

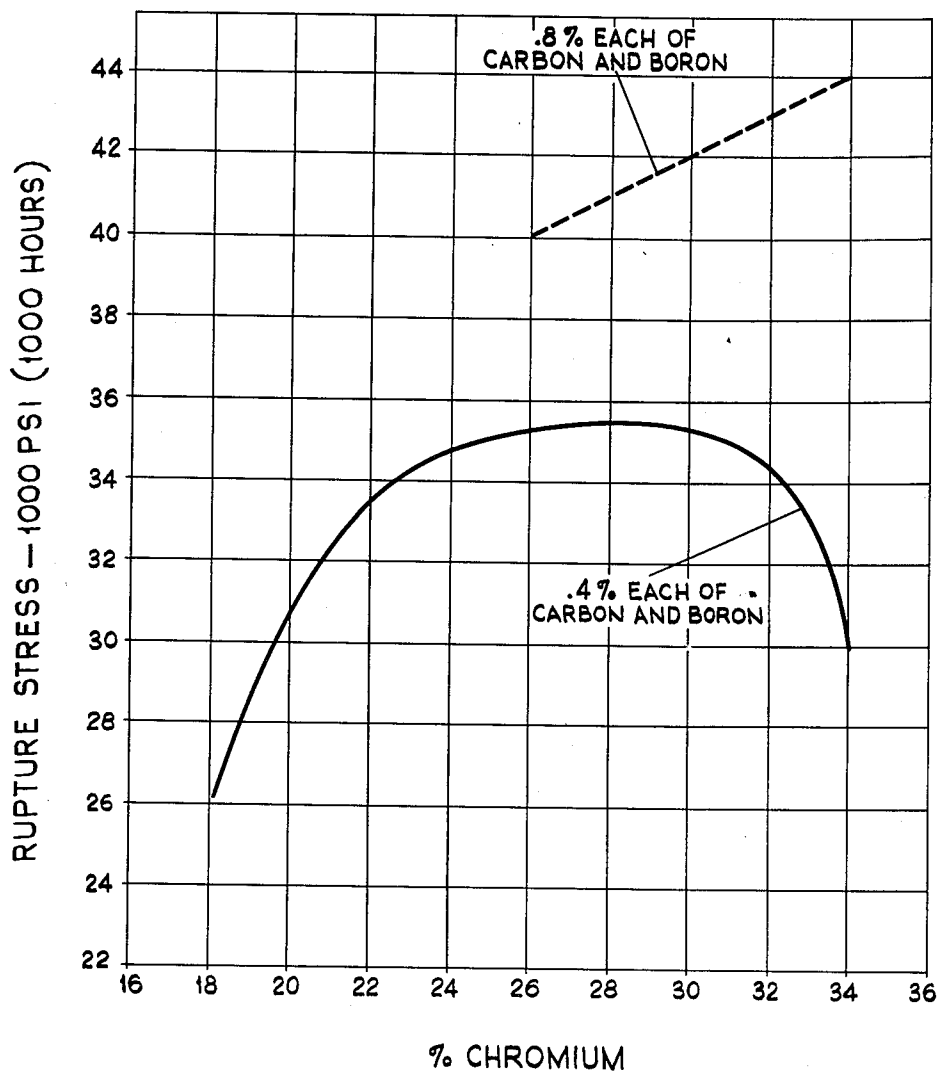
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HIGH TEMPERATURE Co-Cr ALLOYS

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HIGH TEMPERATURE Co-Cr ALLOYS

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6 Claims. (Cl. 75-171)

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 "investment-casting" 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 single figure of the drawing is a graphical representation of tests of alloys according to the invention and illustrates the effects of composition changes on strength at elevated temperatures.

