International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2 Issue 7, July-2013, pp: (140-145), Available online at: www.erpublications.com

Nickel based alloys and their applications

Rishi Raj[1], Vinod Dhull[2], R. K. Kaushik[3]
[1]M.Tech, Department of Mechanical Engineering, SBMNEC, Rohtak, Haryana, India
[2]Assistant Professor, Department of Mechanical Engineering, HIT, Bahadurgarh, Haryana, India
[3]Professor, Department of Mechanical Engineering, HIT, Bahadurgarh, Haryana, India

Abstract: This article will help practicing and teaching engineers to find importance of Nickel based alloys used in manufacturing. From single source readers will find their constituents, properties and applications.

Key word: Nickel based Alloys; this family of alloys is also name by the trade name Nichrome.

Introduction

In 1750, nickel was discovered as an element, but was not used extensively until the twentieth century later it became an essential alloying element in stainless steels other important alloys Nickel ores occurs in form on oxides or sulfides. A good portion of Nickel (About 58%) is used in making stainless steels and about 10% in electroplating. Remainder about 32% is used in making Nickel based alloys. Nickel alloys are unused often because they have unique physical properties. Nickel alloys when alloyed with chromium are frequently used for resistive heating element. Some high nickel iron alloys are heaving good magnetic permeability making them superior for magnetic shielding of electronic devices through in this article we will discuss only Nickel based alloys with their constituents, properties and applications.

MONEL K-500

Nickel + cobalt	63-70%
Aluminum	2.30-3.15%
Titanium	0.35-0.35%
Iron	2.00%
Manganese(max)	1.50%
Carbon (max)	0.25%
Silicon (mix)	0.50%
Sulphar (mix)	0.01%
Copper	Remainder

Properties:

Coefficient of thermal expansion is $13.7 \times 10^{-6}/^{\circ}c$ (21 -93°c)
Thermal conductivity at 20 °c is 0.042 cal/sqcm/cm/sec/°c
Modulus of elasticity (Tension) is 180000N/mm^2
Tensile Strength is 830N/mm^2
Electrical Resistivity at 20° c is 61.8 microhm-cm

Applications:

For making forged components to meet chemical industry requirements possesses good elastic properties at low and high temperature corrosion resistant. Used in propeller shafts, pressure gauges highly stresses nuts and bolts etc.

MONEL R-405

Nickel+cobalt	63-70%
Iron(max.)	2.5%
Manganese(max.)	2.0%
Carbon (max.)	0.3%
Silicon (max.)	0.5%

Sulphur (max.)	0.025-0.060%
Copper	Remainder

Properties:

Coefficient of thermal expansion is $13.9x10^{-6}/^{\circ}c$ (21-93°c)
Thermal conductivity at 20 °c is 0.052 cal/sq.cm/cm/sec/°c
Electrical Resistivity at 20 °c is 513 microhm-cm
Modulus of elasticity (Tension) is 200000 N/mm^2
Tensile Strength is 800N/mm^2

Applications:

It is used where free machining is required. Its greater sulphur content enhances machinability, Corrosion resistant, food processing equipments, nozzles of pelton turbines etc.

MONEL 400

Nickel+cobalt	63-70%
Sulphur (max.)	0.024%
Iron	2.5%
Manganese(max.)	2.0%
Carbon (max.)	0.3%
Silicon (max.)	0.5%
Copper	Remainder

Properties:

Coefficient of thermal expansion is $13.9x10^{-6}/^{\circ}c$ (21-93°c)
Thermal conductivity at 20 °c is 0.052 cal/sq.cm/cm/sec/ °c
Electrical Resistivity at 20 °c is 51.3 microhms-cm
Modulus of elasticity (Tension) is 180000 N/mm^2
Tensile Strength is 600 N/mm^2

Applications:

There are used where good combination of corrosion resistance, strength and ductility is required. Used in valves and chemical processing industries.

