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ALLOY ARTICLES FOR USE AT HIGH TEMPERATURES

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

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

The continued development of such devices as superchargers, gas turbines, jet propulsion apparatus and the like depends upon the production of workable metals and alloys that are strong at the high temperatures at which such devices operate. Although several alloys have been proposed for use in high temperature applications, the utility of such alloys has been limited either because they are not hot-workable or machinable or because they become brittle upon continued exposure to elevated temperatures. One characteristic of highly alloyed ferrous metals which complicates the problem considerably is that as the ferrous solid solution is more heavily loaded with alloying materials to increase the high-temperature strength, the high-temperature stability tends to decrease so that upon prolonged heating the material becomes unduly brittle.

There is accordingly a need for hot-workable, machinable alloys and alloy articles having great strength and stability at highly elevated temperatures, and it is the principal object of this invention to satisfy this need.

This object is achieved by the present invention which comprises a heat resistant alloy containing chromium, nickel, cobalt, tungsten, and at least one metal from the group consisting of columbium, tantalum, titanium, and vanadium, together with minor quantities of manganese, silicon, molybdenum, carbon, nitrogen and impurities commonly present in steels of good quality.

Specifically, the alloy of the present invention contains by weight 15% to 25% chromium; more than 25% but not more than 45% nickel; 10% to 25% cobalt; more than 7.5%, preferably more than 10% but not more than 15% tungsten, an aggregate of 0.5% to 3% of one or more of the elements columbium, tantalum, titanium, and vanadium; and up to 2% manganese, up to 1% silicon, up to 0.35% carbon, 0.05% to 0.25% nitrogen; and the remainder substantially all iron and incidental impurities. Up to about 3.5% molybdenum may be present, but additional molybdenum imparts no substantial benefit. The content of any single element of the columbium, tantalum, titanium, vanadium group should be less than 2%, and the titanium content should not exceed 1.5%. Somewhat more of the minor constituents than the upper limits just specified may on occasion be used. For instance, if excel-

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lent forgeability is not essential, the carbon content may be above 0.35%, up to say 1%. Iron is present in a substantial proportion, the iron content being at least 5%.

- Alloys within the foregoing composition ranges are readily forged, welded, and machined and, as has been demonstrated by test, have remarkably great strength and stability at high temperatures, for example 1200° F. and upwards.
- Machine parts of the alloys may be designed to operate at high stress for long periods of time at 1500° F. and at lower stress for moderate periods at somewhat higher temperatures. The invention includes cast or hot-worked articles and welded articles for use at elevated temperatures and composed of such alloys.

A useful test for determining the suitability of metals and alloys for high temperature applications is the so-called "stress-rupture" test. In this test, each of several samples of a given material is subjected to a measured tensile stress at a particular elevated temperature, and the time required for the sample to fail under these conditions of temperature and stress is noted. The data obtained are then plotted, using time and stress as abscissa and ordinate respectively. A curve is thus established for the material tested, showing for the selected temperature the time required to cause failure of the material when a particular stress is applied. Usually curves are established for several different temperatures, and from these curves can be predicted quite accurately the length of time the material can withstand failure at a given stress applied at a given temperature. This information is valuable for design purposes, especially if the material selected may be subjected to overheating, overloading, or both.

The alloy article of the invention has been shown by stress-rupture tests to have excellent strength at high temperatures and the ability to withstand large stresses for prolonged periods of time at high temperatures. For example, in one test a specimen of an alloy article containing about 20% chromium; 40% nickel; 20% cobalt; 3% molybdenum; 11% tungsten; 1% columbium; 0.14% carbon; and 0.10% nitrogen, remainder substantially all iron withstood a stress of 20,000 pounds per square inch at a temperature of 1500° F. for 232 hours before failure. This specimen had been hot forged and then heated one hour at about 2300° F. and quenched in water before testing.

The alloy article of the invention may be forged or otherwise hot-worked without difficulty

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in the range of 2100° F. to 1600° F. In some cases working should be continued to a temperature somewhat below the recrystallization temperature (about 1200° F.). An alloy article so wrought is said to be in the "cold hot-worked" condition. The alloy article is also easily machinable and has good cold or hot bending and forming properties because of its high ductility.

Another important advantage of the alloy article of this invention is that it may be welded by ordinary welding methods including the various electric arc and oxyacetylene fusion-deposition methods, submerged-melt electric methods and solid-phase pressure welding methods, the welds produced being sound, tough, and ductile both in the weld zone itself and in areas adjacent to and remote from the weld zone.

