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COBALT BASE ALLOYS AND CAST ARTICLES

William O. Binder, Niagara Falls, N. Y., assignor, by mesne assignments, to Union Carbide and Carbon Corporation, a corporation of New York

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This invention relates to alloys and articles made therefrom designed particularly for use in applications where great strength at very high temperatures is required.

The continued development of such devices as gas turbines and jet propulsion apparatus for power sources depends upon the production of metals and alloys which can successfully withstand the high temperatures and stresses encountered in their operation. In the past several years there have been developed many materials which have properties making them suitable for use in the fabrication of such devices. However, in the development of more efficient devices, designers have tended to raise the severity of operating conditions, and there is a continuing demand for new alloys capable of withstanding higher stresses at higher operating temperatures than the materials now commercially available.

Articles such as blades or "buckets," for gas turbines, for example, must resist high centrifugal stresses at temperatures approaching 1600° F. without creeping excessively as close tolerances must be held in the gas turbine for efficient operation. One very satisfactory method of making such articles is the so-called "precision-casting" or "lost-wax" process, and it is desired that alloys for such use be capable of being so cast. Additionally, they should be able to withstand the corrosive effect of high temperature and exhaust gases.

It is the primary object of the present invention to provide alloys and precision-cast articles capable of withstanding high stress at high temperature without excessive creeping.

The invention by means of which this object is achieved, comprises a cobalt-base alloy containing chromium, nickel and tungsten as major alloying constituents and also includes cast articles composed of such an alloy. Typical of such articles are, for example, turbine blades, nozzle-vanes, jet outlet nozzles and other parts of gas turbines. Specifically, the alloy of the invention contains 17% to 20% chromium, 8% to 14% nickel; 12% to 16% tungsten; manganese, used for deoxidation purposes, in a proportion of 0.25% to not more than 2%; carbon in a proportion of 0.3% to 0.7%; less than 5%, and preferably not more than 3% iron; the remainder cobalt, the minimum cobalt content being 45%. Nitrogen in a proportion up to 0.2% may be present in the alloy, tending to improve its stability at high temperatures, and silicon, ordinarily employed for deoxidizing the alloy in addition to manganese may be present in the alloy up to a maximum of 1%. Boron may be present up to 1%, improving high temperature strength, but usually should not exceed 0.4%.

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For the purpose of cheapening the alloy, molybdenum may be used to replace directly a proportion up to 3% of tungsten. That is, instead of say 15% tungsten, the alloy may contain 12% tungsten and 3% molybdenum. In all cases, however, the molybdenum content must not exceed 3% and the sum of the tungsten and molybdenum must not exceed 16%.

The carbon content of the alloy of the invention is of great importance and should always be within the limits above specified. This is true not only from the standpoint of strength at high temperatures but from the standpoint of castability. Alloys of lower carbon content do not have the requisite fluidity for precision casting, and alloys of higher carbon content generally are too brittle.

The high strength of the alloy of the invention at elevated temperatures has been demonstrated by conventional stress-rupture tests. Results of some of these tests are reported in Table I. In the table the stress to cause rupture of a given sample at 1500° F. on 100 hours' exposure and 1000 hours' exposure is reported in pounds per square inch. Also reported in the table is the percentage elongation of the sample occurring upon its fracture, as determined from gage marks originally one inch apart. The samples tested in Table I were machined from castings. In Table I each of the alloy compositions reported contained nitrogen in a proportion not exceeding 0.05%.

Table I

Percent Composition—Remainder Fe							Stress to Rupture at 1,500° F.		Percent Elongation in 1 inch	
Cr	Ni	Co	W	Mn	Si	C	100 hr.	1,000 hr.	100 hr.	1,000 hr.
18	10	54	15	1.5	0.5	0.42	31,500	25,500	3	3
18	10	54	(*)	1	0.4	0.38	32,000	25,000	4	4

*Alloy contained 12% W +3% Mo.

As above indicated, it is important that alloys to be used in gas turbine service, particularly in the case of buckets, be free from excessive creeping under the conditions of service because the efficiency of the gas turbine depends to a significant extent on the maintenance of close tolerances. The alloy of the invention possesses improved resistance to creep when compared to materials now commercially used. For example, a sample of an alloy containing 18% chromium; 15% tungsten; 10% nickel; 0.4% carbon; remainder substantially all cobalt with not more than 0.05% nitrogen when subjected to a stress of 25,000 pounds per square inch at 1500° F. elongated only 1% in 95 hours and showed no cracking or other signs of failure after 150 hours. The elongation of the sample after 150 hours was only 1.1%. Commercial alloys subjected to the same test elongated 1% in 4 hours, one failed after 45 hours and another elongated 8.5% after 140 hours and contained numerous fine cracks.

Results of typical tensile tests conducted at room temperature on typical compositions in the as-cast condition show the alloy of the invention to have excellent properties at room temperature. For example, a cast sample of an alloy containing 18% chromium; 10% nickel; 54% cobalt; 15% tungsten; 1.5% manganese; 0.5% silicon; 0.42% carbon; remainder iron had a yield strength at 0.2% offset of 61,500 pounds per square inch, an ultimate tensile strength of 116,700 pounds per square inch and had an elongation in one inch gage length of 28% with 22% reduction of area at the point of fracture.

