Aluminum/Silicon carbide composite

Description

Image

Caption

Al-SiC brake disc.

The material

Metal matrix composites are metals reinforced with ceramic particles. The most widely used are based on aluminum reinforced with particles of silicon carbide or alumina. The reinforcement increases the stiffness, strength and maximum service temperature without seriously increasing the weight. Production now exceeds 10,000 tonnes per year, at a cost of 2 - 5 £/kg.

Compositional summary

Al/10-40% SiC

General properties

Density		166	-	181	lb/ft^3
Price	*	2.82	-	3.76	USD/lb
Date first used		1982			

Mechanical properties

Young's modulus		11.7	-	14.5	10^6 psi
Shear modulus	*	4.41	-	5.58	10^6 psi
Bulk modulus		9.86	-	12	10^6 psi
Poisson's ratio		0.29	-	0.31	
Yield strength (elastic limit)		40.6	-	47	ksi
Tensile strength		42.1	-	52.9	ksi
Compressive strength		40.6	-	47.1	ksi
Elongation		1	-	5	% strain
Hardness - Vickers		70	-	140	HV
Fatigue strength at 10^7 cycles		7.25	-	16	ksi
Fracture toughness		13.7	-	21.8	ksi.in^0.5

Mechanical loss coefficient (tan delta)	* 0.001	-	0.009	

Thermal properties

Melting point	977	-	1.16e3	°F
Maximum service temperature	440	-	692	°F
Minimum service temperature	-460			°F
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	57.8	-	92.4	BTU.ft/h.ft^2.F
Specific heat capacity	0.191	-	0.215	BTU/lb.°F
Thermal expansion coefficient	8.33	-	12.8	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	5	-	12	µohm.cm

Optical properties

Transparency	Opaque

Processability

Castability	3	-	4
Formability	1	-	3
Machinability	1	-	3
Weldability	2		

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%)	Acceptable
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Limited use
Nitric acid (70%)	Limited use
Phosphoric acid (10%)	Unacceptable
Phosphoric acid (85%)	

	Unacceptable
Sulfuric acid (10%)	Unacceptable
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	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	Excellent
Acetone	Excellent
Ethyl alcohol (ethanol)	Acceptable
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Acceptable

Durability: halogens and gases

Chlorine gas (dry)	Limited use
Fluorine (gas)	Acceptable
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)	Excellent
Tolerance up to 250 C (482 F)	Excellent
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	3.63e7	ton/yr
Reserves, principal component	4.91e7	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 8.96e4	-	9.9e4	kcal/lb
CO2 footprint, primary production	* 48.6	-	53.7	lb/lb
Water usage	* 30	-	89.9	gal(US)/lb

Material processing: energy

Casting energy	* 1.06e3	-	1.17e3	kcal/lb
Non-conventional machining energy (per unit wt removed)	1.38e4	-	1.52e4	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.73	-	0.807	lb/lb
Non-conventional machining CO2 (per unit wt removed)	9.5	-	10.5	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✔			
Embodied energy, recycling	* 3.15e3	-	3.49e3	kcal/lb
CO2 footprint, recycling	* 2.29	-	2.53	lb/lb
Recycle fraction in current supply	2.5	-	3.5	%
Downcycle	✔			
Combust for energy recovery	✘			
Landfill	✔			
Biodegrade	✘			
Toxicity rating	Non-toxic			

A renewable resource?	✖

Environmental notes

The production of MMCs is energy intensive, but not otherwise damaging. Those based on aluminum can be made from part-recycled material, and the product itself can, in principle, be recycled.

Supporting information

Design guidelines

The attraction of metal matrix composites such as Duralcan is their stiffness-to-weight and strength-to-weight ratios, allowing weight saving in automobiles and sports equipment.

Technical notes

Metal matrix composites ('MMCs') are made by stirring finely divided silicon carbide (SiC) or alumina (Al2O3) particles into the molten metal, which is then cast ('Stir-casting'), or by mixing metal and ceramic powders and sintering, followed by forging or extrusion. The most widely used are the DURALCAN range of alloys based on the 6061 grade of aluminum alloy, with 10 to 30% silicon carbide or alumina.

Typical uses

Pistons; engine parts; brake discs, drums and calipers, drive shafts, mountain bike frames; precision instruments and sports equipment such as mountain bike frames and golf club shafts.

Links

Reference

ProcessUniverse

Producers