Solution temperature. 554 °C (1030 °F)
Aging temperature. 177 °C (350 °F)

6010
1.0Si-0.8Mg-0.5Mn-0.35Cu

Specifications

UNS. A96010

Chemical Composition

Composition limits. 0.8 to 1.2 Si; 0.50 max Fe; 0.15 to 0.6 Cu; 0.20 to 0.8 Mn; 0.60 to 1.0 Mg; 0.10 max Cr; 0.25 max Zn; 0.10 max Ti; 0.05 max others (each); 0.15 max others (total); rem Al

Applications

Typical uses. Automobile body sheet

Mechanical Properties

Tensile properties. Typical. T4 temper: tensile strength, 290 MPa (42 ksi); yield strength, 172 MPa (25 ksi); elongation, 24% in 50 mm or 2 in. See also Table 79.
Yield stretch. Following simulated forming and a paint bake cycle consisting of 1 h at 175 °C (350 °F). T4 temper: no stretch, 255 MPa (37 ksi); 5% stretch, 296 MPa (43 ksi); 10% stretch, 324 MPa (47 ksi)
Hardness. T4 temper: 76 HR15T
Poisson's ratio. 0.33
Elastic modulus. Tension, 69 GPa (10×10^6 psi); shear, 25.4 GPa (3.75×10^6 psi)
Fatigue strength. T4 temper: 117 MPa (17 ksi) at 10×10^6 cycles; sheet flexural specimens

Mass Characteristics

Density. 2.70 Mg/m^3 (0.098 lb/in.^{3}) at 20 °C (68 °F)

Thermal Properties

Liquidus temperature. 649 °C (1200 °F)
Solidus temperature. 585 °C (1085 °F)
Incipient melting temperature. 577 °C (1070 °F)
Coefficient of thermal expansion. Linear:

Table 79 Typical tensile properties of alloy 6010 automobile body sheet

Orientation	Tensile strength MPa	Tensile strength ksi	Yield strength MPa	Yield strength ksi	Elongation, %
T4 Temper					
Longitudinal	296	43	186	27	23
Transverse and 45°	290	42	172	25	24
T6 Temper					
Longitudinal	386	56	372	54	11
Transverse and 45°	379	55	352	51	12

Temperature range °C	Temperature range °F	Average coefficient µm/m·K	Average coefficient µin./in.·°F
−50 – +20	−58 – +68	21.5	11.9
20 – 100	68 – 21	23.2	12.9
20 – 200	68 – 392	24.1	13.4
20 – 300	68 – 572	25.1	13.9

Volumetric: 67×10^{-6} m^3/m^3·K (3.72×10^{-5} in.^{3}/in.^{3}·°F) at 20 °C (68 °F)
Specific heat. 897 J/kg·K (0.214 Btu/lb·°F) at 20 °C (68 °F)
Thermal conductivity. At 20 °C (68 °F): O temper, 202 W/m·K (117 Btu/ft·h·°F); T4 temper, 151 W/m·K (87.3 Btu/ft·h·°F); T6 temper, 180 W/m·K (104 Btu/ft·h·°F)

Electrical Properties

Electrical conductivity. Volumetric, at 20 °C (68 °F): O temper, 53% IACS; T4 temper, 39% IACS; T6 temper, 44% IACS
Electrical resistivity. At 20 °C (68 °F): O temper, 32.5 nΩ·m; T4 temper, 44.2 nΩ·m; T6 temper, 39.2 nΩ·m. Temperature coefficient, 0.1 nΩ·m per K at 20 °C (68 °F)

Fabrication Characteristics

Formability. Auto body sheet, T4 temper. 1 *t* radius required for 90° bending, 1 *t* for flanging material 0.80 to 1.30 mm (0.032 to 0.050 in.) thick. Only roped hems, which are made by bending 180° over 2 *t* interface thickness, can be made in auto body sheet 0.80 to 1.30 mm thick. Olsen cup height, typically 0.36 in. when tested using a 1-in. diam top die, 2200 psi hold-down pressure and polyethylene film as a lubricant. Strain-hardening exponent *(n)* typically 0.22; plastic strain ratio *(r)* typically 0.70
Annealing temperature. 413 °C (775 °F)
Solution temperature. 566 °C (1050 °F)
Aging temperature. 177 °C (350 °F)

6061, Alclad 6061
1.0Mg-0.6Si-0.30Cu-0.20Cr

Specifications

AMS. See Table 80.
ASTM. See Table 80.
UNS. A96061
Government. See Table 80.
Foreign. Canada: CSA GS11N. France: NF A-G5UC. United Kingdom: BS H20. ISO: AlMg1SiCu

