Tool steel, molybdenum alloy, AISI M2, regular carbon (high speed)

General information

Designation

AISI M2

Condition	Annealed; oil quenched, salt bath quenched or air cooled; tempered at 540–595°C
UNS number	T11302
US name	AISI / SAE M2
ISO name	~40CrMnNiMo8 6 4
JIS (Japanese) name	~SKH51

Typical uses

Cutting tools, Single point types, Milling cutters, Drills, Reamers, Taps, Threading dies, Form cutters
Hot forging tools and dies, Dies and inserts, Forging machine plungers and piercers (combining hot hardness with high abrasion resistance)
Hot extrusion tools and dies, Extrusion dies and mandrels, Dummy blocks, Valve extrusion tools
Cold-forming dies, bending, forming, drawing, and deep-drawing dies and punches
Shearing tools, Dies for piercing, punching, and trimming, Shear blades
Structural parts for severe service conditions

Composition overview

Compositional summary

Fe79-84 / W5.5-6.8 / Mo4.5-5.5 / Cr3.8-4.5 / V1.6-2.2 / C0.78-0.88 / Mn0.2-0.4 / Si0.2-0.4 (impurities: Ni<0.3, P<0.03, S<0.03)

Material family	Metal (ferrous)
Base material	Fe (Iron)

Composition detail (metals, ceramics and glasses)

C (carbon)	0,78	-	0,88	%
Cr (chromium)	3,75	-	4,5	%
Fe (iron)	* 79	-	83,4	%
Mn (manganese)	0,15	-	0,4	%
Mo (molybdenum)	4,5	-	5,5	%
Ni (nickel)	0	-	0,3	%
P (phosphorus)	0	-	0,03	%
S (sulfur)	0	-	0,03	%
Si (silicon)	0,2	-	0,45	%
V (vanadium)	1,75	-	2,2	%
W (tungsten)	5,5	-	6,75	%

