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COLUMBIUM-TITANIUM BASE OXIDATION-  
RESISTANT ALLOYS

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1 Claim. (Cl. 75-174)

This invention relates to columbium-base alloys containing titanium and aluminum. More particularly it relates to alloys containing more than 50 percent columbium, together with from about 5 to 49 percent titanium and up to about 10 percent aluminum. Some alloys of the present invention contain additional metals, but all contain the three already mentioned, namely: columbium, titanium, and aluminum.

The alloys of this invention are characterized by their outstanding oxidation resistance. In addition, the present alloys possess good room-temperature strength and good bend ductility, are readily fabricable, and have high-temperature strength as indicated by their hot hardness properties.

It is, therefore, a primary object of this invention to provide oxidation-resistant alloys.

It is another object of this invention to provide alloys having good strength both at room temperature and at high temperatures.

Other objects and advantages of the present invention will be apparent from the following detailed description thereof.

In general, this invention comprises oxidation-resistant alloy compositions including columbium, titanium, and aluminum and wherein the columbium is present in the amount of at least 50 percent, titanium in amounts ranging from 5-49 percent, and aluminum in amounts ranging from 1-10 percent. Other metals may be included

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in the present compositions; for example, chromium, tantalum, and vanadium have been used in alloys of this invention.

To demonstrate the oxidation resistance of the present alloys, experimental studies have been made on specimens of the alloys. The results of these studies or tests are tabulated in Table I below. The tabulated data illustrate the resistance of these alloys, in either the cast or wrought condition, to oxidation in a static atmosphere at elevated temperatures. Test specimens measured about 0.25 x 0.50 x 0.04 inch and were prepared as follows: Each specimen was carefully finished on 400-grit paper, cleaned in a solvent, weighed, and measured. The finished specimen was then placed on a small ceramic ring and set inside a crucible cover with a second, larger ceramic ring placed around the specimen to insure retention of any spattered scale. Each test assembly, prepared as described above, was placed on a firebrick, and, thus supported, inserted into a furnace which had been brought up to the test temperature. Specimens were in this manner exposed to air oxidation for periods of 16 hours at test temperatures of 1400° F. and 1800° F. After exposure for the prescribed time, the treated specimens were covered with a second crucible cover and cooled, thus avoiding loss of oxidation products during the cooling period. After the specimens had been cooled, they were each weighed to determine the weight gain. From this, the weight increase per unit original area was computed for each specimen. After being weighed, the test specimens were brushed with a wire brush to remove loose scale, and the percentage of original sample remaining was then determined. In some cases the scale was tightly adherent and could not be removed entirely. As a result, some of the values reported under "percent of original sample remaining" are in excess of 100. The specimens were next sectioned centrally, mounted, polished, and etched for microexamination. Finally, hardness readings were taken in the center of the cross section. Values obtained at 1400° F. and at 1800° F., and in accordance with the procedures described above, are listed in Table I which follows.

