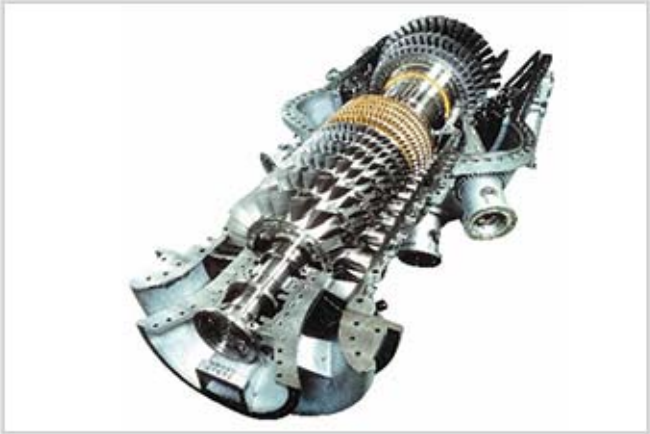
Description

Image



Caption

1. Gas turbine. © Kawasaki Turbines 2. Single superalloy blade. © Kawasaki Turbines

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	551	-	559	lb/ft^3
Price	* 7.87	-	8.65	USD/lb
Date first used	1751			

Mechanical properties

Young's modulus	27.6	-	31.9	10^6 psi
Shear modulus	10.4	-	12.5	10^6 psi
Bulk modulus	23.5	-	29	10^6 psi
Poisson's ratio	0.305	-	0.315	
Yield strength (elastic limit)	10.2	-	131	ksi
Tensile strength	50	-	145	ksi
Compressive strength	10.2	-	145	ksi
Elongation	2	-	60	% strain
Hardness - Vickers	80	-	300	HV
Fatigue strength at 10^7 cycles	* 19.6	-	72.5	ksi
Fracture toughness	72.8	-	100	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 2e-4	-	0.0032	

Thermal properties

Melting point	2.62e3	-	2.67e3	°F

Maximum service temperature	* 464	-	698	°F
Minimum service temperature	-458	-	-456	°F
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	38.7	-	52.6	BTU.ft/h.ft^2.F
Specific heat capacity	0.108	-	0.11	BTU/lb.°F
Thermal expansion coefficient	6.67	-	7.5	µstrain/°F

Electrical properties

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

Optical properties

Transparency	Opaque

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	1.41e6	ton/yr
Reserves	6.99e7	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 1.77e4	-	1.95e4	kcal/lb
CO2 footprint, primary production	* 11	-	12.1	lb/lb
Water usage	* 26.6	-	29.4	gal(US)/lb
Eco-indicator 95	5.2e3			millipoints/kg
Eco-indicator 99	3.06e3			millipoints/kg

Material processing: energy

Casting energy	* 1.16e3	-	1.29e3	kcal/lb
Extrusion, foil rolling energy	* 249	-	275	kcal/lb
Rough rolling, forging energy	* 140	-	155	kcal/lb
Wire drawing energy	* 850	-	939	kcal/lb

Metal powder forming energy	* 3.96e3	-	4.37e3	kcal/lb
Vaporization energy	* 1.28e6	-	1.41e6	kcal/lb
Coarse machining energy (per unit wt removed)	* 67.8	-	75	kcal/lb
Fine machining energy (per unit wt removed)	* 216	-	238	kcal/lb
Grinding energy (per unit wt removed)	* 379	-	419	kcal/lb
Non-conventional machining energy (per unit wt removed)	1.28e4	-	1.41e4	kcal/lb

Material processing: CO2 footprint

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

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 3.12e3	-	3.46e3	kcal/lb
CO2 footprint, recycling	* 2.27	-	2.5	lb/lb
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 metals.

Links

Reference

ProcessUniverse

Producers