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NICKEL-CHROMIUM ALLOYS

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The present invention relates to nickel-chromium alloys and, more particularly, to nickel-chromium alloys which are adapted to be employed as precision cast components in structures subjected in use to the deleterious effects of high temperature, high stress and corrosive atmospheres. In nickel-chromium alloys employed for the aforementioned purpose which have been known heretofore, it is desirable to use as high a chromium content as possible, since it improves their resistance to oxidation. Nevertheless, the maximum chromium content has been limited to about 15%, since it has been found that at higher chromium contents the creep resistance of the alloys at high temperatures falls off. Although attempts were made to provide a nickel-chromium precision casting alloy having good oxidation resistance in combination with an excellent overall combination of room temperature and elevated temperature characteristics, none, as far as I am aware, was entirely successful when carried into practice commercially on an industrial scale.

It has now been discovered that alloys containing more than 15% chromium can be provided which alloys have particularly good stress-rupture lives at high temperatures by ensuring that the contents of titanium, chromium and cobalt are in a particular relationship and by carefully controlling the compositional limits with respect to the other elements present.

It is an object of the present invention to provide a novel nickel-chromium alloy for use in structures adapted to be employed at elevated temperatures under severe stress.

Another object of the invention is to provide a novel, precision casting, nickel-chromium alloy for use as components in structures subjected in use to the deleterious effects of elevated temperature, high stress and corrosive atmospheres.

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

Generally speaking, the present invention contemplates nickel-base alloys containing from more than about 15% (e.g., 20%) to about 22% chromium, from 0% to about 15% cobalt, from about 7% to about 9% tungsten, from about 3.5% to about 4.5% aluminum, from about 1.5% to about 4.5% titanium, from about 0.01% to about 0.20% carbon, from about 0.005% to about 0.15% boron and from about 0.3% to about 0.7% zirconium. Advantageously, the alloys can contain less than about 5% cobalt. In addition, the alloys can contain from 0% to about 0.5% silicon, from 0% to about 0.5% manganese and from 0% to about 0.5% iron. The balance of the alloys is essentially nickel and includes impurities and incidental elements in amounts which do not adversely affect the novel and basic characteristics of the alloys. The contents of titanium (Ti), chromium (Cr), and cobalt (Co), expressed as percentages by weight, must comply with the following relationship:

$$f(\text{TiCoCr}) = -0.8\ \text{TiCoCr} + 10.4\ \text{TiCo} + 1.13\ \text{TiCr} + 1.75\ \text{CoCr} - 19.2\ \text{Co} - 11\ \text{Cr} + 8.4\ \text{Ti} + 123 > 0$$

When the titanium, cobalt and chromium contents of the alloys are plotted in three-dimensional coordinates, the equation $f(\text{TiCoCr}) = 0$ defines a surface which divides the volume defined by the compositional limits of 1.5% to 4.5% titanium, 15% to 22% chromium and 0% to 15% cobalt into two parts and the alloys according to the invention lie within this volume on one side of the surface.

It is found in practice that the alloys defined in this way are characterized by a stress-rupture life as cast of more than 60 hours when tested under a stress of 7 long tons per square inch (t.s.i.) (i.e., 15,680 pounds per square inch) at a temperature of 980° C.

Some examples of alloys according to the invention are given in Table I below, which also shows the value of $f(\text{TiCoCr})$ given above:

Table I

Alloy No.	Composition percent												Life, hr. at 7 t.s.i.	
	C	Zr	Al	Cr	Co	Ti	W	Si	Mn	Fe	B	f(TiCoCr)	960 °C.	980 °C.
1	0.1	0.5	4	20	0	4	8	0	0	0	0.05	+27	160	87
2	0.1	0.5	4	20	10	2	8	0	0	0	0.05	+11	188	70

The results given in Table II below show how the stress-rupture lives of alloys (outside the present invention) otherwise within the composition of the limits set out hereinbefore are impaired when the value of $f(\text{TiCoCr})$ is less than 0.

