat treated, stretched a controlled amount (product dependent) for stress relief and artificially overaged to achieve corrosion resistance and strength level between the T73 and T76 tempers (no further straightening after stretching)	Extruded wire, rod, bar, and profiles
T74511	Same as T74510 except minor straightening allowed after stretching to comply with standard tolerances	Extruded wire, rod, bar, and profiles
T7452	Solution heat treated, compressed to a permanent set of 1 to 5% for stress relief, and artificially overaged to achieve corrosion resistance and strength level between the T73 and T76 tempers	Forgings and forging stock
T7651	Solution heat treated, stretched a controlled amount for stress relief (product dependent), and artificially overaged to achieve moderate corrosion resistance with some reduction in strength relative to the T79 temper (no further straightening after stretching)	Plate
T76510	Solution heat treated, stretched a controlled amount (product dependent) for stress relief, and artificially overaged to achieve moderate corrosion resistance with some reduction in strength relative to the T79 temper (no further straightening after stretching)	Extruded wire, rod, bar, and profiles
T76511	Same as T76510 except minor straightening allowed after stretching to comply with standard tolerances	Extruded wire, rod, bar, and profiles

Table 7 Minimum mechanical properties of alloy 7050-T736 (or -T74) die forgings

Property	Thickness, mm (in.)			
	Up to 50 (2)	50–100 (2–4)	100–125 (4–5)	125–150 (5–6)
Tensile strength, MPa (ksi)				
Longitudinal direction	496 (72)	490 (71)	483 (70)	483 (70)
Transverse direction	469 (68)	462 (67)	455 (66)	455 (66)
Yield strength, MPa (ksi)				
Longitudinal direction	427 (62)	421 (61)	414 (60)	405 (59)
Transverse direction	386 (56)	379 (55)	372 (54)	372 (54)
Compressive yield strength, MPa (ksi)				
Longitudinal direction	434 (63)	434 (63)	434 (63)	427 (62)
Transverse direction	400 (58)	393 (57)(a)	379 (55)	372 (54)
Shear strength, MPa (ksi)	290 (42)	283 (41)	283 (41)	283 (41)
Bearing strength, MPa (ksi)				
e/*d* = 1.5	683 (99)	676 (98)	669 (97)	669 (97)
e/*d* = 2.0	903 (131)	889 (129)	876 (127)	876 (127)
Bearing yield strength, MPa (ksi)				
e/*d* = 1.5	565 (82)	558 (81)	545 (79)	538 (78)
e/*d* = 2.0	662 (96)	655 (95)	641 (93)	634 (92)
Elongation(b),%				
Longitudinal direction	7	7	7	7
Transverse direction	5	4	3	3

(a) For material 75–100 mm (3–4in. thick, 386 MPa (56 ksi). (b) In 50 mm (2 in.).

Table 8 Minimum mechanical properties of aluminum alloy 7050-T73652 hand forgings

Property	Thickness, mm (in.)						
	Up to 50 (2)	50–75 (2–3)	75–100 (3–4)	100–125 (4–5)	125–150 (5–6)	150–175 (6–7)	175–200 (7–8)
Tensile strength, MPa (ksi)							
Longitudinal direction	496 (72)	496 (72)	490 (71)	483 (70)	476 (69)	469 (68)	462 (67)
L-T direction	490 (71)	483 (70)	483 (70)	476 (69)	469 (68)	462 (67)	455 (66)
S-T direction	...	462 (67)	462 (67)	455 (66)	455 (66)	448 (65)	441 (64)
Yield strength, MPa (ksi)							
Longitudinal direction	434 (63)	427 (62)	421 (61)	414 (60)	407 (59)	400 (58)	393 (57)
L-T direction	421 (61)	414 (60)	407 (69)	400 (58)	386 (56)	372 (54)	359 (52)
S-T direction	...	379 (55)	379 (55)	372 (54)	365 (53)	352 (51)	345 (50)
Compressive yield strength, MPa (ksi)							
Longitudinal direction	441 (64)	434 (63)	427 (62)	421 (61)	414 (60)	407 (59)	400 (58)
L-T direction	448 (65)	441 (64)	434 (63)	427 (62)	414 (60)	400 (58)	386 (56)
S-T direction	...	421 (61)	421 (61)	414 (60)	407 (59)	393 (57)	379 (55)
Shear strength, MPa (ksi)	290 (42)	283 (41)	283 (41)	283 (41)	276 (40)	269 (39)	269 (39)
Bearing strength, MPa (ksi)							
e/*d* = 1.5	689 (100)	683 (99)	683 (99)	669 (97)	662 (96)	655 (95)	641 (93)
e/*d* = 2.0	903 (131)	896 (130)	896 (130)	883 (128)	869 (126)	855 (124)	841 (122)
Bearing yield strength, MPa (ksi)							
e/*d* = 1.5	593 (86)	586 (85)	572 (83)	565 (82)	545 (79)	524 (76)	503 (73)
e/*d* = 2.0	696 (10)	689 (100)	676 (98)	662 (96)	641 (93)	621 (90)	593 (86)
Elongation, %							
Longitudinal direction	9	9	9	9	9	9	9
L-T direction	5	5	5	4	4	4	4
S-T direction	...	4	4	3	3	3	3

