Description

Image

Caption

1. Hair dryer with a Nichrome heating element. an alloy of nickel and chromium. © Granta Design 2. Toaster with a Nichrome heating element. an alloy of nickel and chromium. © Granta Design

The material

Nickel forms a wide range of alloys, valued by the chemical engineering and food processing industries for their resistance to corrosion, and by the makers of furnaces and high temperature equipment for their ability to retain useful strength at temperatures up to 1200 C. Typical of these are the nickel-chromium (Ni-Cr) alloys, often containing some iron (Fe) as well. The chromium increases the already-good resistance to corrosion and oxidation by creating a surface film of Cr203, the same film that makes stainless steel stainless. The data given here are for nickel-chromium alloys. There are separate records for stainless steel and nickel-based super alloys.

Composition (summary)

Ni + 10 to 30% Cr + 0 to 10% Fe

General properties

Density	518	-	531	lb/ft^3
Price	* 6.3	-	6.94	USD/lb
Date first used	1905			

Mechanical properties

Young's modulus	29	-	31.9	10^6 psi
Shear modulus	10.4	-	11.9	10^6 psi
Bulk modulus	22.5	-	41.3	10^6 psi
Poisson's ratio	0.305	-	0.315	
Yield strength (elastic limit)	52.9	-	66.7	ksi
Tensile strength	89.2	-	110	ksi
Compressive strength	52.9	-	66.7	ksi
Elongation	20	-	35	% strain

Hardness - Vickers	160	-	200	HV
Fatigue strength at 10^7 cycles	* 35.5	-	55.1	ksi
Fracture toughness	* 72.8	-	100	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 4e-4	-	0.002	

Thermal properties

Melting point	2.45e3	-	2.61e3	°F
Maximum service temperature	* 1.65e3	-	1.83e3	°F
Minimum service temperature	-458	-	-456	°F
Thermal conductor or insulator?	Poor conductor			
Thermal conductivity	5.2	-	8.67	BTU.ft/h.ft^2.F
Specific heat capacity	0.103	-	0.107	BTU/lb.°F
Thermal expansion coefficient	6.67	-	7.78	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	102	-	114	µohm.cm

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	Yes

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%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent

Hydrochloric acid (10%)	Acceptable
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Acceptable
Nitric acid (10%)	Acceptable
Nitric acid (70%)	Limited use
Phosphoric acid (10%)	Acceptable
Phosphoric acid (85%)	Acceptable
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	Excellent
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)	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)	Excellent			
Tolerance up to 850 C (1562 F)	Excellent			
Tolerance above 850 C (1562 F)	Unacceptable			

Geo-economic data for principal component

Annual world production, principal component	1.41e6			ton/yr
Reserves, principal component	6.99e7			l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 1.87e4	-	2.07e4	kcal/lb
CO2 footprint, primary production	* 10.9	-	12.1	lb/lb
Water usage	* 29.4	-	32.4	gal(US)/lb
Eco-indicator 95	5.2e3			millipoints/kg
Eco-indicator 99	2.83e3			millipoints/kg

Material processing: energy

Casting energy	* 1.14e3	-	1.26e3	kcal/lb
Extrusion, foil rolling energy	* 629	-	696	kcal/lb
Rough rolling, forging energy	* 330	-	365	kcal/lb
Wire drawing energy	* 2.28e3	-	2.51e3	kcal/lb
Metal powder forming energy	* 3.72e3	-	4.1e3	kcal/lb
Vaporization energy	* 1.27e6	-	1.4e6	kcal/lb
Coarse machining energy (per unit wt removed)	* 83.2	-	92	kcal/lb
Fine machining energy (per unit wt removed)	* 369	-	407	kcal/lb
Grinding energy (per unit wt removed)				

	* 687	-	758	kcal/lb
Non-conventional machining energy (per unit wt removed)	1.27e4	-	1.4e4	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.785	-	0.868	lb/lb
Extrusion, foil rolling CO2	* 0.44	-	0.48	lb/lb
Rough rolling, forging CO2	* 0.23	-	0.25	lb/lb
Wire drawing CO2	* 1.57	-	1.74	lb/lb
Metal powder forming CO2	* 2.75	-	3.03	lb/lb
Vaporization CO2	* 875	-	967	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0576	-	0.0637	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.255	-	0.282	lb/lb
Grinding CO2 (per unit wt removed)	* 0.475	-	0.525	lb/lb
Non-conventional machining CO2 (per unit wt removed	8.75	-	9.67	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 3.26e3	-	3.61e3	kcal/lb
CO2 footprint, recycling	* 2.37	-	2.62	lb/lb
Recycle fraction in current supply	22	-	26	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✗			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

Nickel alloys are non-toxic and can be recycled.

