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NICKEL-CHROMIUM BASE ALLOY

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3 Claims. (Cl. 75—171)

The present invention is directed to heat-resisting alloys and, more particularly, to heat-resisting alloys containing nickel, chromium, titanium, aluminum, molybdenum, cobalt, boron and zirconium.

It is well known that the creep-resisting properties of alloys having a nickel-chromium base depend on the presence and amount of other alloy constituents. In particular, the presence of both titanium and aluminum is necessary to provide a precipitable phase of the $Ni_3(Ti, Al)$ type and other hardening elements are commonly included when the alloys must have good creep properties at very high temperatures. In particular, cobalt and sometimes also molybdenum have been included to increase the temperatures at which the alloys could safely be used under a given stress. As far as we are aware, the prior art has not been able to provide, in a consistent manner, alloys having excellent creep-resisting characteristics when the alloys are produced on a commercial scale.

It has now been discovered that particularly good creep properties can be obtained when the contents of titanium, aluminum, chromium and molybdenum satisfy certain specific relationships.

It is an object of the present invention to provide a novel alloy having excellent resistance to rupture when subjected to severe loads at elevated temperatures of the order of about 1000° C.

It is a further object of the present invention to provide a novel process for the production of alloys having excellent resistance to rupture when subjected to severe loads at elevated temperatures.

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

Generally speaking, the present invention contemplates nickel-base alloys containing chromium, molybdenum, cobalt, carbon, titanium, aluminum, boron and zirconium in addition to carbon.

In alloys according to the invention, the ratio of the titanium to the aluminum content is in the range 0.7 to 1.0 and the sum of the titanium and aluminum contents lies between X and Y, where

$$X = Mo(0.15\ Cr - 2.7) + (25.6 - 0.9\ Cr) \text{ and}$$
$$Y = Mo(0.15\ Cr - 2.7) + (23.5 - 0.9\ Cr)$$

the above contents being expressed as percentages by weight of the alloy and the symbols Mo and Cr in the foregoing formulae indicating the percent molybdenum and percent chromium by weight, respectively. Subject to these relationships, the composition of the alloys lies within the limits about 11% to about 16% chromium, about 0.1% to about 0.2% carbon, about 1.5% to about 7% molybdenum, about 10% to about 20% cobalt, about 0.01% to about 0.10% zirconium and about 0.005% to about 0.05% boron, the balance, apart from impurities, being essentially nickel. The impurities may include iron, silicon and manganese in a total amount not exceeding 3%.

Increasing the chromium content within the range specified improves the oxidation resistance of the alloys, but at contents greater than 15% the creep resistance begins to fall.

In addition to the elements mentioned above, the alloys can contain up to 2% of vanadium. When this element

is present it acts as a substitute for part of the titanium.

In order to obtain the best creep properties, the alloys are advantageously melted to provide contents of aluminum, titanium and molybdenum as required heretofore cast in high vacuum, e.g., about 1 micron pressure, to ingots and then extruded to bar and heat treated. A suitable heat treatment to harden the alloys is as follows:

(1) Heat for 1½ hours at 1200° C.
(2) Air-cool to room temperature
(3) Heat for 16 hours at 1050° C.
(4) Air-cool to room temperature

To demonstrate the importance of correlating the total content of titanium and aluminum with the contents of molybdenum and chromium, a series of alloys was prepared each containing 0.18% carbon, 15% cobalt, 0.5% zirconium, 0.02% boron, varying amounts of titanium and aluminum in the constant ratio 0.82 and varying amounts of chromium and molybdenum. The alloys were melted in vacuo at 1 micron pressure, cast into ingots, extruded to bar and given the heat treatment set out above. Specimens of each alloy were machined from the heat treated bars and subjected to stress-rupture tests under a stress of 7 long tons per square inch (t.s.i.) at 1000° C. The results are set out in the following two tables. The alloys to which Table I relates are within the scope of the present invention, while the alloys of Table II (which are outside the present invention) contain amounts of titanium and aluminum which are not in the correct relationship to their contents of chromium and molybdenum.