Chemical Composition

Composition limits. 6061: 0.40 to 0.8 Si; 0.7 max Fe;0.15 to 0.40 Cu; 0.15 max Mn; 0.8 to 1.2 Mg; 0.04 to 0.35 Cr; 0.25 max Zn; 0.15 max Ti; 0.05 max others (each); 0.15 max others (total); rem Al. Alclad 6061: 7072 cladding—0.7 max Si + Fe; 0.10 max Cu; 0.10 max Mn; 0.10 max Mg; 0.8 to 1.3 Zn; 0.05 max others (each); 0.15 max others (total); rem Al

Applications

Typical uses. Trucks, towers, canoes, railroad cars, furniture, pipelines and other structural applications where strength, weldability and corrosion resistance are needed

Mechanical Properties

Tensile properties. See Tables 81 and 82.
Shear strength. See Table 81.
Hardness. O temper: 30 HB; T4, T451 tempers: 65 HB; T6, T651 tempers: 95 HB. Data obtained using 500-kg load, 10 mm-diam ball and 30-s duration of loading
Elastic modulus. Tension, 68.3 GPa (10.0×10^6 psi); compression, 69.7 GPa (10.1×10^6 psi)

Fatigue strength. O temper: 62 MPa (9 ksi). T4, T451, T6 and T651 tempers: 97 MPa (14 ksi). Data correspond to 5×10^8 cycles of completely reversed stress in R. R. Moore type tests.

Mass Characteristics

Density. 2.70 Mg/m^3 (0.098 lb/in.^{3}) at 20 °C (68 °F)

Thermal Properties

Liquidus temperature. 652 °C (1206 °F)

Solidus temperature. 582 °C (1080 °F)

Coefficient of thermal expansion. Linear, 23.6 μm/m·K (13.1 μin./in.·°F) at 20 to 100 °C (68 to 212 °F)

Specific heat. 896 J/kg·K (0.214 Btu/lb·°F) at 20 °C (68 °F)

Thermal conductivity. At 25 °C (77 °F): O temper, 180 W/m·K (104 Btu/ft·h·°F); T4 temper, 154 W/m·K (89.0 Btu/ft·h·°F); T6 temper, 167 W/m·K (96.5 Btu/ft·h·°F)

Electrical Properties

Electrical conductivity. Volumetric at 20 °C (68 °F): O temper, 47% IACS; T4 temper, 40% IACS; T6 temper: 43% IACS

Electrical resistivity. At 20 °C (68 °F): O temper, 37 nΩ·m; T4 temper, 43 nΩ·m; T6 temper, 40 nΩ·m

Fabrication Characteristics

Solution temperature. 529 °C (985 °F)

Aging temperature. Rolled or drawn products: 160 °C (320 °F); hold at temperature for 18 h. Extrusions or forgings: 177 °C (350 °F); hold at temperature for 8 h

Table 80 Standard specifications for alloy 6061

Mill form and condition	AMS	Specification No. ASTM	Government
Sheet and plate	4025	B209	QQ-A-250/11
	4026	...	...
	4027	...	...
	4043	...	...
	4053	...	...
Tread plate	...	B632	MIL-F-17132
Wire, rod, and bar (rolled or cold finished)	4115	B211	QQ-A-225/8
	4116	...	...
	4117	...	...
	4128	...	...
	4129	...	...
Rod, bar, shapes and tube (extruded)	4150	B221	QQ-A-200/8
	4160	...	...
	4161	...	...
	4172	...	...
	4173	...	...
Structural shapes	4113	B308	QQ-A-200/8
Tube (extruded, seamless)	...	B241	...
Tube (drawn)	...	B483	...
Tube (seamless)	4079	B210	WW-T-700/6
	4080	...	...
	4082	...	...
Tube (hydraulic)	4081	...	MIL-T-7081
	4083	...	...
Tube (condenser)	...	B234	...
Tube (condenser with integral fins)	...	B404	...
Tube (welded)	...	B313	...
	...	B549	...
Tube (wave guide)	...	...	MIL-W-85
	...	...	MIL-W-23068
	...	...	MIL-W-23351
Pipe	...	B241	MIL-P-25995
Pipe (gas and oil transmission)	...	B345	...
Forgings	4127	B247	QQ-A-367, MIL-A-22771
	4146		
Forging stock	4127	...	QQ-A-367
	4146	...	...
Rivet wire	...	B316	QQ-A-430
Impacts	...	...	MIL-A-12545
Structural pipe and tube (extruded)	...	B429	MIL-P-25995
Alclad			
Sheet and plate	4020	B209	...
	4021	...	...
	4022	...	...
	4023	...	...

