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NICKEL-BASE ALLOY

James H. Moore, Swampscott, Mass., assignor to National Research Corporation, Cambridge, Mass., a corporation of Massachusetts

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This invention relates to the production of metals and in particular to the production of improved high temperature alloys.

A principal object of the invention is to provide improved high temperature nickel-base, age-hardenable alloys.

Another object of the invention is to provide alloys of the above type which possess good ductility and high rupture strength.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description.

In the development of alloys for high temperature use, particularly for such applications as turbine blades in aircraft gas turbines, some of the most promising alloys have been nickel-base, age-hardenable alloys of the type having appreciable quantities of titanium and aluminum in addition to substantial quantities of chromium and cobalt.

However, the manufacture of these alloys has been subject to difficulties due to the reactivity of the alloying elements, particularly titanium and aluminum, which causes loss of workability and variation in alloy content. In addition, the more highly alloyed nickel-base, age-hardenable alloys have exhibited variation in high temperature properties which makes it difficult to use them safely in exacting applications. It has been found, however, that vacuum refining and casting of such nickel-base alloys provides a product which is clearly superior in the above-mentioned respects to the same alloys which have been prepared according to the now existing conventional methods.

Thus, the present invention is directed to improved, high temperature, nickel-base, age-hardenable alloys containing appreciable quantities of chromium, cobalt, titanium, and aluminum which possess good ductility and high rupture strength. The nickel-base alloys of the invention may also contain, in addition to the above-mentioned elements, appreciable amounts of molybdenum, iron or other metals.

The improved alloys of the present invention preferably contain between about 18% to 21% chromium, 9% to 21% cobalt, 2% to 4% titanium, 0.25% to 2% aluminum, 0.05% to 0.20% carbon and at least 50% nickel. In one particular aspect of the invention, the preferred alloys may contain, in addition to the above elements, between about 2% to 12% molybdenum and/or a maximum of 5% iron. In all cases, the alloys of the above compositions contain less than about 0.003% oxygen and less than about 0.01% nitrogen.

The high temperature alloys of the present invention are prepared by melting nickel in a vacuum furnace. Alloying elements, such as cobalt, molybdenum and iron, may be charged and melted with the nickel during this initial melting operation. The melted nickel plus alloying ingredients are then subjected to a hydrogen impingement treatment after the pressure in the vacuum furnace has been reduced to about 10 microns. This hydrogen treatment is more fully described in the copending application of Moore et al. filed on even date herewith. At the conclusion of this deoxidation, argon is introduced into the furnace to maintain a pressure of about 50 mm. Hg. abs. The remainder of the alloying elements are then added, with carbon, chromium, nickel-titanium master alloy, and aluminum being preferably added in the stated order. The addition of the latter elements under an argon pressure of 50 mm. aids in preventing vaporization losses. After a short soaking period to permit solution of the alloying elements, the melt is poured.

Alloys prepared according to the above method and falling within the scope of this invention are found to possess the following composition:

	Percent
(I)	
Cobalt	12.00 to 15.00
Chromium	18.00 to 21.00
Titanium	2.00 to 4.00
Aluminum	.75 to 2.00
Molybdenum	2.50 to 3.50
Iron	Max. 2.00
Carbon	.05 to .15
Nitrogen	Max. .01
Oxygen	Max. .003
Nickel	Balance
(II)	
Cobalt	18.00 to 21.00
Chromium	18.00 to 21.00
Titanium	2.00 to 4.00
Aluminum	.75 to 2.00
Iron	max. 1.00
Carbon	.05 to .15
Nitrogen	Max. .01
Oxygen	Max. .003
Nickel	Balance
(III)	
Cobalt	9.00 to 11.00
Chromium	18.00 to 20.00
Titanium	2.25 to 2.75
Aluminum	.25 to .75
Molybdenum	9.00 to 11.00
Iron	Max. 5.00
Carbon	.15 to .20
Nitrogen	Max. .01
Oxygen	Max. .003
Manganese	1.00 to 1.50
Silicon	.50 to 1.00
Nickel	Balance

It has been found during a series of comparison tests that the above-mentioned alloys were superior to the corresponding conventionally melted alloys which often exhibited not only periodic fabrication difficulties and poor ductility, but also exhibited poor rupture strength at high temperatures and often failed to surpass a 40-hour time to rupture test at 1500° F. and at 32,500 p. s. i. The poor performance of the conventionally melted alloys is believed to be due to the presence of harmful oxides and nitrides. The superiority of vacuum refined and cast alloys is indicated to be due principally to a freedom from stringers of nitrides and oxides and the fact that the alloy has a gas content of less than .003% oxygen and .01% nitrogen.