Price

Price	* 5,72	-	6,88	EUR/kg
Price per unit volume	* 4,62e4	-	5,68e4	EUR/m^3

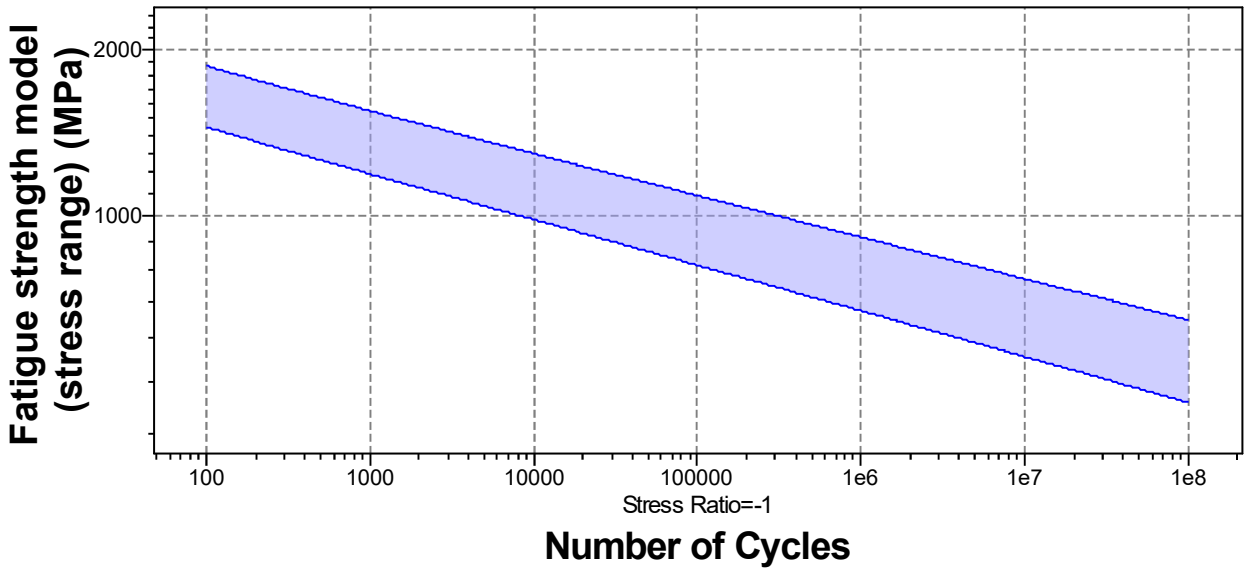
Physical properties

Density	8,08e3	-	8,25e3	kg/m^3

Mechanical properties

Young's modulus	221	-	232	GPa
Yield strength (elastic limit)	* 2e3	-	2,37e3	MPa
Tensile strength	* 2,23e3	-	2,58e3	MPa
Elongation	* 1,9	-	4,5	% strain
Compressive strength	* 2e3	-	2,37e3	MPa
Flexural modulus	* 221	-	232	GPa
Flexural strength (modulus of rupture)	* 2e3	-	2,37e3	MPa
Shear modulus	* 86	-	90	GPa
Bulk modulus	* 175	-	184	GPa
Poisson's ratio	0,285	-	0,295	
Shape factor	12			
Hardness - Vickers	700	-	840	HV
Hardness - Rockwell C	60	-	65	HRC
Fatigue strength at 10^7 cycles	* 599	-	711	MPa
Fatigue strength model (stress range)	* 912	-	1,21e3	MPa

Parameters: Stress Ratio = -1, Number of Cycles = 2,5e4cycles



Mechanical loss coefficient (tan delta)	* 1,45e-5	-	1,94e-5	

Impact & fracture properties

Fracture toughness	* 17,8	-	20,4	MPa.m^0.5

Thermal properties

Melting point	* 1,43e3	-	1,48e3	°C
Maximum service temperature	* 530	-	580	°C
Minimum service temperature	* -73	-	-53	°C
Thermal conductivity	21	-	23	W/m.°C
Specific heat capacity	* 456	-	474	J/kg.°C
Thermal expansion coefficient	* 10	-	10,4	µstrain/°C

Latent heat of fusion	265	-	280	kJ/kg

Electrical properties

Electrical resistivity	* 75,9	-	91,2	µohm.cm
Galvanic potential	* -0,37	-	-0,29	V

Magnetic properties

Magnetic type	Magnetic

Optical properties

Transparency	Opaque

Critical materials risk

Contains >5wt% critical elements?	Yes

Tool steels

Decarburization resistance rating	Average
Distortion resistance rating	Average
Cracking resistance rating	Average
Hot hardness rating	Very good
Machinability rating	Average
Toughness rating	Poor
Wear resistance rating	Good

Processing properties

Metal casting	Unsuitable			
Metal cold forming	Limited use			
Metal hot forming	Limited use			
Metal press forming	Unsuitable			
Metal deep drawing	Unsuitable			
Machining speed	5,49			m/min
Weldability	Poor			
Notes	Preheating and post weld heat treatments are required			
Carbon equivalency	2,78	-	3,41	

Durability

Water (fresh)	Acceptable
Water (salt)	Limited use
Weak acids	Limited use
Strong acids	Unacceptable
Weak alkalis	Acceptable
Strong alkalis	Limited use
Organic solvents	Excellent
Oxidation at 500C	Acceptable
UV radiation (sunlight)	Excellent

Galling resistance (adhesive wear)	Excellent
Notes	Tool steels are designed for applications which require galling resistance. Carbides improve resistance of steels.
Flammability	Non-flammable

Corrosion resistance of metals

Stress corrosion cracking	Susceptible
Note	Rated in chloride; May be susceptible in halide, ammonia, nitrogen, acidic, caustic, carbonate environments

Primary production energy, CO2 and water

Embodied energy, primary production	* 128	-	141	MJ/kg
CO2 footprint, primary production	* 8,84	-	9,74	kg/kg
Water usage	* 92,7	-	102	l/kg

