United States Patent Office

3,047,381
Patented July 31, 1962

3,047,381

HIGH TEMPERATURE HEAT AND CREEP RESISTANT ALLOY

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No Drawing. Filed Feb. 3, 1958, Ser. No. 712,628
5 Claims. (Cl. 75—171)

This invenion relates to an improved high temperature creep resistant alloy.

This application is a continuation-in-part of the copending application Serial No. 439,866 filed June 28, 1954, now abandoned.

The alloy of the present invention is particularly adapted for parts which must withstand high stresses at elevated temperature conditions up to 1600° F., be resistant to oxidation at temperatures up to 2000° F., and at the same time have a relatively high ductility. Illustrative examples of parts for which the alloy is especially adapted are turbine blades or buckets and nozzle diphragms for gas turbines.

In common formation of high temperature alloys, creep resistance is obtained at the expense of ductility and lack of ductility is frequently an imposing limitation on an otherwise promising alloy.

A satisfactory alloy of the type referred to is disclosed in the U.S. patent to Callaway et al. 2,688,536, assigned to the assignee of the present invention, which consists as follows:

	Percent
Carbon	0.10 to 0.20
Manganese (maximum)	0.25
Silicone (maximum)	0.75
Chromium	13 to 17
Molybdenum	4 to 6
Titanium	1.5 to 3.0
Aluminum	2.0 to 4.0
Boron	0.01 to 0.10
Iron	8 to 12
Nickel	Balance

The present invention is based on the surprising discovery that a markedly improved high temperature creep resistant or hot strength alloy having good ductility may be had by reducing the iron content of the above alloy to from 3.5 to 6% and preferably to 4.5% while raising the titanium range to 4% and maintaining the sum of the aluminum and titanium between 5.5 and 7.5% and preferably at about 6.5%.

The alloy of the present invention is as follows:

	Percent
Carbon	0.10 to 0.20
Manganese (maximum)	0.10
Silicone (maximum)	0.30
Chromium	13.00 to 17.00
Molybdenum	4.00 to 6.00
Iron	3.50 to 6.00
Aluminum	2.00 to 4.00
Titanium	1.50 to 4.00
Boron	0.01 to 0.15
Nickel	Balance

In the above alloy the sum of aluminum and titanium is preferably maintained between about 5.5 and 7.5%. A preferred embodiment of the alloy involves limiting the aluminum content to from 3.25 to 4% and the titanium content from 2 to 3% whereby the ratio of aluminum to titanium is between about 1 and 2.

An optimum embodiment of the invention is as follows:

	Percent
Carbon	0.12
Manganese (maximum)	0.10
Silicone (maximum)	0.30
Chromium	15.50
Molybdenum	5.00
Iron	4.50
Aluminum	4.00
Titanium	2.50
Boron	0.08
Nickel	Balance

In an optimum embodiment the ratio of aluminum to titanium is maintained at about 1.6. Ratios of aluminum to titanium of less than 1 may be used in some instances. However, aluminum to titanium ratios greater than 1 are preferred because of ease of casting. Alloys having an aluminum to titanium ratio of less than 1 tend to present foundry difficulties because of the affinity of titanium for mold materials at casting temperatures.

The following examples illustrate the superiority of the alloy of the present invention over the alloy disclosed in the aforementioned patent.

Example 1

Test specimens were made by precision casting an alloy consisting as follows: 0.20% carbon, 0.08% manganese, 0.40% silicon, 15.5% chromium, 5.0% molybdenum, 11.0% iron, 3.22% aluminum, 3.58% titanium, .075% boron and the balance nickel. The test specimens were subjected to a static load of 28,000 pounds per square inch at a temperature of 1600° F. Under these test conditions it took an average time of about 113 hours to rupture the test specimens. The average percentage elongation of the test specimens at rupture was 7.6%.

Test specimens were made by precision casting an alloy consisting as follows: 0.19% carbon, 0.08% manganese, 0.40% silicon, 15.5% chromium, 5.0% molybdenum, 11.0% iron, 4.06% aluminum, 2.22% titanium, .075% boron, and the balance nickel. The test specimens were subjected to a static load of 28,000 pounds per square inch at a temperature of 1600° F. Under these test conditions it took an average time of about 112 hours to rupture the test specimens. The average percentage elongation of the test specimens at rupture was 6.6%.

Example 2

Test specimens were made by precision casting an alloy consisting of 0.06% carbon, less than 0.05% manganese, less than 0.2% silicon, 14.5% chromium, 5.7% molybdenum, 4.5% iron, 3.97% aluminum, 2.53% titanium, 0.085% boron and the balance nickel.

