

UNITED STATES PATENT OFFICE

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HIGH-TEMPERATURE COBALT ALLOY

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The present invention relates to a high-temperature, high-strength cobalt alloy. It is particularly concerned with a heat and corrosion-resistant alloy particularly adapted for fabrication of the buckets and other working parts of gas turbines and the like.

In my prior application Serial No. 592,089, filed May 5, 1945, now abandoned, and assigned to the same assignee as the present invention, there is disclosed and claimed a cobalt alloy containing substantial quantities of chromium and nickel and a low carbon content; the nickel content of the alloy preferably ranging from 9-11% in order to obtain a product which has desirable high-temperature characteristics and which can also be welded.

The present invention relates to an alloy of the type disclosed in my prior application, and is based on the discovery that by decreasing the preferred nickel content to 4-6%, decreasing the chromium content to 19-21%, holding the carbon content within the range 0.25-0.7%, and adding titanium and boron in amounts ranging from 0.25-1% titanium and 0.02-0.1% boron, there can be obtained an alloy possessing exceptional strength and ductility at elevated temperatures. The alloy displays these excellent properties in the as-cast condition and does not require heat treatment.

In carrying out the present invention, I employ a cobalt base alloy containing about 19-21% chromium, 4-6% nickel, 3.5-4.5% tungsten, 3.5-4.5% molybdenum, 0.25-0.7%, preferably 0.25-0.4% carbon, 0.2-1% titanium and 0.02-0.1% boron, balance substantially cobalt except for up to 4% iron added with the titanium and boron and deoxidizing quantities of manganese and silicon, these latter elements being present in amounts not exceeding 1% of each.

The titanium and boron can be added to a melt of the principal ingredients in the form of ferrotitanium and ferroboron. However, due to the fact that the titanium in the form of ferrotitanium is somewhat troublesome in melting, both the titanium and boron are preferably added in the form of a commercially available alloy known as "Carbortam," an alloy of about 18.8% titanium, 2.87% silicon, 5.4% carbon, 1.2% boron, balance iron. This alloy dissolves with relative ease in a melt of the remaining ingredients and serves as a means for introducing titanium and boron in substantially the desired proportions.

The addition of titanium and boron is known to have a profound effect upon the high-temperature strength of various alloys particularly with regards to the rupture and creep properties. While a number of interesting alloys containing titanium and boron have been produced, none of them have proved to be of particular practical value due to the fact that they exhibited both a

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lower ductility and a definite tendency to become increasingly brittle with time at elevated temperatures as compared with the same alloys containing neither of these ingredients. Contrary to normal expectation, the alloy of the present invention containing both of these elements is exceedingly ductile and exhibits no tendency to become brittle when subjected to elevated temperatures for long periods of time.

The present alloy is easily prepared by the usual methods and offers no particular difficulties in casting. For example, the alloy can be prepared by making a melt of the cobalt, nickel, molybdenum, tungsten, chromium, carbon, manganese, silicon, and finally adding the commercial titanium-boron-iron alloy, the latter being dropped beneath the surface of the melt so that the lumps thereof are coated with metal to prevent oxidation of the titanium during solution of the alloy. A preferred alloy hereafter referred to as X52D prepared in this manner contains about 20% chromium, 5% nickel, 4% tungsten, 4% molybdenum, 4% iron, 0.5% manganese, 0.5% silicon, 0.40% carbon, 0.33% titanium, 0.06% boron and balance cobalt. This alloy has been found to have a 100 hour rupture strength (R. S.) of 32,500 lbs. per square inch and an elongation of 23% at a temperature of 1500° F. The 1,000-hour rupture strength at this temperature was 26,000 lbs. per square inch and its elongation 23%. The rupture test by which the rupture strength figures were obtained consists of imposing a constant load on a sample of the alloy at a constant temperature. The variable involved in this test is the time required for fracture. The data obtained from series of such tests employing different loads at the same temperature are then plotted in curves of log stress versus log time. From these curves the strength of the material can be reported as the 100-hour or 1,000-hour rupture strength, that is the stress which will produce failure in the alloy in 100 hours or 1,000 hours at the particular test temperature.