Processing energy, CO2 footprint & water

Casting energy	* 10,7	-	11,8	MJ/kg
Casting CO2	* 0,802	-	0,887	kg/kg
Casting water	* 20,3	-	30,4	l/kg
Rough rolling, forging energy	* 17,2	-	19	MJ/kg
Rough rolling, forging CO2	* 1,29	-	1,42	kg/kg
Rough rolling, forging water	* 8,89	-	13,3	l/kg
Extrusion, foil rolling energy	* 34,1	-	37,6	MJ/kg
Extrusion, foil rolling CO2	* 2,55	-	2,82	kg/kg
Extrusion, foil rolling water	* 16,1	-	24,2	l/kg
Wire drawing energy	* 127	-	140	MJ/kg
Wire drawing CO2	* 9,52	-	10,5	kg/kg
Wire drawing water	* 47,8	-	71,8	l/kg
Metal powder forming energy	* 37	-	40,9	MJ/kg
Metal powder forming CO2	* 2,96	-	3,27	kg/kg
Metal powder forming water	* 40,3	-	60,5	l/kg
Vaporization energy	* 1,09e4	-	1,2e4	MJ/kg
Vaporization CO2	* 815	-	901	kg/kg
Vaporization water	* 4,53e3	-	6,8e3	l/kg
Coarse machining energy (per unit wt removed)	* 3,01	-	3,32	MJ/kg
Coarse machining CO2 (per unit wt removed)	* 0,226	-	0,249	kg/kg
Fine machining energy (per unit wt removed)	* 25,8	-	28,5	MJ/kg
Fine machining CO2 (per unit wt removed)	* 1,94	-	2,14	kg/kg
Grinding energy (per unit wt removed)	* 51,1	-	56,5	MJ/kg
Grinding CO2 (per unit wt removed)	* 3,84	-	4,24	kg/kg
Non-conventional machining energy (per unit wt removed)	* 109	-	120	MJ/kg
Non-conventional machining CO2 (per unit wt removed)	* 8,15	-	9,01	kg/kg

Recycling and end of life

Recycle	✓

Embodied energy, recycling	* 23,9	-	26,5	MJ/kg
CO2 footprint, recycling	* 1,88	-	2,08	kg/kg
Recycle fraction in current supply	52,3	-	57,8	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✓			
Biodegrade	✗			

Notes

Standards with similar compositions

• Argentina:
IRAM M2, (Med C) to IAS
• China:
W6Mo5Cr4V2 to GB 9941, W6Mo5Cr4V2 to GB 9942, W6Mo5Cr4V2 to GB 9943, W6Mo5Cr4V2 to GB/T 3080
• Czech Republic:
19830 to CSN 419830
• Finland:
SFS916 to SFS 916
• India:
THS 4 to IS 1570/6, XT87W6Mo5Cr4V2 to IS 1570/6, XT87W6Mo5Cr4V2 to IS 7291
• Italy:
RM2 HS6-5-2 to UNI 2955
• Mexico:
M2 to NMX-B-082
• Pan America:
M2 to COPANT 337
• Poland:
SW7M to PN-H-85022
• Russia:
84KH4M5F2W6L to GOST 977
• Sweden:
2722 to SS 142722
• USA:
M2 reg C, M2 regular C to ASTM A600-92a, M2 to FED QQ-T-590C, M2 to SAE J438, M2 to SAE J467
• Tradenames:
AL TECH DBL 2, BÖHLER S601, DBL-2, EM 2, EMPIRE DBL 2, FMP 562, HEVA-MOLICORT, LATROBE M2 EUR, REX M2, SAARSTAHL 1.3343, SANDVIK CORONA 62, SPEED STAR HIGH SPEED STEEL, UNAMO 2, W6MO5CR4V2

Links

ProcessUniverse

Producers

Reference

Shape

General information

Designation

6061, wrought

Condition	T6 (Solution heat-treated and artificially aged)
UNS number	A96061
EN name	EN AW-6061 (EN AW-Al Mg1SiCu)
EN number	3.3211

Typical uses

Transportation equipment, heavy duty structures, marine uses, pipe, furniture, bridges, rail, towers, pylons.