The invention comprises a cobalt-base alloy containing chromium, nickel and tungsten as major alloying constituents together with carbon and boron and also includes cast articles composed of such an alloy. Typical of such articles are, for example, turbine blades, nozzles, jet outlet nozzles and other parts of gas turbines. Specifically, the alloy of the invention contains 23% to 36% chromium, 2% to 15% 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 0.9%; 0.25% to 1.0% boron; up to 5% iron; the remainder cobalt. A preferred maximum iron content is 3%. Nitrogen in a proportion up to 0.25% 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%. When the chromium content of the alloy of the invention is 23% to 30%, the carbon content should be 0.30% to 0.7%, the boron content 0.25% to 0.8%, and its minimum cobalt content should be 45%. When the chromi-

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um content is 30% to 36%, the carbon content should be 0.7% to 0.9%, the boron content 0.8% to 1.0%, and the minimum cobalt should be 35%.

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 contents must not exceed 16%.

The composition of the alloy of the invention is critical, and the individual constituents must be present in correct proportions to attain the highest strength. Stress-rupture tests have shown that only slight differences in composition have a profound effect on high temperature strength. Surprisingly, chromium has been shown by such tests to exert a powerful influence on strength particularly when properly balanced against carbon and boron although heretofore chromium has been included in alloys for high temperature service primarily for its oxidation resistance. The following table illustrates this effect of chromium. The tests reported in this table and in Table II below were obtained on precision-cast 1/4 inch diameter reduced-section specimens in the cast condition.

Table I

Composition: About 15% W; 0.4% B; 1.5% Fe; and—				Life in Hours at 40,000 p. s. i. and 1,500° F.	Stress to Rupture at 1,500° F.—100 Hrs.
Percent Cr	Percent Ni	Percent C	Percent Co		
18	10	0.2	54	15	33,000
18	10	0.4	54	8	31,500
23.86	10	0.4	Rest	218	41,500
26	10	0.2	46	32.5	34,500
26	10	0.4	46	250	44,000
28.8	5	0.5	1 Rest	314.4	47,500
33.7	10	0.7	2 Rest	1,648	63,000

¹ Alloy contained 13.7% W; 2.7% Fe.

² Alloy contained 14.8% W; 0.7% Fe; 0.8% B; 0.73% C.

³ Average of several specimens.

It will be observed from the data of Table I that increasing the chromium content of a cobalt-base alloy from 18% to 26% at the expense of the cobalt content more than double the life of the alloy containing 0.2% carbon under the test conditions and the same increase in chromium content of a similar alloy containing 0.4% carbon increased the life of the alloy under the same conditions from 15 hours to 250 hours, a 16.67 fold increase. Further, while increasing the chromium content to 28.8% and the carbon content to 0.5% increased the life of the alloy to over 314 hours, an increase of chromium to 33.7%, of carbon to 0.7%, and of boron to 0.8%, resulted in the very great increase of life to 1648 hours.

These data and other data obtained in a similar manner are well illustrated in the drawing. The sharp increase in strength attained by increasing the chromium content of alloys containing about 15% tungsten, 10% nickel, 0.4% carbon, 0.4% boron, 1.5% to 3% iron, remainder cobalt, is shown by the solid curve. It will be observed that the curve levels off at about 23% chromium and begins to break sharply downward at about 30% chromium. However, by increasing the carbon and boron content to about 0.8% each, as well as the chromium, as shown by the dashed curve, the substantial increase in strength is maintained in alloys containing upwards of 30% chromium.

Table II illustrates the effect on a cobalt-base alloy containing 26% chromium of increasing iron or nickel or both at the expense of cobalt.

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Table II

Composition: 26% Cr; 15% W; 0.4% C; 0.4% B; and—			Life in Hours at 40,000 p. s. i. and 1,500° F.	Stress to Rupture at 1,500° F.—100 Hrs.
Percent Fe	Percent Ni	Percent Co		
1.5	10	45	250	44,000
1.5	20	35	145	42,000
6.0	10	40.5	142	42,000
6.0	20	30.5	127	41,000

It is evident from the data of Table II that iron and nickel have a detrimental effect if increased at the expense of cobalt.

