Description

Image

Caption

1. Moka Express Espresso Maker made of aluminum alloy, cast in three parts (made by Bialetti). © Hans Chr. R. at en.wikipedia - (CC BY-SA 3.0) 2. Aluminum casting alloys almost all contain silicon to make them fluid, allowing castings with good finish and detail.

The material

Almost all aluminum alloys for casting contain 5 - 22% silicon (Si) -- the silicon makes the alloys more fluid so that they fill the mold and take up fine detail, even in thin sections. Further additions of copper (Cu) or magnesium (Mg) give age-hardening alloys. The plain Al-Si alloys are used for marine components and hardware and for cooking utensils because of their good resistance to corrosion in salt water; and they are used for pistons and cylinder liners because of their good thermal conductivity and low expansion. As a general rule the casting alloys have lower ductility and strength than the wrought age-hardening alloys -- few have tensile strengths above 350 MPa.

Compositional summary

Al + 5 - 22% Si, sometimes with some Cu, Mg or Zn to allow

General properties

Density	2.5e3	-	2.9e3	kg/m^3
Price	* 2.29	-	2.63	USD/kg
Date first used	1905			

Mechanical properties

Young's modulus	72	-	89	GPa
Shear modulus	25	-	34	GPa
Bulk modulus	66	-	72	GPa
Poisson's ratio	0.32	-	0.36	
Yield strength (elastic limit)	50	-	330	MPa
Tensile strength	65	-	386	MPa
Compressive strength	50	-	330	MPa
Elongation	0.4	-	10	% strain

Hardness - Vickers	60	-	150	HV
Fatigue strength at 10^7 cycles	32	-	157	MPa
Fracture toughness	18	-	35	MPa.m^0.5
Mechanical loss coefficient (tan delta)	1e-4	-	0.002	

Thermal properties

Melting point	475	-	677	°C
Maximum service temperature	130	-	220	°C
Minimum service temperature	-273			°C
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	80	-	160	W/m.°C
Specific heat capacity	900	-	995	J/kg.°C
Thermal expansion coefficient	16.5	-	24	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	2.5	-	8	µohm.cm

Optical properties

Transparency	Opaque

Processability

Castability	4	-	5
Formability	3	-	4
Machinability	4	-	5
Weldability	3	-	4
Solder/brazability	2	-	3

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Acceptable
Soils, acidic (peat)	Unacceptable
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Limited use
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Acceptable
Hydrochloric acid (10%)	Limited use
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	

	Unacceptable
Nitric acid (10%)	Limited use
Nitric acid (70%)	Acceptable
Phosphoric acid (10%)	Unacceptable
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Limited use
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Unacceptable
Sodium hydroxide (60%)	Unacceptable

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Excellent
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Excellent
Toluene	Excellent
Turpentine	Excellent
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Excellent
Acetone	Excellent
Ethyl alcohol (ethanol)	Acceptable
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Limited use
Methyl alcohol (methanol)	Acceptable

Durability: halogens and gases

Chlorine gas (dry)	Limited use
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Excellent

Sulfur dioxide (gas)	Acceptable

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Excellent

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Acceptable
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Geo-economic data for principal component

Annual world production, principal component		3.69e7			tonne/yr
Reserves, principal component		4.74e10	-	5.24e10	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	191	-	211	MJ/kg
CO2 footprint, primary production	*	11.5	-	12.7	kg/kg
Water usage	*	1.05e3	-	1.16e3	l/kg
Eco-indicator 95		780			millipoints/kg
Eco-indicator 99		219			millipoints/kg

Material processing: energy

Casting energy	*	11	-	12.2	MJ/kg
Metal powder forming energy	*	20.2	-	24.5	MJ/kg
Vaporization energy	*	1.55e4	-	1.71e4	MJ/kg
Coarse machining energy (per unit wt removed)	*	0.858	-	0.949	MJ/kg
Fine machining energy (per unit wt removed)	*	4.31	-	4.76	MJ/kg
Grinding energy (per unit wt removed)	*	8.14	-	9	MJ/kg
Non-conventional machining energy (per unit wt removed)		155	-	171	MJ/kg

Material processing: CO2 footprint

Casting CO2	*	0.826	-	0.913	kg/kg
Metal powder forming CO2	*	1.62	-	1.96	kg/kg

Vaporization CO2	* 1.16e3	-	1.28e3	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0644	-	0.0712	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.323	-	0.357	kg/kg
Grinding CO2 (per unit wt removed)	* 0.611	-	0.675	kg/kg
Non-conventional machining CO2 (per unit wt removed)	11.6	-	12.8	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✔			
Embodied energy, recycling	* 23.9	-	26.4	MJ/kg
CO2 footprint, recycling	* 1.88	-	2.08	kg/kg
Recycle fraction in current supply	33	-	55	%
Downcycle	✔			
Combust for energy recovery	✖			
Landfill	✔			
Biodegrade	✖			
Toxicity rating	Non-toxic			
A renewable resource?	✖			

Environmental notes

Aluminum ore is abundant. It takes a lot of energy to extract aluminum, but it is easily recycled at low energy cost.