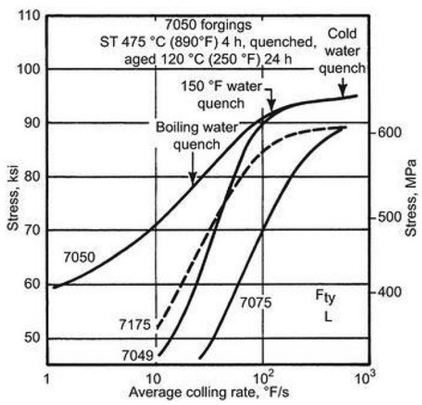

Fig. 1 Effect of average cooling rate after solution treatment on maximum yield strength of 7050, 7145, 7049, and 7075 forging alloys after aging. Source: Ref 3

7xxx alloys, is artificially aged to produce a stable alloy. For all products, double aging is used (details depend on product form). Typical aging of 7050, 7075, and 7475 extrusions is typically a two-stage treatment consisting of 330 h at 120 °C (250 °F) followed by 1518 h at 160 °C (325 °F). Alternative two-stage treatments of extrusions include:

- Age 8 h at 100 °C (210 °F) followed by 2428 h at 160 °C (325 °F)
- Age for 68 h at 105 °C (225 °F) followed by 68 h at 175 °C (350 °F)

The typical aging process for other wrought forms of 7050, 7075, and 7475 is a two-stage aging treatment consisting of 6 to 8 h at 105 °C (225 °F) followed by:

- 2430 h at 160 °C (325 °F) for sheet and plate
- 810 h at 175 °C (350 °F) for rolled and cold-finished rod and bar
- 68 h at 175 °C (350 °F) for tube
- 810 h at 175 °C (350 °F) for forgings in the T73 temper
- 68 h at 175 °C (350 °F) for forgings in the T7352 temper

Treatments for various tempers of 7050 are:

- Plate is subjected to a two-stage treatment for T7451 temper: 3 to 6 h at 120 °C (250 °F), followed by 24 – 30 h at 165 °C (330 °F). Also, parts are stress relieved by stretching to produce a specified amount of set subsequent to solution treatment and prior to precipitation treatment.
- Plate is subjected to a different treatment for the T7651 temper: 3 – 6 h at 120 °C (250 °F), followed by 12 – 15 h at 165 °C (330 °F). Also, parts are stress relieved by stretching to produce a specified amount of permanent set subsequent to solution treatment and prior to precipitation treatment.
- Rolled or cold-finished wire and rod are treated to a T7 temper by subjecting them to a two-stage treatment: 4 h at 120 °C (250 °F), followed by 6 – 10 h at 180 °C (355 °F).
- Extruded rod, bar, and shapes are treated to T73510 and T73511 tempers in a two-stage treatment: 24 h at 120 °C (250 °F), followed by 10 – 14 h at 175 °C (350 °F).
- Extruded rod, bar, and shapes are treated to T74510 and T74511 tempers in a two-stage treatment: 24 h at 120 °C (250 °F), followed by 8 – 12 h at 175 °C (350 °F).

Control of temperature and time to achieve the mechanical properties and corrosion resistance specified for these tempers is more crucial than the control required in producing the T6 temper. Moreover, the rate of heating from the first to the second aging step must be considered, because precipitation occurs during this period.

Heat treaters attempt to adjust these problems by empirically modifying soak times to compensate for precipitation during heating and for effects of soaking at temperatures above or below the nominal. A method has been developed (Ref 5) that permits quantitative compensation for the effects of precipitation during heating and of soaking either above or below the recommended temperature. For overaging, these effects can be described by Eq 1:

$$YS = Y \exp - \left(\frac{t_c}{F_{YS}} + \theta \right) \quad \text{(Eq 1)}$$