Table II

Alloy No.	Composition percent												Life, hr. at 7 t.s.i.	
	C	Zr	Al	Cr	Co	Ti	W	Si	Mn	Fe	B	f(TiCoCr)	960 °C.	980 °C.
3	0.1	0.5	4	20	0	2	8	0	0	0	0.05	−36	50	25
4	0.1	0.5	4	20	10	4	8	0	0	0	0.05	−39	47	21

When nickel-chromium base alloys are employed in gas turbine engines, they are sometimes corroded by the products of combustion. A measure of the extent of this corrosion is given by immersing the alloys for one hour in a mixture containing 75% sodium sulfate and 25% sodium chloride at 900° C. and it is undesirable that under these conditions the alloy should lose more than 5 mg. weight per sq. cm. It is found that this condition is satisfied by the alloys within the limits of composition given above whose composition satisfies the relationship

$$f(\text{TiCoCr}) > 0$$

and also the relationship $f_{\text{loss}}(\text{TiCoCr}) < 0$, where

$$f_{\text{loss}}(\text{TiCoCr}) = -0.057\ \text{TiCoCr} + 1.325\ \text{TiCo} + 3.944\ \text{TiCr} + 0.228\ \text{CoCr} - 5.32\ \text{Co} - 15.762\ \text{Cr} - 80.225\ \text{Ti} + 319.25$$

The values of this function are given in Table III for Alloys 1 and 2, together with the corresponding weight losses in the corrosion test specified above. It will be seen that both of the alloys satisfy both relationships:

Table III

Alloy No.	f_{loss}(TiCoCr)	Weight loss, mg./cm.^{2}
1	−4.2	0.8
2	−3.9	1.1

It is also desirable that alloys used under severe conditions of stress at very high temperatures should be reasonably ductile at room temperature. Preferably their elongation in room temperature tensile tests exceeds 4% before rupture occurs.

It is found that provided the alloys according to the invention also satisfy the relationship

$$f_{elong}(TiCoCr)>0$$

where

$$f_{elong}(TiCoCr)=-0.0181\ TiCoCr+0.0437\ CrCo+0.2753\ TiCo+0.3125\ TiCr-0.6406\ Co-1.25\ Cr-7.625\ Ti+28.75$$

they also have advantageous room temperature elongations.

The values of f_{elong}(TiCoCr) for Alloys 1 and 2 are given in Table IV, from which it will be seen that Alloy 2, which satisfies the relationship, has an elongation greater than 4% at room temperature, whereas Alloy 1, which does not satisfy the relationship, has an elongation less than 4%.

Table IV

Alloy No.	f_{elong}(TiCoCr)	Elongation, percent at room temperature
2	+1.6	5.62
1	−1.8	2.25

The alloys according to the present invention are primarily intended for use in the as-cast state. It has been found, however, that certain of the alloys of the present invention which contain about 15% to 22% chromium, about 5% to 15% cobalt, about 7% to 9% tungsten, about 3.5% to 4.5% aluminum, about 1.5% to 4.5% titanium, about 0.01% to 0.20% carbon, about .005% to 0.15% boron and about 0.3% to 0.6% zirconium can be hot worked and can be used in the wrought condition after a suitable heat treatment to precipitate a $Ni_3(Ti, Al)$ phase. In particular, alloys containing from 8% to 15% cobalt and from 1.5% to 3% titanium have good creep properties at elevated temperatures in the wrought state.

A suitable heat treatment consists in heating the alloys for 1½ hours at 1200° C., air-cooling to room temperature, then heating for 16 hours at 1050° C. and finally again air-cooling. After hot working and heat treatment in this way, Alloy 2, which contains 10% cobalt and 2% titanium, was found to have a life to rupture of 172 hours under a stress of 7 tons per square inch at 960° C., whereas Alloy 1, which contains no cobalt and 4% titanium, had a life of only 15 hours under the same conditions.