Supporting information

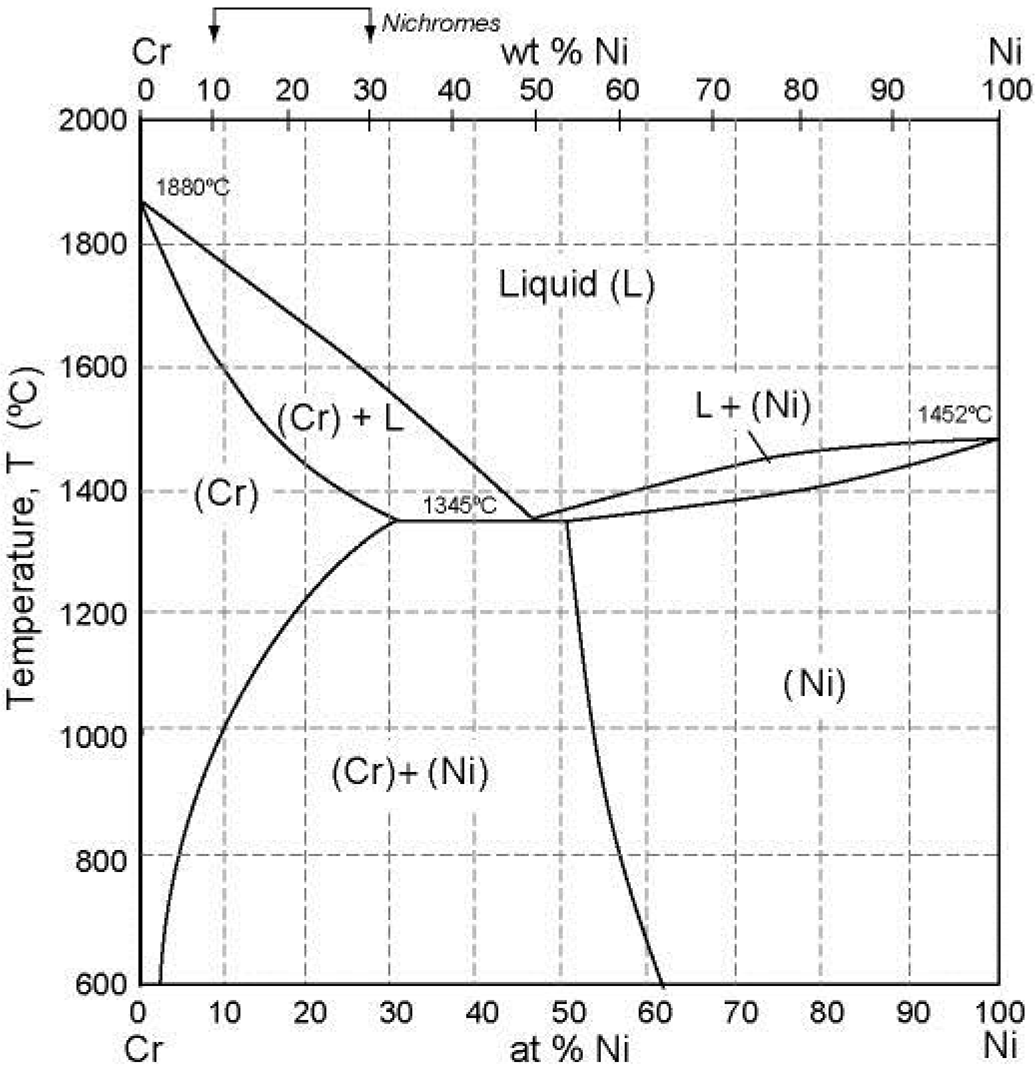
Design guidelines

Few other alloy systems can equal the nickel-based alloys in their combination of corrosion resistance and strength at low and high temperature. They are used in marine applications for heat exchanges in other structures. Nickel-iron alloys have high magnetic permeability (where electronic shielding and magnetic coils) and low thermal expansion (good for glass-to-metal joints). Invar, an alloy based on nickel, has essentially zero thermal expansion coefficient near room temperature; a magnetic contraction counteracts the ordinary thermal expansion, canceling it out. Nickel-chrome-iron alloys have high electrical resistance and are used as heating elements in toasters and industrial furnaces. Bi-metallic sheet of nickel bonded to copper is used as actuators for thermostats and safety devices. Alloys with titanium (Nitanols) have the remarkable property that they spring back to shape after severe deformation - they are called "shape memory alloys" for this reason.

Technical notes

Ni-Cr-Fe alloys are marketed under a bewildering catalog of tradenames. Chromels are straight Ni-Cr alloys with up to 20% Cr. Durimet and Nichromes contain iron. There are many more.

Phase diagram



Phase diagram description

Nichromes are alloys of nickel (Ni) with 10 - 30% chromium (Cr). They have useful strength and oxidation resistance to 1200 C.

Typical uses

Heating elements and furnace windings, bi-metallic strips, thermocouples, springs, food processing equipment, chemical engineering equipment.

Links

Reference

ProcessUniverse

Producers