Composition overview

Compositional summary

Al96-99 / Mg0.8-1.2 / Si0.4-0.8 / Cu0.15-0.4 / Cr0.04-0.35 (impurities: Fe<0.7, Zn<0.25, Mn<0.15, Ti<0.15, Other<0.15)

Material family	Metal (non-ferrous)
Base material	Al (Aluminum)

Composition detail (metals, ceramics and glasses)

Al (aluminum)	* 95,8	-	98,6	%
Cr (chromium)	0,04	-	0,35	%
Cu (copper)	0,15	-	0,4	%
Fe (iron)	0	-	0,7	%
Mg (magnesium)	0,8	-	1,2	%
Mn (manganese)	0	-	0,15	%
Si (silicon)	0,4	-	0,8	%
Ti (titanium)	0	-	0,15	%
Zn (zinc)	0	-	0,25	%
Other	0	-	0,15	%

Price

Price	* 1,73	-	1,82	EUR/kg
Price per unit volume	* 4,66e3	-	4,97e3	EUR/m^3

Physical properties

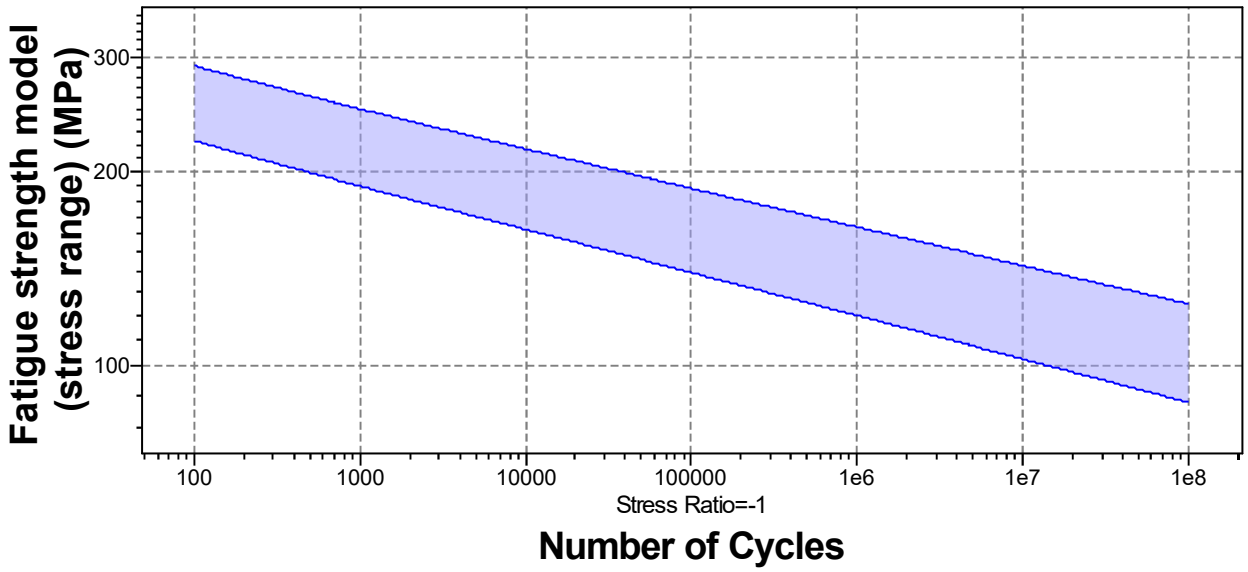
Density	2,69e3	-	2,73e3	kg/m^3

Mechanical properties

Young's modulus	66,6	-	70	GPa
Yield strength (elastic limit)	240	-	280	MPa
Tensile strength	290	-	338	MPa
Elongation	10	-	14,4	% strain
Compressive modulus	67,9	-	71,3	GPa
Compressive strength	* 240	-	280	MPa

