United States Patent Office

2,912,323
Patented Nov. 10, 1959

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2,912,323

CAST NICKEL BASE ALLOY FOR HIGH TEMPERATURE SERVICE

Clarence G. Bieber, Bayonne, and George N. Ziegler, Chatham, N.J., assignors to The International Nickel Company, Inc., New York, N.Y., a corporation of Delaware

No Drawing. Application September 16, 1957 Serial No. 683,929

5 Claims. (Cl. 75—171)

The present invention relates to alloys suitable for use under stress at elevated temperatures and, more particularly, to cast nickel alloys characterized by relatively high rupture life under severe stress at temperatures of 1700° F. and above.

As is well known to those skilled in the art, the constant improvements being made with respect to materials employed in the field of high temperature application necessitate the utilization of metals and/or alloys capable of withstanding for relatively long periods of time the higher temperatures and stresses encountered during service. Turbine blades, for example, are subjected to intense heat and severe stress during use. While such blades often perform satisfactorily at relatively low temperatures, e.g., 1300° F., they rupture comparatively quickly at temperatures of 1700° F. and above because the alloys from which they are made are incapable of affording the necessary resistance to fracture under stress at such high temperatures.

The problem becomes particularly acute, and indeed magnified, when it is considered that the metallurgist is without recourse to any specific formula or absolute yardstick which he can call upon to reliably predict the expected properties of a particular alloy composition under specified but untested temperature and stress. This is to say, a metallurgist, while he may have access to a voluminous fund of data concerning the properties and successful operating characteristics of several alloys at various temperatures, e.g., 1400° F. or 1500° F., would normally be unable to predict with any degree of accuracy the properties to be expected at temperatures of 1700° F. or 1800° F. and above. Moreover, under such circumstances, the metallurgist would be unable to predict without reservation what alloy would render the best performance, although it be an unsatisfactory performance, at the higher temperatures. Experience has shown that one alloy having properties superior to those of a second alloy at a specified temperature and stress will have inferior properties at conditions of higher temperature and stress. Thus, the "second alloy" may exhibit what may be termed "retentive powers" even to the extent which would make its use practical at higher operating levels of temperature and stress. It should be added that the problem is further complicated by the fact that if a precision cast article is desired, even the alloy with satisfactory physical properties, e.g., fracture properties, may be unsuitable if it cannot be cast in desired shape. Castability of an alloy has often been undesirably achieved at the expense of the physical properties thereof by altering the composition of the alloy.

There presently exists a vital need for cast, creep resistant alloys capable of affording substantial resistance to fracture under high stresses, e.g., 30,000 p.s.i. (pounds

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per square inch), at temperatures of 1700° F. and above. Too, there is a need for such alloys which can be readily precision cast into various forms, e.g., blades for jet engine turbines and other gas turbines. Alloys which have been heretofore proposed for use at elevated temperatures have been found not to exhibit satisfactory rupture life properties under high stress at temperatures of 1700° F. and above. Although attempts were made to overcome the foregoing difficulties, none, as far as we are aware, were entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that cast nickel alloys containing a special molybdenum content in combination with chromium, aluminum, titanium, and columbium in amounts specified hereinafter resist rupture for a relatively long period of time under high stress at elevated temperatures.

It is an object of the present invention to provide a cast alloy capable of withstanding high stress at elevated temperatures for relatively long periods of time.

Another object of the invention is to provide a cast alloy capable of offering appreciable resistance to rupture and affording a relatively long service life at temperatures of 1700° F. and above when subjected to severe stress, e.g., 30,000 p.s.i.

The invention also contemplates providing precision cast alloys suitable for use as blades in jet engine turbines and other gas turbines and capable of rendering highly satisfactory service under severe stress at elevated temperatures of 1700° F. and above.

Other objects and advantages will become apparent from the following description.

Generally speaking, the present invention provides cast nickel alloys, and particularly precision cast nickel alloys, capable of exhibiting substantial resistance to rupture for relatively long periods of time at temperatures of 1700° F. when subjected to severe stress. In accordance with the principles of the present invention, the alloys contain from 6.0% to about 10% molybdenum, about 10% to 35% chromium, about 4% to 8% aluminum, about 0.1% to 3% titanium, and about 0.1% to about 5% columbium, the balance being essentially nickel. Particularly good results are obtainable anent both rupture life and castability properties in accordance with preferred alloys of our invention which contain about 6.0% to about 9% molybdenum, about 10% to about 17% chromium, about 5% to 7% aluminum, about 0.3% to about 1.5% titanium, and about 1% to about 3% columbium, the balance being essentially nickel. We have found that best results are achieved with respect to castability of the alloys when the alloys contain aluminum and titanium in amounts of 5% to 7% aluminum and 0.3% to 1.5% titanium, the sum of the aluminum plus titanium being at least about 5.5%. Experience has shown that a high titanium content, e.g., 4% or 5%, contributes to poor castability because it promotes and causes the formation of nitrides which are difficult to flux off, whereas an aluminum content of 5% to 7% renders the alloys fluid and facilitates the ease of casting.

We have found it important that the molybdenum content of the alloys be not less than 6.0% nor greater than about 10% if the high rupture life properties contemplated are to be attained. The data tabulated in Table I hereinbelow illustrate the importance of maintaining the molybdenum content of the alloys over the range of 6.0% to 10%.