INCONEL 600

Nickel+cobalt(min)	72%
Chromium	14.0-17.0%
Iron	6.0-10.0%
Manganese(max.)	1.0%
Carbon (max.)	0.15%
Cooper (max.)	0.5%
Silicon (max.)	0.015%
Sulphur	0.05%

Properties:

Coefficient of thermal expansion is $13.3x10^{-6}/^{\circ}c$ (21-93°c)
Thermal conductivity at 20 °c is 0.035 cal/sq.cm/cm/sec/ °c
Electrical Resistivity at 20 °c is 103.5 microhms-cm
Modulus of elasticity (Tension) is 210000 N/mm^2
Tensile Strength is 550 N/mm^2

Applications:

It's mechanical properties and resistance to corrosion are excellent. The alloy's high temperature strength to oxidation are outstanding. Besides being non-magnetic, it has a high creep strength. It is used for high temperature applications (upto 1090 °C). So is used for engine exhaust manifolds, furnace and other heat treating equipments.

CORRONEL Constituents

Nickel	66%
Molybdenum	28%
Iron	6%

Properties:

Data is not available. But it is particularly resistant to attack by mineral acids and acid chloride solutions under the most extreme conditions.

Applications:

Chemical and Petroleum industries for the construction of reaction vessels, pump, filter parts values, heat exchangers and immersion heaters.

HASTELLOY A constituents (Note: Hastelloy is a trade name)

Nickel	58%
Chromium	20%
Molybdenum	3%
Copper	2%
Balance	iron

Complete data is not available but find use in chemical industries where anti-corrosion properties are required.

HASTELLOY B constituents

Chromium (max.)	1.00%
Iron	4.0-6.0%
Carbon (max.)	0.05%
Silicon (max.)	1.00%
Cobalt (max.)	2.50%
Manganese (max.)	1.00%
Sulphur (max.)	0.030%
Phosphorus (max.)	0.025%
Vanadium	0.20-0.40%
Molybdenum	26.00-30.00%
Nickel	Remainder

Properties:

Coefficient of thermal expansion 10.1×10^{-6}/°c (21-93°c)
Thermal conductivity at 20 °c is 0.025cal/sq.cm/cm/sec/ °c
Modulus of elasticity (Tension) is 213000 N/mm^2
Electrical Resistivity at 20 °c is 135 microhms-cm
Tensile Strength is 730 N/mm^2

Applications:

Very high corrosion resistance and high strength at elevated temperatures make it very useful in chemical industries where corrosive liquids (Chemicals) at very high pressure are used. It is also used in transporting and storing hydrochloric, phosphoric and other non-oxidising acids.

HASTELLOY C constituents

Chromium	14.5-16.5%
Tungsten	3.0-4.5%
Iron	4.0-7.0%
Carbon (max)	0.02%
Silicon (max)	0.05%
Cobalt (max)	2.5%
Manganese (max)	1.00%
Sulphur (max)	0.030%
Phosphorus (max)	0.030%
Vanadium	0.35%
Molybdenum	15.0-17.0%
Nickel	Remainder

Properties:

Difficult to machine
Hardness HRC 25-30
Tensile Strength 700 N/mm^2 approx.
Modulus of Electricity 220000 N/mm^2

Applications:

Have good corrosion resistance and strength. Also find applications in chemical and petroleum industries.

MONEL R Constituents

Nickel	67%
Copper	30%
Iron	1.4%
Manganese	1.00%
Carbon	0.15%
Sulphur	0.035%

Properties

Tensile Strength is 590 N/mm^2
Brinell Hardness is (145-180)
Elongation is 30%
Yield strength (0.2% offset) is 415 N/mm^2

Applications:

Good Machinability and corrosion resistant alloy, so very much used in making precision parts, screws and bolts.

MONEL KR Constituents

Nickel	66%
Copper	29%
Iron	0.9%
Aluminum	2.75%
Silicon	0.05%
Manganese	0.75%
Carbon	0.28%
Sulphur	0.05%

Properties:

Tensile Strength is 690 N/mm^2 for hot rolled,1030 N/mm^2 for cold-rolled and age hardened,790 N/mm^2 for cold-drawn,1060 N/mm^2 for cold-drawn and age hardened.