Table 81 Typical mechanical properties of alloy 6061

Temper	Tensile strength MPa	Tensile strength ksi	Yield strength MPa	Yield strength ksi	Elongation, % 1.6 mm (1/16 in.) thick specimen	Elongation, % 13 mm (1/2 in.) diam specimen	Shear strength MPa	Shear strength ksi
6061								
O	124	18	55	8	25	30	83	12
T4, T451	241	35	145	21	22	25	165	24
T6, T651	310	45	276	40	12	17	207	30
Alclad 6061								
O	117	17	48	7	25	...	76	11
T4, T451	228	33	131	19	22	...	152	22
T6, T651	290	42	255	37	12	...	186	27

Table 82 Typical tensile properties of alloy 6061-T6 or T651 at various temperatures

Temperature °C	Temperature °F	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength(a)(b) MPa	Yield strength(a)(b) ksi	Elongation, %
−196	−320	414	60	324	47	22
−80	−112	338	49	290	42	18
−28	−18	324	47	283	41	17
24	75	310	45	276	40	17
100	212	290	42	262	38	18
149	300	234	34	214	31	20
204	400	131	19	103	15	28
260	500	51	7.5	34	5	60
316	600	32	4.6	19	2.7	85
371	700	24	3	12	1.8	95

(a) Lowest strength for exposures up to 10 000 h at temperature, no load; test loading applied at 5 000 psi/min to yield strength and then at strain rate of 5% per min to fracture. (b) 0.2% offset.

Table 84 Typical mechanical properties of alloy 6063

Temper	Tensile strength MPa	Tensile strength ksi	Yield strength MPa	Yield strength ksi	Elongation, %	Hardness(a), HB	Shear strength MPa	Shear strength ksi	Fatigue strength MPa	Fatigue strength ksi
O	90	13	48	7	...	25	69	10	55	8
T1(c)	152	22	90	13	20	42	97	14	62	9
T4	172	25	90	13	22	...	...	...	...	...
T5	186	27	145	21	12	60	117	17	69	10
T6	241	35	214	31	12	73	152	22	69	10
T83	255	37	241	35	9	82	152	22	...	...
T831	207	30	186	27	10	70	124	18	...	...
T832	290	42	269	39	12	95	186	27	...	...

(a) 500-kg load; 10-mm diam ball. (b) At 5 x 10^8 cycles; R. R. Moore type test. (c) Formerly T42 temper.

6063
0.7Mg-0.4Si

Specifications

AMS. Extruded wire, rod, bar, shapes and tube: 4156
ASME. Extruded wire, rod, bar, shapes and tube: SB221. Pipe: SB241
ASTM. See Table 83.
SAE. J454
UNS. A96063
Government. QQ-A-200/9, MIL-P-25995
Foreign. Austria: Onorm AlMgSi0,5. Canada: CSA GS10. France: NF A-GS. Italy: UNI P-AlSi0.4Mg. United Kingdom: BS H19; DTD 372B. Germany: DIN AlMgSi0.5; Werkstoff-Nr. 3.3206. ISO: AlMgSi

Chemical Composition

Composition limits. 0.20 to 0.6 Si; 0.35 max Fe; 0.10 max Cu; 0.10 max Mn; 0.45 to 0.9 Mg; 0.10 max Cr; 0.10 max Zn; 0.10 max Ti; 0.05 max others (each); 0.15 max others (total); rem Al

Applications

Typical uses. Pipe, railings, furniture, architectural extrusions, truck and trailer flooring, doors, windows, irrigation pipes

Mechanical Properties

Tensile properties. See Tables 84 and 85.
Hardness. See Table 84.
Poisson's ratio. 0.33
Elastic modulus. Tension, 68.3 GPa (9.91 × 10^6 psi); shear, 25.8 GPa (3.75 × 10^6 psi); compression, 69.7 GPa (10.1 × 10^6 psi)

Mass Characteristics

Density. 2.69 Mg/m^3 (0.097 lb/in.^{3})

Thermal Properties

Liquidus temperature. 655 °C (1211 °F)
Solidus temperature. 615 °C (1139 °F)

Table 83 ASTM specifications for alloy 6063

Mill form and condition	ASTM No.
Wire, rod, bar, shapes and tube (extruded)	B221
Tube (extruded, seamless); pipe	B241
Tube (extruded, coiled)	B491
Tube (drawn)	B483
Tube (drawn, seamless)	B210
Pipe (gas and oil transmission)	B345
Structural pipe and tube (extruded)	B429

Coefficient of thermal expansion. Linear:

Temperature range °C	Temperature range °F	Average coefficient µm/m·K	Average coefficient µin./in.·°F
−50 – +20	−58 – +68	21.8	12.1
20 – 100	68 – 212	23.4	13.0
20 – 200	68 – 392	24.5	13.6
20 – 300	68 – 572	25.6	14.2

Specific heat. 900 J/kg·K (0.215 Btu/lb·°F) at 20 °C (68 °F)
Thermal conductivity. At 25 °C (77 °F):

Temper	Conductivity W/m·K	Conductivity Btu/ft·h·°F
O	218	126
T1 (formerly T42)	193	112
T5	209	121
T6	201	116