It is to be noted that the alloys of the present invention are highly advantageous when compared as to overall characteristics with alloys such as Alloy A which nominally contains 0.1% carbon, 0.05% boron, 0.05% zirconium, 12% chromium, 10% cobalt, 8% tungsten, 4% aluminum, 4% titanium, with the balance being essentially nickel. The following schedule contains a numerical indication of the merit of the alloys of the present invention as compared to Alloy A (wherein the value of 4 indicates excellent, 3 indicates good, 2 indicates acceptable, 1 indicates poor and 0 indicates very poor) for various desirable characteristics of the alloys similar in purpose to the alloys of the present invention:

Schedule

Characteristics	Alloys of the present invention	Alloy A
Stress-rupture strength at 980° C.	2	4
Room temperature ductility	3	3
Room temperature strength	4	4
Resistance to sulfur laden atmospheres	4	2
Castability	4	2
Resistance to oxidation	4	2
Resistance to thermal-fatigue	4	2
Total	25	19

It is to be noted that the total merit indicia set forth in the foregoing schedule clearly illustrate the overall superiority of the alloys of the present invention.

The alloys of the present invention are particularly adapted to be employed as articles such as turbine blades which are subjected in use to a combination of high stress, high temperature and corrosive atmospheres.

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.

I claim:

1. An alloy having an advantageous combination of high temperature and room temperature characteristics specifically adapted to be employed at elevated temperatures in contact with sulfur-containing atmospheres under high stress which consists essentially of more than about 15% to about 22% chromium, up to about 15% cobalt, about 7% to about 9% tungsten, about 3.5% to about 4.5% aluminum, about 1.5% to about 4.5% titanium, about 0.01% to about 0.20% carbon, about 0.005% to about 0.15% boron, about 0.3% to about 0.7% zironium, up to about 0.5% silicon, up to about 0.5% manganese, up to about 0.5% iron, the balance of the alloy being essentially nickel, the respective contents of titanium (Ti), chromium (Cr) and cobalt (Co), expressed as percentages by weight, being so correlated that the relationship

$$-0.8\ TiCoCr+10.4\ TiCo+1.13\ TiCr+1.75\ CoCr-19.2\ Co-11\ Cr+8.4\ Ti+123$$

is greater than zero and said respective contents of titanium, chromium and cobalt being so correlated that the relationship

$$-0.057\ TiCoCr+1.325\ TiCo+3.944\ TiCr+0.228\ CoCr-5.32\ Co-15.762\ Cr-80.225\ Ti+319.25$$

is less than zero.

2. An alloy having an advantageous combination of high temperature and room temperature characteristics specifically adapted to be employed at elevated temperatures under high stress which consists essentially of more than about 15% to about 22% chromium, up to about 15% cobalt, about 7% to about 9% tungsten, about 3.5% to about 4.5% aluminum, about 1.5% to about 4.5% titanium, about 0.01% to about 0.20% carbon, about 0.005% to about 0.15% boron, about 0.3% to about 0.7% zirconium, up to about 0.5% silicon, up to about 0.5% manganese, up to about 0.5% iron, the balance of the alloy being essentially nickel, the respective contents of titanium (Ti), chromium (Cr), and cobalt (Co), ex-

pressed as percentages by weight, being so correlated that the relationship

$$-0.8\ TiCoCr+10.4\ TiCo+1.13\ TiCr+1.75\ CoCr-19.2\ Co-11\ Cr+8.4\ Ti+123$$

is greater than zero, said respective contents of titanium, chromium and cobalt being so correlated that the relationship

$$-0.057\ TiCoCr+1.325\ TiCo+3.944\ TiCr+0.228\ CoCr-5.32\ Co-15.762\ Cr-80.225\ Ti+319.25$$

is less than zero and said respective contents of titanium,

chromium and cobalt also being so correlated that the relationship

$$-0.0181\ TiCoCr+0.0437\ CrCo+0.2753\ TiCo+0.3125\ TiCr-0.6406\ Co-1.25\ Cr-7.625\ Ti+28.75$$

is greater than zero.

References Cited in the file of this patent

UNITED STATES PATENTS

2,809,110	Darmara	Oct. 8, 1957
2,920,956	Nisbet et al.	Jan. 12, 1960
2,951,757	Brown	Sept. 6, 1960