The above-described alloy X52D was also compared with a similar alloy prepared without the addition of "Carbortam" with the following results at a temperature of 1500° F. for 100 hours:

	R. S. p. s. i.	Percent El.
X52D	32,500	23
X52D without Carbortam addition	27,000	12

Although difficulty has previously been experienced with alloys strengthened by the addition of titanium and boron in the loss of considerable titanium and boron upon remelting of the alloys, so that such alloys did not lend themselves to casting procedures involving the re-

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melting and reuse of scrap sets from previous castings, the alloys of the present invention can be successfully remelted without substantial loss in titanium or boron content or of the properties imparted by these elements. For example, a portion of alloy X52D was remelted and precision cast into test bars and tested at 1500° F. The remelted alloy had a 100-hour rupture strength of 34,000 lbs. per square inch and an elongation of 20%. Chemical analysis showed that there was no change in composition except that the carbon content had increased to about 0.40% and the titanium decreased to 0.30%.

Preferably the alloy of the present invention is precision cast, for example, as turbine buckets by pouring at any temperature of from 1500°-1700° C. into molds held at temperatures not substantially exceeding 750° C. The optimum casting conditions depend upon the specific part which is being produced. A comparison of the compositions and properties of the alloy X52D, within the scope of the present invention, with closely related alloys differing only in their nickel, molybdenum, or tungsten contents can be made from the following tables, in which Table 1 lists the compositions of the alloys and Table 2 the results of rupture tests. The carbon and titanium values given in the table are all actual determinations, while the others are nominals which were spot checked and found to be within the range of experimental error:

Table 1

	C	Mn	Si	Cr	Ni	Mo	W	Ti	B	Co	Fe
X52A-----	.38	.5	.5	20	5	---	6	.30	.06	bal.	14
X52B-----	.34	.5	.5	20	10	---	6	.28	.06	bal.	14
X52C-----	.38	.5	.5	20	10	4	4	.39	.06	bal.	14
X52D-----	.28	.5	.5	20	5	4	4	.33	.06	bal.	14
X52E-----	.32	.5	.5	20	5	6	---	.42	.06	bal.	14
X52F-----	.28	.5	.5	20	10	6	---	.33	.06	bal.	14

¹ Maximum.

Table 2

	100 hours		1,000 hours	
	R. S., p. s. i.	Per Cent El.	R. S., p. s. i.	Per Cent El.
1,500° F.				
X52A-----	29,500	20	---	---
X52B-----	29,000	14	---	---
X52C-----	31,500	27	25,500	20
X52D-----	32,500	23	26,000	23
X52E-----	29,000	25	24,500	18
X52F-----	29,000	27	---	---
X52D (remelted from master heat)-----	34,000	20	27,000	20
1,700° F.				
X52A-----	---	---	---	---
X52B-----	15,500	27	---	---
X52C-----	14,500	24	---	---
X52D-----	16,000	33	---	---
X52E-----	14,500	30	---	---
X52F-----	15,000	22	---	---
X52D (remelted from master heat)-----	17,000	25	---	---

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From the tabulated test data it will be seen that while most of the compositions listed possess high rupture strength and excellent ductility, best results are obtained when the chromium, nickel, molybdenum and tungsten are present within the range of proportions specified hereinbefore.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A heat and corrosion-resistant alloy characterized by good rupture strength and ductility at elevated temperatures, said alloy containing 19-21% chromium, 4-6% nickel, 3.5-4.5% molybdenum, 3.5-4.5% tungsten, from 0.25 to 0.7% carbon, from 0.2 to 1% titanium, 0.02 to 0.1% boron, not over 4% iron balance cobalt except for manganese and silicon in deoxidizing quantities less than 1%.

2. A heat and corrosion-resistant, high-temperature cast alloy containing from 0.25 to 0.4% carbon, manganese and silicon in deoxidizing quantities less than 1% of each, about 20% chromium, about 5% nickel, about 4% of each of the elements tungsten and molybdenum, not over 4% iron, from 0.2 to 1% titanium and 0.02 to 0.1% boron, balance cobalt, said alloy being characterized by good rupture strength and ductility at 1500° F.

EDWARD EPREMIAN.

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