Flexural modulus	* 66,6	-	70	GPa
Flexural strength (modulus of rupture)	* 240	-	280	MPa
Shear modulus	25,6	-	26,9	GPa
Shear strength	186	-	217	MPa
Bulk modulus	* 66,6	-	70	GPa
Poisson's ratio	0,325	-	0,335	
Shape factor	24,8			
Hardness - Vickers	100	-	107	HV
Hardness - Brinell	90	-	100	HB
Fatigue strength at 10^7 cycles	* 112	-	131	MPa
Fatigue strength model (stress range)	* 153	-	205	MPa

Parameters: Stress Ratio = -1, Number of Cycles = 2,5e4cycles



Mechanical loss coefficient (tan delta)	* 1e-4	-	0,002	

Impact & fracture properties

Fracture toughness	* 30	-	36	MPa.m^0.5

Thermal properties

Melting point	580	-	650	°C
Maximum service temperature	130	-	150	°C
Minimum service temperature	-273			°C
Thermal conductivity	152	-	169	W/m.°C
Specific heat capacity	878	-	914	J/kg.°C
Thermal expansion coefficient	22,7	-	23,9	µstrain/°C
Latent heat of fusion	384	-	393	kJ/kg

Electrical properties

Electrical resistivity	3,9	-	4,1	µohm.cm
Galvanic potential	* -0,79	-	-0,71	V

Magnetic properties

Magnetic type	Non-magnetic

Optical properties

Transparency	Opaque

Critical materials risk

Contains >5wt% critical elements?	No

Processing properties

Metal casting	Unsuitable	
Metal cold forming	Excellent	
Metal hot forming	Excellent	
Metal press forming	Acceptable	
Metal deep drawing	Acceptable	
Machining speed	85,3	m/min
Weldability	Good	
Notes	Preheating is not required, post weld heat treatment is required	

Durability

Water (fresh)	Excellent
Water (salt)	Acceptable
Weak acids	Excellent
Strong acids	Excellent
Weak alkalis	Acceptable
Strong alkalis	Unacceptable
Organic solvents	Excellent
Oxidation at 500C	Unacceptable
UV radiation (sunlight)	Excellent
Galling resistance (adhesive wear)	Limited use

Notes

Aluminum alloys perform poorly when self-mated but can be processed without galling when mated with steels.

Flammability	Non-flammable

Corrosion resistance of metals

Stress corrosion cracking	Not susceptible
Note	Rated in chloride; Other susceptible environments: Halide, water

Primary production energy, CO2 and water

Embodied energy, primary production	* 190	-	210	MJ/kg
CO2 footprint, primary production	* 12,6	-	13,9	kg/kg
Water usage	* 1,13e3	-	1,25e3	l/kg

Processing energy, CO2 footprint & water

Rough rolling, forging energy	* 6,03	-	6,67	MJ/kg

Rough rolling, forging CO2	* 0,452	-	0,5	kg/kg
Rough rolling, forging water	* 4,13	-	6,2	l/kg
Extrusion, foil rolling energy	* 11,8	-	13	MJ/kg
Extrusion, foil rolling CO2	* 0,884	-	0,977	kg/kg
Extrusion, foil rolling water	* 6,59	-	9,88	l/kg
Wire drawing energy	* 43,4	-	48	MJ/kg
Wire drawing CO2	* 3,25	-	3,6	kg/kg
Wire drawing water	* 16,4	-	24,5	l/kg
Metal powder forming energy	* 22,2	-	24,6	MJ/kg
Metal powder forming CO2	* 1,78	-	1,96	kg/kg
Metal powder forming water	* 24,2	-	36,3	l/kg
Vaporization energy	* 1,55e4	-	1,71e4	MJ/kg
Vaporization CO2	* 1,16e3	-	1,28e3	kg/kg
Vaporization water	* 6,46e3	-	9,69e3	l/kg
Coarse machining energy (per unit wt removed)	* 1,34	-	1,48	MJ/kg
Coarse machining CO2 (per unit wt removed)	* 0,1	-	0,111	kg/kg
Fine machining energy (per unit wt removed)	* 9,1	-	10,1	MJ/kg
Fine machining CO2 (per unit wt removed)	* 0,682	-	0,754	kg/kg
Grinding energy (per unit wt removed)	* 17,7	-	19,6	MJ/kg
Grinding CO2 (per unit wt removed)	* 1,33	-	1,47	kg/kg
Non-conventional machining energy (per unit wt removed)	* 155	-	171	MJ/kg
Non-conventional machining CO2 (per unit wt removed)	* 11,6	-	12,8	kg/kg