The alloy of the invention may be used in the cast condition, requiring no heat treatment, but the resistance of castings of the alloy to creep may be improved by a pre-service aging treatment in which the castings are heated at a temperature of about 1350° to 1500° F. and air cooled.

Because of the excellent properties exhibited by the alloy of the invention in laboratory tests, a number of turbine blades were fabricated from it by precision casting. These blades were then placed in a turbosupercharger especially equipped for test purpose. Blades composed of six other alloy compositions were tested at the same time. From the standpoint of creep, the alloy of the invention was markedly superior to all of the other alloys tested. The following table sets forth data observed in one 30 hour test period with the turbosupercharger operating at 23,000 revolutions per minute and a tail cone temperature of 1425° F. Of the alloys in the table, alloy A is a commercial material containing about 30% chromium; 5% molybdenum; 1% maximum iron, the remainder cobalt and conventional quantities of manganese, silicon and carbon; alloy B is the alloy of the invention and contained 18% chromium; 15% tungsten; 10% nickel; about 2% iron; 0.4% carbon; about 0.007% boron; the remainder cobalt with not more than 0.65% silicon and 1.5% manganese; alloy C contained 18% chromium; 15% tungsten; 20% nickel; 40% cobalt; 0.4% boron; 0.2% carbon; the remainder iron with conventional quantities of manganese (not more than 1.5%) and silicon (not more than 1%). Both alloys B and C were tested after having been aged as above described. Alloy A was tested in the cast condition.

Table II

Blade Material	Creep in Inches (×1,000)		
	Minimum	Maximum	Average
Alloy A	5.5	25	15.3
Alloy B	2.0	5	3.5
Alloy C	5.8	8	6.9

The data in Table II illustrates the important reduction in creep attained by the alloy of the invention despite the relatively slight differences in composition between it and the other alloys. Thus, the average creep of the alloy of the invention is less than one quarter of the commercial alloy and only one half of that of alloy C which differs from the alloy of the invention primarily in cobalt, iron and carbon contents.

Although specific compositions are given herein as examples of the alloy of the invention, the invention is not limited to or by these examples, and certain modifications of its composition will be apparent. For example, as is well known, elements of the group consisting of columbium, tantalum, vanadium and titanium have a strengthening effect on alloys intended for high temperature use, and the alloy of the invention may contain up to 3% in the aggregate of one or more of these elements without detrimentally affecting its castability. If titanium is present, the titanium content should not exceed 1.5%.

This application is in part a continuation of application Serial No. 62,971, filed December 1, 1948, now abandoned.

I claim:

1. A castable cobalt-base alloy composed substantially of 18% chromium; 10% nickel; 15% tungsten; up to 3% molybdenum directly replacing an equal proportion of tungsten; up to 1% silicon; 0.25% to less than 2% manganese; 0.35% to 0.50% carbon; up to 0.2% nitrogen; up to 0.4% boron; up to 3% iron; the remainder cobalt.

2. A cast turbine blade composed of the alloy defined in claim 1.

3. A castable cobalt-base alloy composed substantially of 18% chromium; 10% nickel; 15% tungsten; 2% iron; 0.4% carbon; 0.007% boron; the remainder cobalt, silicon and manganese, silicon not exceeding 0.65% and manganese not exceeding 1.5%.

4. A cobalt-base alloy characterized by high resistance to rupture under stress at temperatures upward of 1500° F., said alloy having substantially the following composition: 45 to 58% cobalt; 7 to under 12% nickel; 17 to 20% chromium; 12 to 16% tungsten; 0.3 to 0.7% carbon, and the balance iron, the iron content not exceeding 5%.

5. A cast article made of a cobalt-base alloy characterized by high resistance to rupture under stress at temperatures upward of 1500° F., said alloy having substantially the following composition: 45 to 55% cobalt; 7 to under 12% nickel; 17 to 20% chromium; 12 to 16% tungsten; 0.3 to 0.7% carbon, and the balance iron, the iron content not exceeding 5%.

6. A cast article made of a cobalt-base alloy characterized by high resistance to rupture under stress of temperatures upward of 1500° F., said alloy having substantially the following composition: 45 to 55% cobalt; 7 to under 12% nickel; 17 to 20% chromium; 12 to 16% tungsten; up to 3% molybdenum; 0.3 to 0.7% carbon; manganese up to 2%; silicon up to 1%; the balance iron, the iron content not exceeding 5%.

7. A cobalt-base alloy characterized by high resistance to rupture under stress at temperatures upward of 1500° F., said alloy having substantially the following composition: 45 to 58% cobalt; 8 to under 12% nickel; 17 to 20% chromium; 12 to 16% tungsten; 0.3 to 0.7% carbon; 0.25% to less than 2% manganese; and the balance iron, the iron content not exceeding 5%.

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