United States Patent Office

2,703,277

Patented Mar. 1, 1955

2,703,277

NICKEL-BASE ALLOY FOR HIGH TEMPERATURE SERVICE

Howard R. Spendelow, Jr., Snyder, and Walter Crafts, Niagara Falls, N. Y., assignors to Union Carbide and Carbon Corporation, a corporation of New York

No Drawing. Application June 12, 1952, Serial No. 293,202

2 Claims. (Cl. 75—171)

This invention relates to alloys primarily for use at high temperatures, but also of utility for their resistance to attack by various corrosive media, and refers more particularly to a nickel-base alloy of relatively low strategic metal content for this purpose.

The so-called "super alloys" which have been developed over the past several years for use in the drastic conditions of temperatures and stresses encountered in jet engines have served their purpose well. They possess great strength at temperatures of the order of 1500° F. and above and have the ability to withstand high stresses at such temperatures for protracted periods of time. Their availability has made possible tremendous improvements in jet engines.

However, these alloys depend largely for their superior high temperature properties on the presence of relatively large quantities of metals in short supply and of great strategic importance. Among such metals are niobium, tantalum, wolfram and cobalt. Because of the importance of conserving these metals there is a demand for alloys having properties comparable to the properties of the present alloys but which contain little or no strategic metals.

It is the principal object of this invention to satisfy this demand. Another object of the invention is the provision of such an alloy with good formability. A still further object of the invention is the provision of such an alloy with good corrosion resistance, so that it may withstand the corrosive attack of pickling media and of other corrosive agents to which such alloys are not infrequently exposed.

These objects are achieved by the invention which comprises a nickel-base alloy containing 20% to 23% chromium; 17% to 20% iron; 8% to 10% molybdenum; up to 2.5% cobalt; up to 1% wolfram; up to 1% manganese; up to 1% silicon; 0.05% to 0.15% carbon; the remainder nickel and incidental impurities. Although cobalt and wolfram are not essential constituents of the alloy, these metals are ordinarily unavoidably present, usually in amounts of about 0.5% cobalt and 0.1% wolfram being derived from both virgin raw materials and scrap used in their manufacture. A specific example of a preferred composition is: 22% chromium; 18% iron; 9% molybdenum; 0.1% carbon; the remainder nickel, incidental impurities and not more than 1% each of manganese and silicon.

The strength of the alloy of the invention at high temperatures is substantially equal to that of one of the most widely-used of the "super alloys" which contains about 20% cobalt and 1% niobium in addition to 20% chromium; 20% nickel; 3% molybdenum; 2% wolfram; remainder iron. For instance, Aircraft Materials Specification 5532A requires that the "super alloy," just referred to, shall withstand a stress of 18,000 p. s. i. at 1500° F. for 24 hours without rupture. Wrought specimens of an alloy according to this invention, having the composition set forth, not only meet, but exceed the requirements of this specification by 25%.

Typical calculated average stress-rupture properties, based on tests made on wrought sheet material composed of the alloy of this invention are set forth in Table I. In these tests the specimens were composed of an alloy containing substantially 22% chromium; 18% iron; 9% molybdenum; 1.5% cobalt; 0.6% wolfram; 0.6% manganese; 0.4% silicon; 0.1% carbon; the remainder nickel. The specimens were in the annealed condition, having

been heated to about 2100° F. to 2200° F. and cooled slowly before testing.

Table I

Temp., ° F.	Calculated stresses in pounds per square inch to cause rupture in hours indicated				
	10 hours	50 hours	100 hours	500 hours	1,000 hours
1,200	62,000	49,000	43,000	34,500	30,000
1,350	35,000	28,500	25,000	20,000	18,000
1,500	21,000	16,000	14,000	11,000	9,800

The short-time tensile properties of annealed sheet composed of the alloy of the invention are set forth in Table II.