TABLE I

Oxidation resistance of columbium base alloys containing  
titanium and aluminum

| Nominal Composition,<br>Wt. percent | 16 Hours at 1,400 F.                |                                  |                |                                                    |                                  | 16 Hours at 1,800 F.             |                |                                                    |                                  |          | Material<br>Form of<br>Oxidation<br>Specimen |
|-------------------------------------|-------------------------------------|----------------------------------|----------------|----------------------------------------------------|----------------------------------|----------------------------------|----------------|----------------------------------------------------|----------------------------------|----------|----------------------------------------------|
|                                     | Original<br>VHN<br>(10 kg.<br>load) | Weight Increase<br>per Unit Area |                | Percent of<br>Original<br>Sample<br>Remain-<br>ing | Final<br>VHN<br>(10 kg.<br>load) | Weight Increase<br>per Unit Area |                | Percent of<br>Original<br>Sample<br>Remain-<br>ing | Final<br>VHN<br>(10 kg.<br>load) |          |                                              |
|                                     |                                     | G./sq.<br>in.                    | Mg./sq.<br>cm. |                                                    |                                  | G./sq.<br>in.                    | Mg./sq.<br>cm. |                                                    |                                  |          |                                              |
| Cb                                  |                                     |                                  |                |                                                    |                                  | 2.50                             | 387.0          | 0                                                  |                                  | Wrought. |                                              |
| 50Cb-50Ti                           | 138                                 | 0.0166                           | 2.58           |                                                    | 202                              | 0.4756                           | 73.7           | 18                                                 | 370                              | Do.      |                                              |
| 50Cb-49Ti-1Al                       | 179                                 |                                  |                | 101                                                |                                  | 0.2130                           | 33.0           | 91                                                 | 345                              | Cast.    |                                              |
| 50Cb-47Ti-3Al                       | 201                                 |                                  |                |                                                    |                                  | 0.1036                           | 16.0           | 100                                                | 327                              | Do.      |                                              |
| 50Cb-45Ti-5Al                       | 243                                 | 0.0243                           | 3.77           | 101                                                | 238                              | 0.1476                           | 22.9           | 88                                                 | 322                              | Wrought. |                                              |
| 50Cb-43Ti-7Al                       | 314                                 | 0.0109                           | 1.69           | 100                                                | 302                              | 0.0691                           | 10.7           | 101                                                | 292                              | Do.      |                                              |
| 65Cb-30Ti-5Al                       | 253                                 |                                  |                |                                                    |                                  | 0.0992                           | 15.4           | 97                                                 | 285                              | Cast.    |                                              |
| 65Cb-28Ti-7Al                       | 289                                 |                                  |                |                                                    |                                  | 0.0835                           | 12.9           | 99                                                 | 306                              | Do.      |                                              |
| 85Cb-10Ti-5Al                       | 327                                 |                                  |                |                                                    |                                  | 0.1935                           | 29.9           | 85                                                 | 345                              | Do.      |                                              |
| 50Cb-47.5Ti-2.5Cr                   | 187                                 | 0.0218                           | 3.37           | 100                                                | 196                              | 0.2686                           | 41.6           | 82                                                 | 394                              | Wrought. |                                              |
| 50Cb-45Ti-5Cr                       | 215                                 | 0.0119                           | 1.85           | 100                                                | 227                              | 0.0629                           | 9.8            | 91                                                 | 325                              | Do.      |                                              |
| 50Cb-40Ti-10Cr                      | 289                                 | 0.0345                           | 5.35           | 97                                                 | 281                              | 0.0597                           | 9.3            | 96                                                 | 380                              | Do.      |                                              |
| 50Cb-42Ti-4Al-4Cr                   | 281                                 |                                  |                |                                                    |                                  | 0.0477                           | 7.4            | 102                                                | 383                              | Do.      |                                              |
| 65Cb-10Ti-5Al-20Ta                  | 330                                 |                                  |                |                                                    |                                  | 0.1140                           | 17.7           | 98                                                 | 322                              | Cast.    |                                              |
| 50Cb-7Ti-3Al-40Ta                   | 294                                 |                                  |                |                                                    |                                  | 0.2670                           | 41.4           | 88                                                 |                                  | Do.      |                                              |
| 50Cb-40Ti-2Al-8V                    | 240                                 | 0.0315                           | 4.88           | 100                                                | 218                              | 0.2108                           | 32.7           | 89                                                 | 405                              | Wrought. |                                              |
| 50Cb-30Ti-3Al-17V                   | 317                                 | 0.1250                           | 19.4           | 97                                                 | 294                              | 0.9087                           | 140.9          | 0                                                  |                                  | Do.      |                                              |

As has been noted above, the alloys of this invention possess useful mechanical properties such as room-temperature and high-temperature strength. Table 2 below lists mechanical properties for illustrative alloy compositions of the present invention. These representative data serve to illustrate the desirable mechanical properties of the alloys of this invention.

Specimens for this test were prepared and tested as described in detail above in connection with Table 1. In addition, the scale thickness and depth of contamination were measured. Scale thickness was determined by comparing the original thickness of the specimen with the thickness of the unaffected base material. In determining depth of contamination, contamination was consid-

