Description

Image

Caption

1. Shaver body. © Chris Lefteri 2. Carburetor body made using zinc die-casting. © Granta Design

The material

Zinc is a bluish-white metal with a low melting point (420 C). The slang in French for a bar or pub is "le zinc"; bar counters in France used to be clad in zinc - many still are - to protect them from the ravages of wine and beer. Bar surfaces have complex shapes - a flat top, curved profiles, rounded or profiled edges. These two sentences say much about zinc: it is ductile; it is hygienic; it survives exposure to acids (wine), to alkalis (cleaning fluids), and to misuse (upset customers). These remain among the reasons it is still used today. Another is the "castability" of zinc alloys - their low melting point and fluidity gives them a leading place in die-casting.

Composition (summary)

Zn + 3-30% Al, typically, often with up to 3%Cu

General properties

Density		4.95e3	-	7e3	kg/m^3
Price	*	2.21	-	2.42	USD/kg
Date first used		1849			

Mechanical properties

Young's modulus		68	-	100	GPa
Shear modulus	*	25	-	40	GPa
Bulk modulus		50	-	90	GPa
Poisson's ratio	*	0.25	-	0.33	
Yield strength (elastic limit)		80	-	450	MPa
Tensile strength		135	-	510	MPa
Compressive strength		80	-	450	MPa
Elongation		1	-	30	% strain
Hardness - Vickers		55	-	160	HV
Fatigue strength at 10^7 cycles	*	20	-	160	MPa

Fracture toughness	*	10	-	70	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	6e-4	-	0.006	

Thermal properties

Melting point		375	-	492	°C
Maximum service temperature	*	80	-	110	°C
Minimum service temperature		-55.2	-	-43.2	°C
Thermal conductor or insulator?		Good conductor			
Thermal conductivity		100	-	130	W/m.°C
Specific heat capacity		405	-	535	J/kg.°C
Thermal expansion coefficient		23	-	28	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	5.4	-	7.2	µohm.cm

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Processability

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

Durability: water and aqueous solutions

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

Durability: acids

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

Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Unacceptable
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Limited use
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Limited use
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Acceptable
Sodium hydroxide (60%)	Limited use

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Acceptable
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	Limited use
Acetone	Excellent
Ethyl alcohol (ethanol)	Acceptable
Ethylene glycol	Excellent
Formaldehyde (40%)	Acceptable
Glycerol	Acceptable
Methyl alcohol (methanol)	Limited use

Durability: halogens and gases

Chlorine gas (dry)	Acceptable
Fluorine (gas)	Acceptable
O2 (oxygen gas)	Unacceptable

Sulfur dioxide (gas)	Limited use

Durability: built environments

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

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Excellent
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	1.11e7	tonne/yr
Reserves, principal component	2e8	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 57.2	-	63.2	MJ/kg
CO2 footprint, primary production	* 3.9	-	4.31	kg/kg
Water usage	* 396	-	438	l/kg
Eco-indicator 95	3.2e3			millipoints/kg
Eco-indicator 99	472			millipoints/kg

Material processing: energy

Casting energy	* 6.48	-	7.16	MJ/kg
Metal powder forming energy	* 10.2	-	12.3	MJ/kg
Vaporization energy	* 4.47e3	-	4.94e3	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.838	-	0.926	MJ/kg
Fine machining energy (per unit wt removed)	* 4.11	-	4.54	MJ/kg
Grinding energy (per unit wt removed)	* 7.74	-	8.55	MJ/kg
Non-conventional machining energy (per unit wt removed)	44.7	-	49.4	MJ/kg

Material processing: CO2 footprint

Casting CO2	* 0.486	-	0.537	kg/kg
Metal powder forming CO2	* 0.813	-	0.983	kg/kg

Vaporization CO_2	* 335	-	370	kg/kg
Coarse machining CO_2 (per unit wt removed)	* 0.0629	-	0.0695	kg/kg
Fine machining CO_2 (per unit wt removed)	* 0.308	-	0.34	kg/kg
Grinding CO_2 (per unit wt removed)	* 0.58	-	0.641	kg/kg
Non-conventional machining CO_2 (per unit wt removed	3.35	-	3.7	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✔			
Embodied energy, recycling	* 13	-	14.4	MJ/kg
CO_2 footprint, recycling	* 1.02	-	1.13	kg/kg
Recycle fraction in current supply	20	-	25	%
Downcycle	✔			
Combust for energy recovery	✘			
Landfill	✔			
Biodegrade	✘			
Toxicity rating	Non-toxic			
A renewable resource?	✘			

Environmental notes

Zinc vapor is toxic - if you inhale it you get the "spelter-shakes" - but adequate protection is now universal. In all other ways zinc is a star: it is non toxic, has low energy content, and - in bulk - can be recycled (not, of course, as plating).