Table II

Test temp., ° F.	Ultimate strength, lbs./sq. in.	Percent elongation in 2 inches
Room	116,000	44.5
400	104,000	42.0
600	101,500	44.0
800	100,000	45.0
1,000	94,000	44.0
1,200	82,000	38.0
1,350	68,000	31.0
1,500	48,000	37.0
1,650	31,000	41.0
1,800	20,000	41.0
1,900	16,000	37.0

The elongation data in Table II demonstrate the ductility of the alloy. It possesses unusually good formability and has been rolled without difficulty into sheet 0.05 inch thick. Evidence of its working properties was obtained in standard Erichsen tests in which a sheet is clamped between two dies in such a way that the metal is free to flow while a tool having a rounded end is moved against it under the influence of a ram actuated by a micrometer screw. The depth of impression in millimeters to obtain fracture is the "Erichsen value." The average Erichsen value for the alloy of the invention is 11.0 to 12.0.

A more recently devised formability test referred to as the "wedge-draw" test is described in "Metal Progress," vol. 41, No. 5, pages 663–668, published May 1942 by the American Society for Metals. The "drawability ratio" of the alloy of the invention as determined by this test averages about 1.76 as compared to 1.73 for type 347 stainless steel and 1.65 for "ELC" 18% chromium-8% nickel stainless steel.

In more conventional tests, sheet composed of the alloy of the invention may be bent 180° without failure.

A particularly outstanding property of the alloy is its exceptional resistance to oxidation at elevated temperatures. For instance sheet 3/16 inch thick has been used to form a sheath over refractory rollers 7 inches in outside diameter in a roller hearth furnace operating at temperatures of 2100° F. to 2200° F. After 1500 hours of service the loss of metal from the sheath due to oxidation was negligible although similar sheaths fabricated from a cobalt-base alloy, considered one of the best of the high temperature alloys, had lost half their thickness by oxidation after only 200 hours under these conditions.

Indicative of the alloy's resistance to attack by corrosive media, specimens tested in boiling 5% nitric acid for 24 hours showed a corrosion rate of only 5.6 mils (thousandths of an inch penetration) per year, while the rate in boiling 25% nitric acid was only 10.7 mils per year. In boiling 10% sulfuric acid solutions, the average corrosion rate of the alloy was only 13.6 mils per year.

The properties described above are based on tests conducted on annealed sheet fabricated from the alloy of the invention. However, the alloy may be cast readily by precision-investment casting methods and as cast has properties which compare favorably with those of the super alloys.

Thus the alloy of the invention has properties making it suitable for use under extremely severe conditions of

temperature and stress in place of the super alloys in many instances, as well as resistance to attack by various corrosive media and these properties are achieved without the use of substantial quantities of strategic materials.

The relative strategic importance of various alloying metals is presently rated by a numerical system, the higher the number the more strategic the metal and the more rigidly controlled. In the several variations of such an index now in use, the strategic rating increases progressively from nickel and from chromium derived from ferrochromium alloy, upwards through chromium metal, molybdenum, wolfram and cobalt, to tantalum and niobium, so that the last named are rated several hundred fold greater than the first.

The alloy of this invention does not include those metals of the higher strategic ratings and, moreover, being made by conventional melting practice using ferrochromium instead of chromium metal has an exceptionally low content of strategic metals. Yet, in its high temperature properties it is substantially equivalent to many alloys the use of which is restricted because of their high content of strategic metals.

What is claimed is:

1. A nickel-base alloy capable of being rolled to sheet and composed of about 22% chromium; 18% iron; 9% molybdenum; up to 2.5% cobalt; up to 1% wolfram; up to 1% manganese; up to 1% silicon; 0.05% to 0.15% carbon; the remainder nickel.

2. Rolled sheet metal capable of withstanding a stress of 7500 pounds per square inch at a temperature of 1500° F. for at least 1000 hours, said metal being composed of the allow defined by claim 1.

References Cited in the file of this patent

UNITED STATES PATENTS

2,392,821	Kreag	Jan. 15, 1946
2,403,128	Scott et al.	July 2, 1946
2,503,608	Banister	Apr. 11, 1950