Accordingly, the nickel content of the alloy of the invention does not exceed 15%. Nickel is, however, an important constituent since its presence inhibits notch sensitivity in the alloy. Iron is an unavoidable impurity that should be held at a minimum, preferably below 3%. A preferred carbon content is 0.4% when the chromium content does not exceed 30%. If less than this proportion is present, the alloy suffers in hot strength, but if the carbon content is much higher than 0.4%, cold and hot ductility are seriously impaired. Boron similarly has a detrimental effect on ductility and preferably does not exceed 0.4% of the alloy when the chromium content is not more than 30%. However, as already indicated both carbon and boron should be increased, preferably to not more than about 0.8% each when the chromium content is in excess of 30%.

A typical example of a preferred composition for the alloy of the invention is: 26% chromium; 10% nickel; 1.5% maximum iron; 15% tungsten; 0.4% boron; 0.4% carbon; the remainder cobalt.

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.

This application is a continuation-in-part of our application Serial No. 125,156, filed November 2, 1949, now abandoned.

What is claimed is:

1. A cobalt-base alloy capable of withstanding prolonged exposure to mechanical stress of at least 31,500 pounds per square inch at elevated temperatures of the order of 1,500° F. and above, said alloy containing 23% to 36% chromium; 12% to 16% tungsten; up to 3% molybdenum, the sum of tungsten and molybdenum not exceeding 16%; 2% to 15% nickel; 0.25% to less than 2% manganese; 0.3% to 0.9% carbon; up to 1% silicon; up to 0.25% nitrogen; less than 5% iron; 0.25% to 1.0% boron, the remainder cobalt, the composition of said alloy being so balanced that when its chromium content is in the range 23% to 30% its carbon content is 0.30%

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to less than 0.5%, its boron content is 0.25% to 0.8% and its minimum cobalt content is 45%; and when its chromium content is in the range 30% to 36% its carbon content is 0.5% to 0.9%, its boron content is 0.8% to 1.0%, and its minimum cobalt content is 35%.

2. A cobalt-base alloy capable of withstanding prolonged exposure to mechanical stress of at least 31,500 pounds per square inch at elevated temperatures of the order of 1,500° F. and above, said alloy containing 23% to 30% chromium; 12% to 16% tungsten; up to 3% molybdenum, the sum of tungsten and molybdenum not exceeding 16%; 2% to 15% nickel; 0.25% to less than 2% manganese; up to 1% silicon; up to 0.25% nitrogen; less than 5% iron; 0.30% to less than 0.5% carbon; 0.25% to 0.8% boron; remainder cobalt; the cobalt content being at least 45%.

3. A cobalt-base alloy capable of withstanding prolonged exposure to mechanical stress of at least 31,500 pounds per square inch at elevated temperatures of the order of 1,500° F. and above, said alloy containing more than 30% but not more than 36% chromium; 12% to 16% tungsten; up to 3% molybdenum; the sum of tungsten and molybdenum not exceeding 16%; 2% to 15% nickel; 0.25% to less than 2% manganese; up to 1% silicon; up to 0.25% nitrogen; less than 5% iron; 0.5% to 0.9% carbon; 0.8% to 1.0% boron; the remainder cobalt, the cobalt content being at least 35%.

4. A castable cobalt-base alloy capable of withstanding prolonged exposure to mechanical stress of at least 31,500 pounds per square inch at elevated temperatures of the order of 1,500° F. and above, said alloy composed essentially of 26% chromium; 10% nickel; 15% tungsten; up to 1% silicon; 0.25% to less than 2% manganese; 0.4% carbon; 0.4% boron; up to 0.2% nitrogen; up to 2% iron; the remainder cobalt.

5. A cast article required in normal use to withstand mechanical stress at elevated temperature, said article being composed of the alloy defined in claim 2.

6. A cast article required in normal use to withstand mechanical stress at elevated temperature, said article being composed of the alloy defined in claim 3.

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