Typical improved high temperature properties of the preferred nickel-base alloys may be illustrated by showing the stress rupture properties of the above-mentioned alloy designated as (I). At a temperature of 1350° F. and at a stress of 52,500 pounds per square inch, the minimum time to rupture was 230 hours, while the maximum time to rupture was recorded at 1275 hours. The

percent elongation was from a minimum of 4.1 to a maximum of 8.3. At a temperature of 1500° F. and at a stress of 32,500 pounds per square inch, the minimum time to rupture was 89 hours, while the maximum time to rupture was recorded at 380 hours. The percent elongation was from a minimum of 7.8 to a maximum of 21.1.

Thus, it can be seen that the improved high temperature properties of the alloys of the present invention make them especially suitable for use on such exacting applications as turbine blades in aircraft gas turbines.

Since certain changes may be made in the above process without departing from the scope of the invention herein involved, it is intended that all matter contained in the description shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An improved high temperature nickel-base, age-hardenable alloy consisting by weight approximately of 12.00 to 15.00% cobalt, 18.00 to 21.00% chromium, 2.00 to 4.00% titanium, 2.50 to 3.50% molybdenum, 0.75 to 2.00% aluminum, 0.05 to 0.15% carbon, less than 2.00% iron, less than 0.01% nitrogen and less than 0.003% oxygen, the balance being substantially all nickel.

2. An improved high temperature nickel-base, age-hardenable alloy consisting by weight approximately of 18.00 to 21.00% cobalt, 18.00 to 21.00% chromium, 2.00 to 4.00% titanium, 0.75 to 2.00% aluminum, 0.05 to 0.15% carbon, less than 1.00% iron, less than about 0.01% nitrogen and less than about 0.003% oxygen, the balance being substantially all nickel.

3. An improved high temperature nickel-base, age-hardenable alloy comprising by weight essentially 9.00 to 11.00% cobalt, 18.00 to 20.00% chromium, 9.00 to 11.00% molybdenum, 2.25 to 2.75% titanium, 0.25 to 0.75% aluminum, maximum 5.00% iron, 0.15 to 0.20% carbon, 1.00 to 1.50% manganese, 0.50 to 1.00% silicon, less than about 0.01% nitrogen and less than about 0.003% oxygen, the balance being substantially all nickel.

4. An improved high temperature nickel-base, age-hardenable alloy essentially free of stringers of nitrides and oxides, said alloy consisting by weight approximately of 18.00 to 21.00% chromium, 9.00 to 21.00% cobalt, 2.00 to 4.00% titanium, 0.25 to 2.00% aluminum, 0.05 to 0.20% carbon, less than about 0.01% nitrogen, and less than about 0.003% oxygen, the balance being substantially all nickel.

5. An improved high temperature nickel-base, age-hardenable alloy consisting by weight approximately of 18.00 to 21.00% chromium, 9.00 to 21.00% cobalt, 2.00 to 4.00% titanium, 0.25 to 2.00% aluminum, 0.05 to 0.20% carbon, 2.00 to 12.00% molybdenum, less than about 0.01% nitrogen, and less than about 0.003% oxygen, the balance being substantially all nickel.

6. An improved high temperature nickel-base, age-hardenable alloy consisting by weight approximately of 18.00 to 21.00% chromium, 9.00 to 21.00% cobalt, 2.00 to 4.00% titanium, 0.25 to 2.00% aluminum, 0.05 to 0.20% carbon, 2.00 to 12.00% molybdenum, a maximum of 5.00% iron, less than about 0.01% nitrogen, and less than about 0.003% oxygen, the balance being substantially all nickel.

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