J. HOCKIN ET AL
TUNGSTEN CONTAINING ALLOY
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FIG. 1

1000X

FIG. 2

250X
TUNGSTEN CONTAINING ALLOY


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ABSTRACT OF THE DISCLOSURE

A high temperature alloy containing nickel and, in percent by weight, about 5.5% aluminum, about 0.02% boron, about 0.18% carbon, about 10% cobalt, about 9.5% chromium, about 1.5% hafnium, about 2.5% molybdenum, about 4.0% titanium, about 1% vanadium, about 3.7% tungsten and about 0.06% zirconium.

DESCRIPTION

Generally speaking, the present invention contemplates nickel-base alloys containing alloying elements in ranges of percent by weight as set forth in Table I.

<table>
<thead>
<tr>
<th>Element</th>
<th>Broad range, percent</th>
<th>Advantages range, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>4.7-8.2</td>
<td>6.8-8.5</td>
</tr>
<tr>
<td>C</td>
<td>0.002-0.05</td>
<td>0.002-0.03</td>
</tr>
<tr>
<td>Cr</td>
<td>0.12-4.5</td>
<td>0.13-6.9</td>
</tr>
<tr>
<td>Fe</td>
<td>5-20</td>
<td>7.2-10.5</td>
</tr>
<tr>
<td>Ni</td>
<td>8.8-12</td>
<td>8.5-11</td>
</tr>
<tr>
<td>Mo</td>
<td>0.9-9.1</td>
<td>1.1-3.7</td>
</tr>
<tr>
<td>Ti</td>
<td>1.2-4.0</td>
<td>1.7-3.5</td>
</tr>
<tr>
<td>Zr</td>
<td>0.1-0.3</td>
<td>0.2-0.5</td>
</tr>
</tbody>
</table>

With respect to the broad range, it is advantageous to balance the alloy composition with respect to the elements tungsten and titanium such that when the titanium is at the low end of the range, the tungsten is at the high end and vice versa. Those skilled in the art will appreciate that between these extremes any number of alloys can be formulated within the ambit of the invention. As a practical working guide one can be assured of obtaining excellent alloys within the ranges of the present invention if the sum of the percent titanium plus one-tenth the percent of tungsten is about 3.8% to about 4.5%.

The alloys of the present invention are advantageously made up using as pure materials as are commercially feasible. The nickel content set forth in Table I as "Balance E" is essentially the balance of the alloy and includes small amounts of impurities and incidental elements which do not detrimentally affect the basic and novel characteristics of the alloy. Those skilled in the art will appreciate that metals such as lead, bismuth and the like, metalloids such as arsenic and non-metals such as phosphorus, sulfur, oxygen and the like are highly detrimental to nickel-base alloys of the kind disclosed herein and should be rigidly excluded.

It is highly advantageous to melt and cast the alloys of the invention under high vacuum to and employ current state of the art techniques of investment casting to provide cast hardware such as turbine blades for gas turbine engines. When cast in such a manner, the alloys of the present invention exhibit a microstructure of the present invention if the sum of the percent titanium plus one-tenth the percent of tungsten is about 3.8% to about 4.5%.
Each of the foregoing examples and alloys were melted and cast under vacuum to provide cast-to-size, 0.250 inch (6.35 mm.) test bars. These test bars were subjected to room temperature tensile tests and creep-rupture tests at 1800°F (982°C) and 1400°F (760°C). These tests show that the alloys of the present invention, i.e., Examples 1 and 2, exhibit highly advantageous mechanical characteristics when compared to characteristics exhibited by alloys outside the present invention. The results of room temperature tensile tests on cast-to-size specimens are set forth in Table III.

Table III shows that at room temperature all four specific alloys tested exhibited substantially equivalent mechanical characteristics.

Creep-rupture data are set forth in Table IV.

Table IV shows that an alloy (Alloy Z) containing hafnium but with a low titanium content, that is an alloy wherein the percent titanium plus 0.1 times the percent tungsten is about 3.6, exhibits a relatively low life-to-rupture at 1800°F, as does Alloy Y which does not contain hafnium. At 1400°F, the alloy without hafnium (Alloy Y) has low prior creep and low life-to-rupture whereas the most advantageous alloy of the present invention (Example 1) has an extraordinarily long life-to-rupture and an excellent level of prior creep. Example 2 is an example of an alloy of the present invention which exhibits slightly higher life-to-rupture at 1800°F than Example 1 at some sacrifice of 1400°F characteristics.

Alloys of the present invention are particularly adapted to be used in the cast condition as gas turbine components and other structures which are subjected in use to stress over a range of operating temperatures. Another alloy of the present invention containing in percent by weight 5.5% aluminum, 3.75% titanium, 2% molybdenum, 15% cobalt, 10% chromium, 0.014% boron, 0.06% zirconium, 0.18% carbon, 1% vanadium, 1.5% hafnium, 2% tungsten with the balance being nickel was melted and cast under vacuum into turbine blade molds. Specimens machined from the cast turbine blade gave room temperature tensile results of 127.0 k.s.i. ultimate tensile strength, 107.9 k.s.i. 0.2% yield strength, 8.5% elongation and 18.7% reduction in area. At 1400°F, under a load of 85 k.s.i. specimens of the alloy machined from blades had lives of 206 and 226 hours, 2.85% and 3.56% prior creep, 3.2% and 3.8% elongation and 7.3% and 9.0% reduction in area. At 1600°F, under a load of 45 k.s.i. similar specimens had lives of 496.8 and 455.2 hours, 9.5% and 5.7% prior creep, 10.3% and 5.9% elongation and 15% and 13% reduction in area. These data show that metal taken directly from turbine blades cast of an alloy of the present invention is eminently suited for the intended use in gas turbines. While the present invention has been described in conjunction with advantageous embodiments, those skilled in the art will recognize that modifications and variations may be resorted to without departing from the spirit and scope of the invention. Such modifications and variations are considered to be within the purview and scope of the invention.

We claim:

1. A cast alloy consisting essentially in percent by weight of about 4.7% to about 6.2% aluminum, about 0.002% to about 0.05% boron, about 0.10% to about 0.25% carbon, about 5% to about 20% cobalt, about 8.5% to about 12% chromium, about 0.8% to about 3% hafnium, about 1.5% to about 4% molybdenum, about 3.5% to about 4.5% titanium, up to about 1.5% vanadium, about 1% to about 4.7% tungsten, up to about 0.25% zirconium with the balance being essentially nickel, said alloy being balanced so that the sum of the percent titanium plus one-tenth the percent of tungsten is about 3.8% to about 4.5%.

2. A cast alloy as in claim 1 which contains 4.8% to 5.5% aluminum, 0.002% to 0.03% boron, 0.015% to 0.20% carbon, 7.5% to 12.5% cobalt, 8.5% to 11% chromium, 1% to 2% hafnium, 1.75% to 3.25% molybdenum, 3.3% to 4.2% titanium, 0.75% to 1.25% vanadium, 2% to 4.6% tungsten and 0.01% to 0.15% zirconium.

3. A vacuum-cast turbine blade made of the alloy of claim 1.

4. A vacuum-cast turbine blade made of the alloy of claim 2.

5. A cast alloy as in claim 1 containing about 3.7% tungsten and about 3.7% to about 4.2% titanium.

6. A cast alloy as in claim 1 containing about 2% tungsten and about 3.8% titanium.

References Cited

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RICHARD O. DEAN, Primary Examiner

U.S. Cl. X.R.

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