Description

Image

Caption

1. Nickel used in almost pure form for coinage. © Granta Design 2. AA battery. © Sbn1984 at en.wikipedia - Public domain

The material

The US 5¢ piece is, as its name suggests, almost pure nickel. Look at one - much can be learned from it: that nickel is a ductile, silvery metal, easily formed by stamping (or rolling or forging), hard when worked, and with good resistance to corrosion. Not bad for 5¢. Nickel has a high melting point (1450 C) and is one of the few elements that are ferro-magnetic (with Fe and Co). You don't see pure nickel very often, but its alloys are everywhere. Alloyed with copper it is widely used for coinage (the Euro, the "silver" dollar, the British 50 p piece). As Nichrome, a Ni-Cr alloy, it forms the heating elements of electric fires, toasters and hair dryers. Alloyed with iron and chromium it becomes stainless steel, familiar in every kitchen. And most exotic of all are the range of nickel-based materials known as "superalloys" because of their exceptional combination of high temperature strength and corrosion resistance. This record is for pure nickel. There are separate records for stainless steels, nickel-chromium alloys and superalloys.

Composition (summary)

99.8% Ni

General properties

Density		8.83e3	-	8.95e3	kg/m^3
Price	*	8.5	-	9.5	USD/kg
Date first used		1751			

Mechanical properties

Young's modulus		190	-	220	GPa
Shear modulus		72	-	86	GPa
Bulk modulus		162	-	200	GPa
Poisson's ratio		0.305	-	0.315	
Yield strength (elastic limit)		70	-	900	MPa
Tensile strength		345	-	1e3	MPa

Compressive strength		70	-	1e3	MPa
Elongation		2	-	60	% strain
Hardness - Vickers		80	-	300	HV
Fatigue strength at 10^7 cycles	*	135	-	500	MPa
Fracture toughness		80	-	110	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	2e-4	-	0.0032	

Thermal properties

Melting point		1.44e3	-	1.47e3	°C
Maximum service temperature	*	240	-	370	°C
Minimum service temperature		-272	-	-271	°C
Thermal conductor or insulator?		Good conductor			
Thermal conductivity		67	-	91	W/m.°C
Specific heat capacity		452	-	460	J/kg.°C
Thermal expansion coefficient		12	-	13.5	µstrain/°C

Electrical properties

Electrical conductor or insulator?		Good conductor			
Electrical resistivity		8	-	10	µohm.cm

Optical properties

Transparency		Opaque			

Critical Materials Risk

High critical material risk?		No			

Processability

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

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)		Acceptable			

Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Acceptable
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Limited use
Nitric acid (10%)	Limited use
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Limited use
Phosphoric acid (85%)	Limited use
Sulfuric acid (10%)	Acceptable
Sulfuric acid (70%)	Acceptable

Durability: alkalis

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

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

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Excellent
O2 (oxygen gas)	Acceptable
Sulfur dioxide (gas)	Limited use

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	1.43e6	tonne/yr
Reserves, principal component	7.1e7	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 163	-	180	MJ/kg
CO2 footprint, primary production	* 11	-	12.1	kg/kg
Water usage	* 222	-	245	l/kg
Eco-indicator 95	5.2e3			millipoints/kg
Eco-indicator 99	3.06e3			millipoints/kg

Material processing: energy

Casting energy	* 10.7	-	11.9	MJ/kg
Extrusion, foil rolling energy	* 2.3	-	2.54	MJ/kg
Rough rolling, forging energy	* 1.29	-	1.43	MJ/kg
Wire drawing energy	* 7.85	-	8.67	MJ/kg
Metal powder forming energy	* 36.5	-	40.3	MJ/kg
Vaporization energy	* 1.18e4	-	1.3e4	MJ/kg

Coarse machining energy (per unit wt removed)	* 0.626	-	0.692	MJ/kg
Fine machining energy (per unit wt removed)	* 1.99	-	2.2	MJ/kg
Grinding energy (per unit wt removed)	* 3.5	-	3.87	MJ/kg
Non-conventional machining energy (per unit wt removed)	118	-	130	MJ/kg

Material processing: CO2 footprint

Casting CO2	* 0.806	-	0.891	kg/kg
Extrusion, foil rolling CO2	* 0.173	-	0.191	kg/kg
Rough rolling, forging CO2	* 0.097	-	0.107	kg/kg
Wire drawing CO2	* 0.588	-	0.65	kg/kg
Metal powder forming CO2	* 2.92	-	3.22	kg/kg
Vaporization CO2	* 882	-	974	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.047	-	0.0519	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.149	-	0.165	kg/kg
Grinding CO2 (per unit wt removed)	* 0.262	-	0.29	kg/kg
Non-conventional machining CO2 (per unit wt removed	8.82	-	9.74	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 28.8	-	31.9	MJ/kg
CO2 footprint, recycling	* 2.27	-	2.5	kg/kg
Recycle fraction in current supply	28	-	33	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✗			
Biodegrade	✗			
Toxicity rating	Slightly toxic			
A renewable resource?	✗			

Environmental notes

About 10% of the population is sensitive to nickel, causing them to react even to the nickel in stainless steel watch straps. Compounds of nickel can be more toxic; nickel carbonyl, used in the extraction of nickel, is deadly.

Supporting information

Design guidelines

Pure nickel has good electrical conductivity, thermal conductivity, and strength and corrosion resistance; nickel and its alloys are used in marine applications for heat exchanges in other structures. The allergic reaction it sometimes causes limits the use of pure nickel in consumer products, but its alloys are largely immune from this problem.

Technical notes

Most nickel is use in alloys with chromium (Nichromes, Chromels), with iron (stainless steels) and as complex super-alloys (Hastelloy, Nimonic, Udimet).

Typical uses

Coinage, battery electrodes, as an electro-plate for corrosion protection of other

Links

Reference

ProcessUniverse

Producers