To ensure the attainment of the desirable characteristics of the alloy article of the invention it is most important that the composition limits set forth be adhered to so that the alloying elements are present in the proper proportions. For example, nitrogen is beneficial to high temperature properties in the range given, but too high a nitrogen content is detrimental. Similarly, if the proportions of molybdenum, tungsten, columbium, tantalum, titanium, vanadium, and carbon be higher than the ranges given, the alloy article suffers in hot-workability and weldability; welds made in such alloys lack toughness and ductility. The deleterious effects of too high proportions of these elements can not satisfactorily be offset by increasing the proportions of cobalt and nickel in the alloy. Accordingly, care should be taken that the composition limits described be observed in making the alloy article.

If the alloy article is intended for uses in which it will be exposed to temperatures not in excess of about 1350° F. compositions near the lower limits of the ranges given may be used, but if the alloy article will be used where exposure to temperatures above 1350° F. is probable, compositions near the upper limits of the ranges given should be employed. If the alloy article is to be used where temperatures not in excess of 1200° F. will be encountered, it may be used in the cold hot-worked condition, but where exposure to temperatures above 1200° F. is expected, the alloy article should be annealed at a temperature of about 2200° F. to 2320° F. before use for best service.

Typical of articles for which the alloy of the invention is well suited are blades, wheels and other parts of turbines. Such articles may be either cast or wrought.

Although particular emphasis has been laid on the hot working properties of the alloy of the invention and the use of the alloy for wrought articles, castings of the alloy also possess very useful properties at high temperatures.

We claim:

1. A heat resistant alloy article which in normal use is exposed to elevated temperatures upwards of 1200° F. and has great strength and stability when subjected to high stresses at such elevated temperatures, said article being composed of a machinable, castable, weldable, hot-

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workable alloy consisting of 15% to 25% chromium; more than 25% but not more than 45% nickel; 10% to 25% cobalt; more than 10% but not more than 15% tungsten; up to about 3.5% molybdenum; an aggregate of 0.5% to 3% of one or more of the elements of the group consisting of columbium, tantalum, titanium and vanadium, the amount of any single element of the last-named group being less than 2% of the alloy except the titanium content being not in excess of 1.5%; up to 2% manganese; up to 1% silicon; up to 1% carbon; 0.05% to 0.25% nitrogen; and the remainder iron and incidental impurities, the iron content being at least 5%.

2. A heat resistant alloy article which in normal use is exposed to elevated temperatures of 1200° F. and upwards and has great strength when subjected to high stresses at such elevated temperatures, said article being composed of a machinable, weldable, castable and hot-workable alloy consisting of 15% to 25% chromium; more than 25% but not more than 45% nickel; 10% to 25% cobalt; more than 10% but not more than 15% tungsten; up to 3.5% molybdenum; 0.5% to less than 2% columbium; up to 2% manganese; up to 1% silicon; up to 0.35% carbon; 0.05% to 0.25% nitrogen; and the remainder iron and incidental impurities, the iron content being at least 5%.

3. A heat resistant alloy article which in normal use is exposed to elevated temperatures of 1200° F. and upwards and has great strength when subjected for prolonged periods of time to high stresses at such elevated temperatures, said article being composed of a machinable, weldable, castable and hot-workable alloy consisting substantially of 20% chromium; 40% nickel; 20% cobalt; 3% molybdenum; 11% tungsten; 1% columbium; 0.14% carbon; 0.1% nitrogen, the remainder iron.

RUSSELL FRANKS.
WILLIAM O. BINDER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,774,862	Wissler	Sept. 2, 1930
2,245,366	Rohn	June 10, 1941
2,246,078	Rohn	June 17, 1941
2,398,702	Fleischmann	Apr. 16, 1946
2,432,615	Franks et al.	Dec. 16, 1947
2,432,618	Franks et al.	Dec. 16, 1947

FOREIGN PATENTS

Number	Country	Date
219,293	Great Britain	May 7, 1925
371,334	Great Britain	Apr. 13, 1932

OTHER REFERENCES

Kinzel & Franks: Alloys of Iron & Chromium, published by McGraw-Hill Book Co., N. Y., vol. II, 1940, pages 87, 88, 180, 192-194, 455.

Progress Report on NDRC Research Project, NRC-8, P. B. 39, 578, October 7, 1942, pages 1-21 inclusive (particularly page 5); Declassified to open January 28, 1946.