Recycling and end of life

Recycle	✓			
Embodied energy, recycling	* 32,4	-	35,8	MJ/kg
CO2 footprint, recycling	* 2,54	-	2,81	kg/kg
Recycle fraction in current supply	40,5	-	44,7	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✓			
Biodegrade	✗			

Notes

Other notes

Immediate strength extrusion alloy. Prices of Aluminum alloys fluctuate greatly and are dependent on batch size, unit size, forming methods, etc.

Standards with similar compositions

• Australia:
6061 to AS 1734, 6061 to AS 1865, 6061 to AS 1866, 6061 to AS 1867, 6061 to AS 2848.1, 6061A to AS 2848.1
• Canada:
0.6061 to CSA HA.4, 0.6061 to CSA HA.5, 0.6061 to CSA HA.6, 0.6061 to CSA HA.7, 0.6061 to CSA HA.7.1, 0.6061 to CSA HA.8
• Europe:
EN AW-6061 to CEN EN 573-3
• France:
6061 to NF A50-411, 6061 to NF A50-451
• Germany:
3.3211/AlMgSi1Cu to DIN 1725-1
• International:
AlMg1SiCu to ISO 209-1
• Japan:
6061 to JIS H4120, A6061FD to JIS H4140, A6061FH to JIS H4140, A6061P to JIS H4000, A6061S to JIS H4100, A6061TB to JIS H4180, A6061TD to JIS H4080, A6061TE to JIS H4080
• Russia:
1330 to GOST 4784, AD33 to GOST 4784
• UK:
6061 to BS 1471, 6061 to BS 1473, 6061 to BS 1474, 6061 to BS 1475
• USA:
6061, 6061 to AMS 4025, 6061 to AMS 4026, 6061 to AMS 4027, 6061 to AMS 4043, 6061 to AMS 4053, 6061 to AMS 4115, 6061 to AMS 4116, 6061 to AMS 4117, 6061 to ASTM B209M, 6061 to ASTM B210M, 6061 to ASTM B211M, 6061 to ASTM B221M, 6061 to ASTM B234, 6061 to ASTM B241M, 6061 to ASTM B247M, 6061 to ASTM B308/B308M, 6061 to ASTM B313/B313M, 6061 to ASTM B316/B316M, 6061 to ASTM B345/B345M, 6061 to ASTM B404/B404M, 6061 to ASTM B429, 6061 to ASTM B483/B483M, 6061 to ASTM B547/B547M, 6061 to ASTM B632/B632M, 6061 to MIL F-17132, 6061 to MIL P-25995B, 6061 to QQ A-225/8, 6061 to QQ A-250/11, 6061A, 6062, UNS A96061
• Venezuela:
6061 to COPANT 862
• Yugoslavia:
3.5456.00/AlMg1SiCu to JUS C.C2.100
• Tradenames:
ALCOA 6061 COLD FINISHED BAR, ALUMINUM C58, ANTICORODAL-082, BAW 6061, KAISER ALUMINUM 6061

Links

ProcessUniverse

Producers

Reference

Shape