The test specimens were subjected to a static tensile load of 28,000 pounds per square inch at a temperature of 1600° F. Under these test conditions it took an average time of 470 hours to rupture the test specimens. The average percentage elongation of the test specimens at rupture was 12.2%.

Examples 1 and 2 provide a striking illustration of the hot strength superiority of the alloy of the present invention. The test results of Example 2 also indicated that in addition to having high superiority in hot strength properties, the alloy had good ductility. Markedly improved hot strength properties are also obtained in alloys involving the range of constituents set forth above wherein

the sum of the aluminum and titanium is between 5.5 and 7.5%. Good ductility is also obtained.

Example 3

Test specimens were made by precision casting a composition consisting substantially as follows: 0.18% carbon, 0.10% manganese, 0.60% silicon, 15.5% chromium, 5.00% molybdenum, 4.5% iron, 3.00% aluminum, 2.00% titanium, 0.075% boron and the balance nickel. A test specimen of this composition was subjected to a static tensile load of 28,000 pounds per square inch at a temperature of 1600° F. Under these test conditions, it took 99.6 hours to rupture the cast test specimen. The test specimen had a percentage elongation at rupture of 13.44. Another test specimen of this analysis was solution treated at 2100° F. for one hour and air cooled. This solution treated test specimen was subjected to a static tensile load of 28,000 pounds per square inch at a temperature of 1600° F. Under these test conditions it took 155 hours to rupture the test specimen. The test specimen had a percentage elongation at rupture of 13.2.

Example 4

Test specimens were made by precision casting an alloy consisting as follows: 0.12% carbon, 0.12% manganese, 0.57% silicon, 14.9% chromium, 5.03% molybdenum, 4.80% iron, 2.39% aluminum, 2.16% titanium, 0.056% boron, balance nickel. Some of the test specimens were subjected to a static tensile load of 35,000 pounds per square inch at a temperature of 1500° F. Under these test conditions, it took an average time of 103.6 hours to rupture the test specimens. The average percentage elongation of the test specimens at rupture was 16.20. Another test specimen of this composition was subjected to a static tensile load of 20,000 pounds per square inch at a temperature of 1700° F. Under these test conditions, it took 17.2 hours to rupture the test specimen. The test specimen had a percentage elongation at rupture at 19.80.

The Examples 3 and 4 illustrate that satisfactory hot strength alloys may be had at the outer limits of the ranges set forth above. These alloys also have good ductility.

The alloys of the present invention may be compounded or made up in any desired manner. Any desired melting furnaces may be used. Typical examples of melting furnaces which have been used are the indirect arc and induction types. Preferably melting is accomplished in a vacuum to insure cleanliness of the metal and for greater chemical control of the alloy composition whereby markedly improved stress-rupture and thermal fatigue properties are obtained in comparison to alloys compounded by air melting. Protective atmospheres are employed during the melting operation. It is preferable also to employ protective atmospheres in the molds in which the material is cast. Mold materials may be those employed for conventional high temperature alloys.

Various changes in modifications of the embodiments of the invention described herein may be made without departing from the experiment thereof.

We claim:

1. A high temperature creep resistant alloy consisting as follows:

	Percent
Carbon	0.10 to 0.20
Manganese (maximum)	0.25
Silicone (maximum)	0.75
Chromium	13.00 to 17.00
Molybdenum	4.00 to 6.00
Titanium	1.50 to 4.00
Aluminum	2.00 to 4.00
Boron	0.01 to 0.15
Iron	3.50 to 6.00
Nickel	Balance

said titanium and aluminum being equal to a sum of about 5.5% to 7.5%.

2. Claim 1 wherein the aluminum to titanium ratio is greater than 1.

3. A high temperature creep resistant alloy consisting as follows:

	Percent
Carbon	0.10–0.20
Manganese (maximum)	0.10
Silicone (maximum)	0.30
Chromium	13.00–17.00
Molybdenum	4.00–6.00
Iron	3.50–6.00
Aluminum	3.25–4.00
Titanium	2.00–3.00
Boron	0.05–0.10
Nickel	Balance

said titanium and aluminum being equal to a sum of at least 5.5%.

4. Claim 3 wherein the iron content is about 4.5% and the ratio of aluminum to titanium is about 1.6%.

5. A high temperature creep resistant alloy consisting as follows:

	Percent
Carbon	0.12
Manganese (maximum)	0.10
Silicone (maximum)	0.30
Chromium	15.50
Molybdenum	5.00
Iron	4.50
Aluminum	4.00
Titanium	2.50
Boron	0.08
Nickel	Balance

References Cited in the file of this patent

UNITED STATES PATENTS

2,688,536	Callaway et al.	Sept. 7, 1954
2,798,827	Hanink	July 9, 1957

FOREIGN PATENTS

607,616	Great Britain	Sept. 2, 1948