Electrical Properties

Electrical conductivity. At 20 °C (68 °F):

Temper	Conductivity, % IACS: Equal volume	Conductivity, % IACS: Equal weight
O	58	191
T1 (formerly T42)	50	165
T5	55	181
T6, T83	53	175

Electrical resistivity. At 20 °C (68 °F):

Temper	Resistivity, nΩ·m
O	30
T1 (formerly T42)	35
T5	32
T6, T83	33

Chemical Properties

General corrosion resistance. Highly resistant to all types of corrosion

Fabrication Characteristics

Machinability. Fair, depending on temper

Weldability. For all commercial processes, excellent weldability and brazability

Annealing temperature. 415 °C (775 °F); hold at temperature 2 to 3 h; cool at 28 °C (50 °F) per h from 415 °C (775 °F) to 260 °C (500 °F)

Solution temperature. 520 °C (970 °F)

Aging temperature. T5 temper: 205 °C (400 °F), hold at temperature for 1 h; or 182 °C (360 °F), hold at temperature for 1 h. All other artificially aged tempers: 175 °C (350 °F); hold at temperature for 8 h

Table 85 Typical tensile properties of alloy 6063 at various temperatures

Temperature °C	Temperature °F	Tensile strength(a) MPa	Tensile strength(a) ksi	Yield strength(b) MPa	Yield strength(b) ksi	Elongation, %
−196	−320	234	34	110	16	44
−80	−112	179	26	103	15	36
−28	−18	165	24	97	14	34
24	75	152	22	90	13	33
100	212	152	22	97	14	18
149	300	145	21	103	15	20
204	400	62	9	45	6.5	40
260	500	31	4.5	24	3.5	75
316	600	23	3.2	17	2.5	80
371	700	16	2.3	14	2	105
T5 Temper						
−196	−320	255	37	165	24	28
−80	−112	200	29	152	22	24
−28	−18	193	28	152	22	23
24	75	186	27	145	21	22
100	212	165	24	138	20	18
149	300	138	20	124	18	20
204	400	62	9	45	6.5	40
260	500	31	4.5	24	3.5	75
316	600	23	3.2	17	2.5	80
371	700	16	2.3	14	2	105
T6 Temper						
−196	−320	324	47	248	36	24
−80	−121	262	38	228	33	20
−28	−18	248	36	221	32	19
24	75	241	35	214	31	18
100	212	214	31	193	28	15
149	300	145	21	133	20	20
204	400	62	9	45	6.5	40
260	500	31	4.5	24	3.5	75
316	600	23	3.3	17	2.5	80
371	700	16	2.3	14	2	105

(a) Lowest strength for exposures up to 10 000 h at temperature, no load; test loading applied at 5 000 psi/min to yield strength and then at strain rate of 5%/min to fracture. (b) 0.2% offset.

6066
1.4Si-1.1Mg-1.0Cu-0.8Mn

Specifications

ASTM. Extruded wire, rod, bar, shapes and tube: B221

SAE. J454

UNS number. A96066

Government. Extruded wire, rod, bar, shapes and tube: QQ-A-200/10. Forgings: QQ-A-367

Foreign. United Kingdom: BS H11

Chemical Composition

Composition limits. 0.9 to 1.8 Si; 0.50 max Fe; 0.7 to 1.2 Cu; 0.6 to 1.1 Mn; 0.8 to 1.4 Mg; 0.40 max Cr; 0.25 max Zn; 0.20 max Ti; 0.50 max others (each); 0.15 max others (total); rem Al

Applications

Typical uses. Forgings and extrusions for welded structures

Mechanical Properties

Tensile properties. See Table 86.

Shear strength. Typical. O temper: 97 MPa (14 ksi); T4 and T451 tempers: 200 MPa (29 ksi); T6 and T651 tempers: 234 MPa (34 ksi)

Hardness. O temper: 43 HB; T4 and T451 tempers: 90 HB; T6 and T651 tempers: 120 HB

Table 86 Tensile properties of alloy 6066

Temper	Tensile strength MPa	Tensile strength ksi	Yield strength(a) MPa	Yield strength(a) ksi	Elongation(b), %
Typical Properties					
O	150	22	83	12	18
T4, T451	360	52	207	30	18
T6, T651	395	57	359	52	12
Property Limits, Extrusions					
	Minimum		Minimum		Minimum
O	200 max	29 max	125 max	18 max	16
T4, T4510, T4511	275	40	170	25	14
T42	275	40	165	24	14
T6, T6510, T6511	345	50	310	45	8
T62	345	50	290	42	8
Property Limits, Die Forgings					
T6	345	50	310	45	...

(a) 0.2% offset. (b) In 2 in. or $4d$, where d is diameter of reduced section of tensile test specimen.