Supporting information

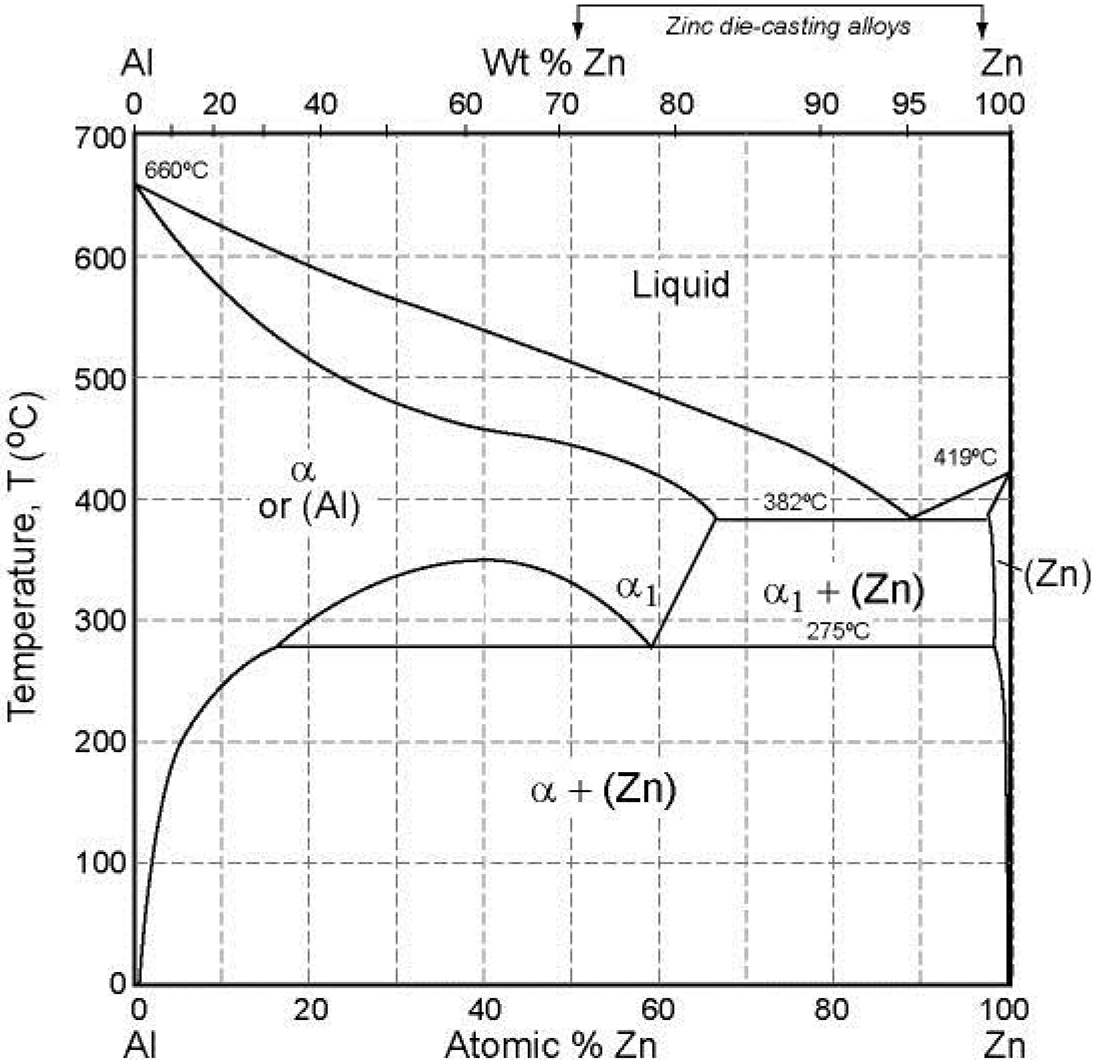
Design guidelines

Zinc die-casting alloys are strong enough for most consumer products; and the metal itself is cheap (they are the metallic answer to injection molded polymers). As die castings, zinc alloys offer higher strength than other die-casting alloys except those of copper. Die cast parts can be held to close tolerances, in thin sections and are easily machined, though little may be needed. They can be of complex shape: car carburetor bodies, "Dinky" toys (model cars) and small gears are examples.

Technical notes

Most zinc alloys are die cast; for this, the prime alloys are AG40A and AC41A. Superplastic zinc alloys can be formed by methods normally used for polymers - vacuum forming, compression molding - as well as traditional metal processes like deep drawing and impact extrusion. Extrusion and forging is done with zinc-manganese alloys.

Phase diagram



Phase diagram description

Zinc die-casting alloys are based on zinc (Zn) with 3 - 30% aluminum (Al), for which this is the phase diagram. Many also contain up to 3% copper.

Typical uses

Die castings, automotive parts and tools, gears, household goods, office equipment, building hardware, padlocks, toys, business machines, audio equipment, hydraulic valves, pneumatic valves, soldering, handles.

Links

Reference

ProcessUniverse

Producers