Table I

Cast Alloy No.	Percent Cr	Percent Mo	Percent Cb	Percent Al	Percent Ti	Percent Ni[1]	Test Temp., ° F.	Test Stress, p.s.i.	Time Fracture, Hours
1	12	4	2	5.5	0.5	Bal	1,700	30,000	24
2	12	8	2	5.5	0.5	Bal	1,700	30,000	48
3	12	12	2	5.5	0.5	Bal	1,700	30,000	17

[1] Alloys contained iron, silicon, manganese, carbon, zirconium, calcium and boron in nominal amounts of 1%, 0.25%, 0.1%, 0.12%, 0.05%, 0.03% and 0.02%, respectively.

The data in the foregoing table illustrate that the alloys having a molybdenum content falling outside the molybdenum range of the invention manifest a markedly inferior resistance to fracture as compared to alloy No. 2 having a molybdenum content falling inside the scope of the present invention.

It is also significant to note that the cast alloys of the present invention are characterized by other highly desirable properties. For example, the alloys possess a markedly high tensile strength at elevated temperatures and exhibit highly satisfactory elongation properties. Thus, an alloy having a composition similar to alloy No. 2 of Table I but containing 6% aluminum manifested a tensile strength of 69,250 p.s.i. and an elongation of 20% when tested at a temperature of 1742° F. (950° C.). Another alloy tested at 1742° F. (950° C.) having a composition similar to alloy No. 2 herein but containing 1% titanium showed a tensile strength of 63,400 p.s.i. and 20% elongation.

It is further preferred in accordance with the invention, particularly where good ductility is desired or required, that the alloys contain boron in a small but effective amount up to about 0.1% and zirconium in an amount up to about 2%. It is particularly important that the boron content not exceed 0.1% because the presence of greater amounts thereof is detrimental to achieving castings having good properties, e.g., excessive amounts result in brittle castings.

As will be readily understood by those skilled in the art, the expression "balance essentially nickel" does not exclude the presence of other elements commonly present in such alloys as incidental elements, e.g., deoxidizing and cleansing elements, and impurities ordinarily associated therewith in small amounts which do not adversely affect the basic characteristics of our alloys. The nickel content of the alloys is at least 40% by weight and it is preferred to employ a nickel content of 50% or more. Other elements which can be present in the alloys of the invention without adversely affecting the basic characteristics and which are contemplated within the scope of the invention include up to 8% silicon, up to 25% cobalt, e.g., up to about 15% cobalt, up to 25% iron, up to 0.25% carbon, up to 2% copper and up to 2.5% manganese.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

We claim:

1. A cast nickel-base alloy characterized by a long rupture life when subjected to stress at temperatures of 1700° F. and above, said alloy containing from 6.0% to about 9% molybdenum, about 10% to 17% chromium, about 5% to 7% aluminum, about 0.3% to 1.5% titanium, the sum of the aluminum and titanium being at least 5.5%, about 1% to 3% columbium, boron in a small but sufficient amount up to 0.1% to enhance the ductility of said alloy, up to 2% zirconium, up to about 15% cobalt and the balance essentially nickel.

2. A cast nickel-base alloy characterized by a long rupture life when subjected to stress at temperatures of 1700° F. and above, said alloy containing from 6.0% to about 9% molybdenum, about 10% to 17% chromium, about 5% to 7% aluminum, about 0.3% to 1.5% titanium, about 1% to 3% columbium, boron in a small but sufficient amount up to 0.1% to improve the ductility of said alloy, up to 2% zirconium, up to about 15% cobalt and the balance essentially nickel.

3. A cast nickel-base alloy capable of withstanding high stress at elevated temperatures for a relatively long period of time, said alloy containing from 6.0% to about 10% molybdenum, about 10% to 35% chromium, about 4% to 8% aluminum, about 0.1% to 3% titanium, about 0.1% to about 5% columbium, boron in a small but sufficient amount up to 0.1% to enhance the ductility of said alloy, up to 2% zirconium, up to 8% silicon, up to 2.5% manganese, up to 25% iron, up to 25% cobalt, up to 0.25% carbon, up to 2% copper and the balance essentially nickel.

4. A cast nickel-base alloy capable of withstanding high stress at elevated temperatures for a relatively long period of time, said alloy containing from 6.0% to about 10% molybdenum, about 10% to 35% chromium, about 4% to 8% aluminum, about 0.1% to 3% titanium, about 0.1% to about 5% columbium, about 0.02% to 0.1% boron, up to 2% zirconium, up to 8% silicon, up to 2.5% manganese, up to 25% iron, up to 25% cobalt, up to 0.25% carbon, up to 2% copper and the balance essentially nickel.

5. A nickel-base alloy capable of withstanding relatively high stress at elevated temperatures for a relatively long period of time, said alloy containing from 6.0% to about 10% molybdenum, about 10% to about 35% chromium, about 4% to about 8% aluminum, about 0.1% to about 3% titanium, about 0.1% to about 5% columbium, boron in a small but sufficient amount up to 0.1% to enhance the ductility of said alloy, up to 8% silicon, up to 2.5% manganese, up to 25% iron, up to 25% cobalt, up to 0.25% carbon, up to 2% copper and the balance essentially nickel.

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