Supporting information

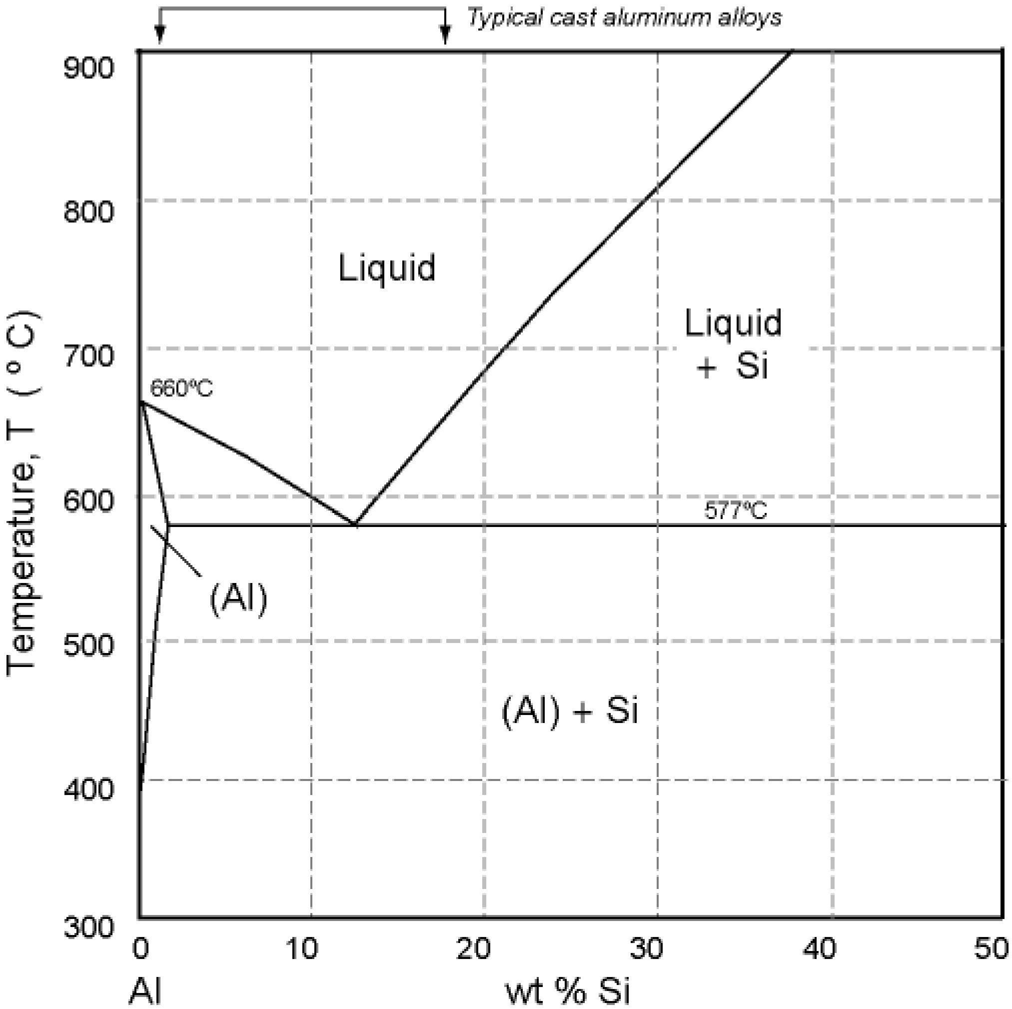
Design guidelines

Aluminum casting alloys are designed to be fluid so that they fill the mold and take up details well -- alloying with silicon is the most effective way to do this. Some of the alloys are designed for die-casting, some for permanent mold casting and some for sand casting. The main challenge with aluminum casting is coping with the shrinkage of 3.5 to 8.5 % that happens during solidification; this requires mold design to get the right final dimensions and to avoid hot tearing, cracking or porosity. Despite this constraint, aluminum castings of great complexity are practical. Recent developments in rheo-casting and squeeze casting overcome some of the problems of dimensional accuracy. The mechanical properties of the cast alloys are less good and more variable than those of the wrought series.

Technical notes

No classification system for cast aluminum alloys has international acceptance. In the most widely used (the AAUS system), the first digit indicates the alloy group. In the 1xx.x group, the second two digits indicate the minimum percentage of aluminum; thus 150.x indicates a composition containing a minimum of 99.5% aluminum. The digit to the right of the decimal point indicates the product form: 0 means 'castings' and 1 means 'ingot'. In the 2xx.x to 9xx.x groups, the second two digits are simply serial numbers. The digit to the right of the decimal point again indicates product form. Age-hardening alloys carry the suffix T and a number between 0 and 8 to indicated the state of heat treatment. More information on designations and equivalent grades can be found on the Granta Design website at www.grantadesign.com/designations

Phase diagram



Phase diagram description

Most cast aluminum alloys are based on alloys of aluminum (Al) with 1 - 18% silicon (Si), for which this is the phase diagram.

Typical uses

Aerospace engineering; automotive engineering - pistons, clutch housings, exhaust manifolds; die cast chassis and casings for household and electronic products.

Links

Reference

ProcessUniverse

Producers