Brinell Hardness is 160,280,210 and 290 respectively.
Elongation is 40%,25%,25% and 20% respectively.
Yield strength is 310 N/mm^2 ,750 N/mm^2,585 N/mm^2 and 790 N/mm^2 respectively.

Applications:

Since possessing good mach inability, turned precision parts on auto lathes are made. These parts are mostly used in chemical industries for their good corrosion resistance properties.

MONEL S Constituents

Nickel	63%
Copper	30%
Iron	2%
Silicon	4%
Manganese	0.75%
Carbon	0.1%
Sulphur	0.15%

Properties:

Tensile Strength is 620 N/mm^2 for annealed sand cast, 890 N/mm^2 for as sand cast.
Brinell Hardness is 275,320 and 350 respectively.
Elongation is 3%,2% and 2% respectively
Yield strength(0.2% offset) is 480 N/mm^2 ,887 N/mm^2 and 890 N/mm^2 respectively.

Applications:

This is a extra hard casting alloy which is non-galling corrosion resisting, non-magnetic, age-hardenable and has low sparking properties, that is why it is used for gall-resistant pump and valve parts. Those parts have to withstand high temperatures, corrosive chemicals and severe abrasion.

MONEL H Constituents

Nickel	63%
Copper	31%
Iron	2%
Silicon	3%
Manganese	0.75%
Carbon	0.1%
Sulphur	0.015%

Properties:

Tensile Strength is 690 N/mm^2 for as cast-sand cast condition.
Brinell Hardness is 210.
Elongation is 15% .
Yield strength is 410 N/mm^2 for as cast-sand cast condition.

Applications:

This is a extra hard casting alloy with good ductility, intermediate strength and hardness which makes it find application for pumps, impellers and steam nozzles.

INCOLOY:

It is a nickel-iron-chromium alloy. Its resistant to a verity of reducing acids and oxidizing chemicals. Particularly it is exceptionally resistant to sulphuric and phosphoric acids and sea water. Its application is pipe fitting in pipe line of chemical industries and is also used in marine applications. These alloys are used where high temp. resistant materials are required.

INCOLOY (High- temperature resistance alloy)

Composition (%)				Tensile strength of annealed rod	Resistivity	Maximum	Uses
Ni	Cr	Fe	Mn	MN/m2	10-8 Ω m	Working temp(◦c)	
80	20	_	_	911	103	1150	Heaters for electric furnaces, cookers, hair dryer, toasters etc.
65	15	20	_	726	106	950	Similar uses as above but for goods of low quality also for soldering-irons laundry irons, tubular heater etc.
34	4	64	_	664	91	700	Cheaper quality heaters working at low temp, but mainly as a resistance wire for motor-starter resistances etc.
45	_	_	55	402	48	300	Limited use for low temperature heaters such as bed- warmers etc. mainly as a resistance wire for instruments shunts, field regulators are resistances.

Conclusion

The main feature of the nickel chromium alloys is their ability to rasist oxidation at high temperature. If further suitable alloy additions are made the strength is increased under condition of stress at high temperature, as we have seen in nickel alloys. From the above table it is clear that as percentage of nickel lowers, the maximum working, temperature also lowers.

References

[1]. Metallurgy for engineers by E. C. Rollason.
[2]. Engineering Materials by Kanneth G. Budinshi.
[3]. Fundamentals of engineering Metallurgy and Materials F.W. J. Bailey.
[4]. Corrosion of Nickel and Nickel-base alloys by Everhart, john L.
[5]. Metals haul Book 9th Edition Vol. 2: Properties and selection: Non-ferrous alloys and special- purpose materials. Metal park, OH: ASM international, 1991.
[6]. Machinery's Hand Book, 22nd Edition industrial Press, New York.