TABLE 2  
Mechanical properties of Cb-Ti-Al alloys

| Nominal Composition,<br>Wt. percent | Hardness (VHN—10 kg. load) |         |        |          |          | Room Temperature Tensile Properties of<br>Sheet Material |                                                           |                        |       |                                  | Bend<br>Ductil-<br>ity, T |
|-------------------------------------|----------------------------|---------|--------|----------|----------|----------------------------------------------------------|-----------------------------------------------------------|------------------------|-------|----------------------------------|---------------------------|
|                                     | Cast,<br>80 F.             | Wrought |        |          |          | Ultimate<br>Tensile<br>Strength,<br>1,000 p.s.i.         | Yield<br>Strength<br>(0.2%<br>offset),<br>1,000<br>p.s.i. | Elongation,<br>percent |       | Reduction<br>in Area,<br>percent |                           |
|                                     |                            | 80 F.   | 930 F. | 1,290 F. | 1,650 F. |                                                          |                                                           | Uniform                | Total |                                  |                           |
| 50Cb—45Ti—5Al                       | 176                        | 243     | 282    | 205      | 28       | 107                                                      | 99                                                        | 12                     | 13    | 28                               | 0.5                       |
| 50Cb—43Ti—7Al                       | 202                        | 314     | 241    | 52       | 23       | 145                                                      | 135                                                       | 2                      | 2     | 5                                | 5.0                       |
| 50Cb—47.5Ti—2.5Cr                   | 203                        | 187     |        |          |          | 76                                                       | 75                                                        | 10                     | 15    | 54                               | 0                         |
| 50Cb—45Ti—5Cr                       | 251                        | 215     |        |          |          | 94                                                       | 93                                                        | 11                     | 18    | 48                               | 0                         |
| 50Cb—40Ti—10Cr                      | 322                        | 289     |        |          |          | 130                                                      | 124                                                       | 7                      | 7     | 15                               | 6.2                       |
| 50Cb—40Ti—8V—2Al                    | 228                        | 240     | 181    | 90       | 23       | 94                                                       | 93                                                        | 4                      | 13    | 35                               | 0                         |
| 50Cb—30Ti—17V—3Al                   | 325                        | 317     | 246    | 163      | 57       | 139                                                      | 136                                                       | 6                      | 10    | 28                               | 0                         |
| 50Cb—42Ti—4Cr—4Al                   | 266                        | 281     |        |          |          | 152                                                      | 147                                                       |                        | 16    | 27                               | 1.4                       |

Referring to the data in Table 1, it is seen that 16 hours' exposure at 1400° F. had no unduly severe effects on alloys of this invention. The data obtained at 1800° F.

ered to have occurred where a Vickers Hardness Number increase of 75 had taken place (over the VHN of the original material).

TABLE 3  
Oxidation resistance of wrought  
Cb-42Ti-4Al-4Cr

| Temperature, F. | Time, hours | Weight Increase per Unit Area |                      | Oxidation Rate, Mg./cm. <sup>2</sup> /hr. | Scale Thickness, inch | Depth of Contamination, inch |
|-----------------|-------------|-------------------------------|----------------------|-------------------------------------------|-----------------------|------------------------------|
|                 |             | G./sq.in.                     | Mg./cm. <sup>2</sup> |                                           |                       |                              |
| 1,800           | 16          | 0.0477                        | 7.39                 | 0.46                                      |                       |                              |
| 1,800           | 16          | 0.0115                        | 1.78                 | 0.11                                      | <0.001                | 0.007                        |
| 2,000           | 0.5         | 0.0116                        | 1.80                 | 3.60                                      | <0.001                | 0.006                        |
| 2,100           | 0.5         | 0.0200                        | 3.10                 | 6.20                                      | <0.001                | 0.010                        |
| 2,100           | 0.5         | 0.0193                        | 3.00                 | 6.00                                      | <0.001                | 0.012                        |
| 2,200           | 0.5         | 0.0234                        | 3.63                 | 7.26                                      | <0.001                | 0.011                        |
| 2,300           | 0.5         | 0.0339                        | 5.25                 | 10.50                                     | <0.001                | >0.024                       |

illustrate the greatly improved oxidation resistance of the present alloys as compared with that of unalloyed columbium and with the columbium-49 percent titanium alloy. The inclusion of even a small amount of aluminum produces a significant improvement in oxidation resistance. This may be easily seen by comparing the weight increase values (after 16 hours at 1800° F.) for the Cb-50Ti and the Cb-49Ti-1Al alloys.

The data disclose improved oxidation-resistant alloys containing 50 percent or more columbium, from 5 to 49 percent titanium, and from 1 to about 10 percent aluminum. The data also show that beneficial additions of refractory metals such as chromium, vanadium, and tantalum may be made in these oxidation resistant alloys. Operable ranges are indicated to be from 0.5 to 10.0 percent chromium, from 0.5 to 10 percent vanadium, and from 1 to 40 percent tantalum. An especially good composition is the 50Cb-42Ti-4Al-4Cr alloy.

To illustrate further the extremely outstanding oxidation-resistance properties which alloys of this invention are capable of exhibiting, a series of oxidation-resistance studies was made at temperatures in the range of from 1800-2300° F. Results are tabulated in Table 3, below.

The alloys of this invention exhibit good fabricability—in some cases as much as 99% reduction by cold working, after the initial breakdown of the original cost structure has been possible.

It will be apparent that new and useful alloys having desirable characteristics and properties have been disclosed. It is, therefore, desired to further describe the invention as set forth in the appended claim.

What is claimed is:

An oxidation-resistant alloy consisting essentially of about 50 percent columbium, about 42 percent titanium, about 4 percent aluminum, and about 4 percent chromium.

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