Table I

Alloy No.	Cr	Mo	Ti+Al, actual	Range of Ti+Al required by X≥Ti+Al≥Y	Life, 7 t.s.i., 1,000° C.
1	12	3.5	11.0	11.7–9.6	137
2	12	5	9.0	10.3–8.2	103
3	12	6.5	9.0	9.0–6.9	67
4	15	2	10.0	11.2–9.1	108
5	15	2	10.5	11.2–9.1	53
6	15	3.5	9.0	10.5–8.4	119
7	15	3.5	10.1	10.5–8.4	140

Table II

Alloy No.	Cr	Mo	Ti+Al, actual	Range of Ti+Al required by X≥Ti+Al≥Y	Life, 7 t.s.i., 1,000° C.
8	12	2	9.0	13.0–10.9	12
9	12	5	13.0	10.3– 8.2	17
10	12	6.5	13.0	9.0– 6.9	18
11	15	2	13.0	11.2– 9.1	3
12	15	3.5	13.0	10.5– 8.4	2
13	15	5.0	11.0	9.9– 7.8	11
14	15	5.0	13.0	9.9– 7.8	5

It is to be noted that the alloys within the ambit of the present invention in Table I, which all contained all four of the elements cobalt, molybdenum, boron and zirconium, had lives to rupture in excess of 50 hours under the extremely severe test conditions used.

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 nickel-base alloy having excellent resistance to creep when subjected to severe loads at a temperature of about 1000° C. consisting essentially of about 11% to about 16% chromium, about 10% to about 20% cobalt, about 1.5% to about 7% molybdenum, about 0.1% to

0.2% carbon, about 0.01% to about 0.10% zirconium, about 0.005% to about 0.05% boron, aluminum and titanium in such amounts that the ratio of the percentage of titanium to the percentage of aluminum is from 0.7 to 1.0 and that the sum of the percentage of aluminum plus the percentage of titanium is between X and Y where

$$X=\text{Mo}(0.15\ \text{Cr}-2.7)+(25.6-0.9\ \text{Cr})$$

and

$$Y=\text{Mo}(0.15\ \text{Cr}-2.7)+(23.5-0.9\ \text{Cr})$$

with the balance being nickel, said alloy exhibiting in the wrought and age hardened condition a life to rupture of at least about 50 hours when tested at 1000° C. under a load of 7 long tons per square inch.

2. A nickel-base alloy having excellent resistance to creep when subjected to severe loads at a temperature of about 1000° C. consisting essentially of about 15% cobalt, about 12% to 15% chromium, about 3.5% molybdenum, about 0.18% carbon, about 0.05% zirconium, about 0.02% boron, about 9.0% to 11.0% titanium plus aluminum with the ratio of titanium to aluminum of about 0.82 with the balance being nickel, the elements in said alloy being correlated so that the sum of the percentage of aluminum plus the percentage of titanium is between X and Y where

$$X=\text{Mo}(0.15\ \text{Cr}-2.7)+(25.6-0.9\ \text{Cr})$$

and

$$Y=\text{Mo}(0.15\ \text{Cr}-2.7)+(23.5-0.9\ \text{Cr})$$

said alloy exhibiting in the wrought and age hardened condition a life to rupture of at least about 50 hours when tested at 1000° C. under a load of 7 long tons per square inch.

3. A wrought nickel-base alloy having excellent resistance to creep when subjected to severe loads at a temperature of about 1000° C. consisting essentially of about 11% to about 16% chromium, about 10% to about 20% cobalt, about 1.5% to about 7% molybdenum, about 0.1% to 0.2% carbon, about 0.01% to about 0.10% zirconium, about 0.005% to about 0.05% boron, aluminum and titanium in such amounts that the ratio of the percentage of titanium to the percentage of aluminum is from 0.7 to 1.0 and that the sum of the percentage of aluminum plus the percentage of titanium is between X and Y where

$$X=\text{Mo}(0.15\ \text{Cr}-2.7)+(25.6-0.9\ \text{Cr})$$

and

$$Y=\text{Mo}(0.15\ \text{Cr}-2.7)+(23.5-0.9\ \text{Cr})$$

with the balance being nickel, said alloy exhibiting in the wrought and age hardened condition a life to rupture of at least about 50 hours when tested at 1000° C. under a load of 7 long tons per square inch.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,110,587 November 12, 1963

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It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 15, for "0.5%" read -- 0.05% --.

Signed and sealed this 2nd day of June 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents