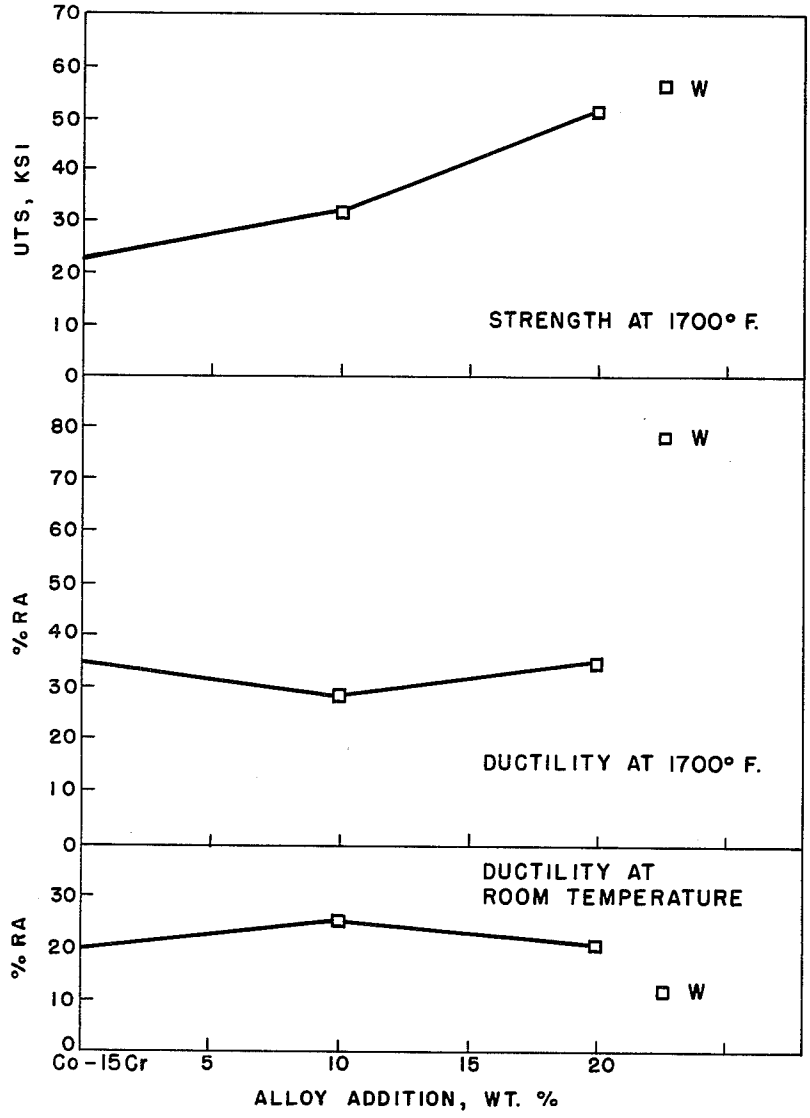
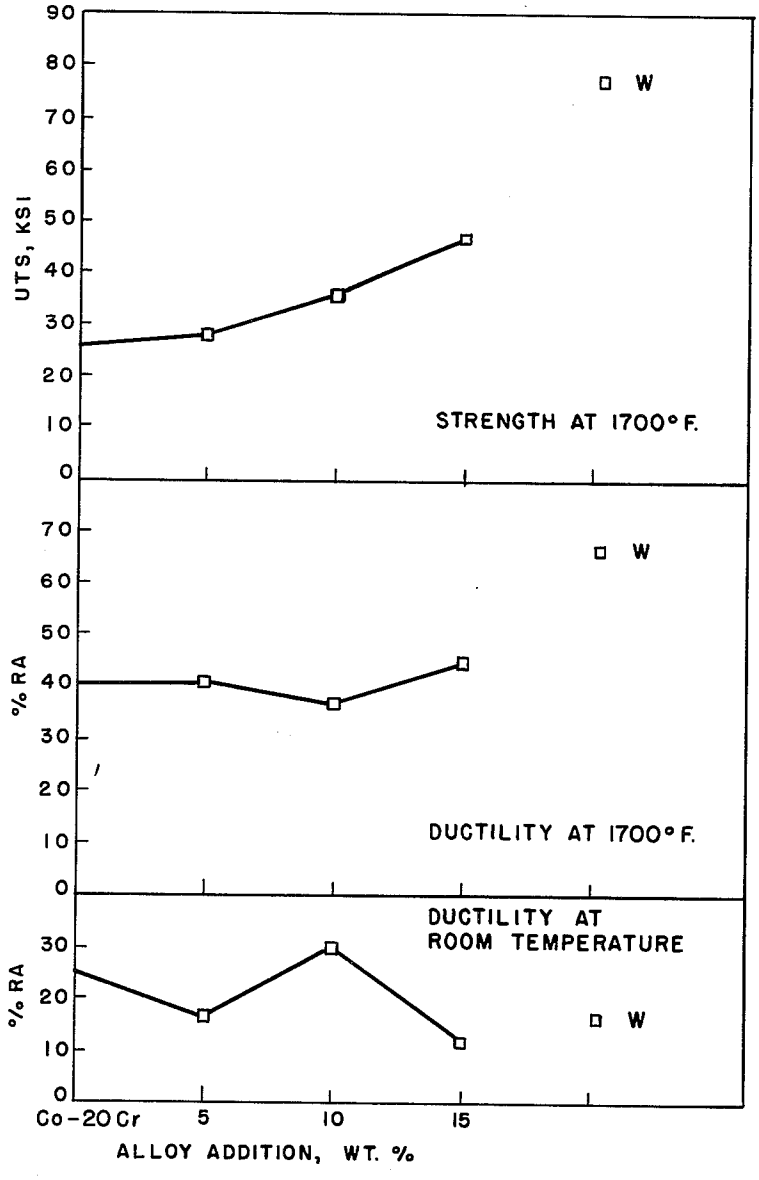
Dec. 14, 1965 J. J. RAUSCH ETAL 3,223,522
CHROMIUM, TUNGSTEN COBALT BASE ALLOYS CONTAINING ADDITIONS OF TANTALUM, TITANIUM AND NIOBIUM
Filed Jan. 31, 1963 3 Sheets-Sheet 1



EFFECT OF ADDITION ON THE PROPERTIES OF THE BASE COMPOSITION Co-15 Cr.

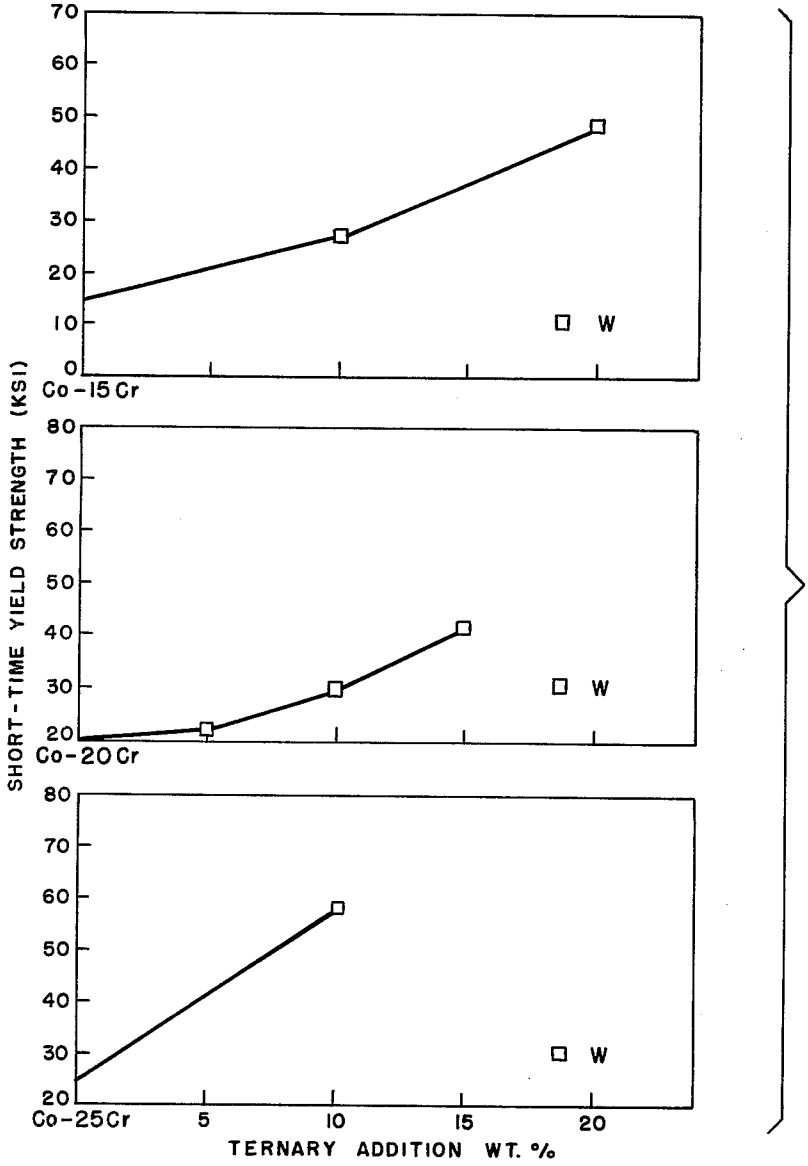
FIG. 1

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EFFECT OF ADDITION ON THE PROPERTIES OF THE BASE COMPOSITION Co - 20 Cr.

FIG. 2



EFFECT OF TUNGSTEN ADDITION ON THE 1700°F. SHORT-TIME YIELD STRENGTH OF Co-Cr-BASE ALLOYS.

FIG. 3

United States Patent Office

3,223,522

Patented Dec. 14, 1965

3,223,522

CHROMIUM, TUNGSTEN COBALT BASE ALLOYS CONTAINING ADDITIONS OF TANTALUM, TITANIUM AND NIOBIUM

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Filed Jan. 31, 1963, Ser. No. 255,415
2 Claims. (Cl. 75—171)

The present invention relates to improved cobalt alloys and to methods of making the same. More particularly, the present invention relates to the addition of predetermined amounts of various selected materials to cobalt and cobalt-base alloys whereby alloys having markedly improved physical and metallurgical properties are obtained.

The present commercial cobalt alloys do not provide the strengths demanded by modern high-temperature applications in highly oxidative atmospheres. Attempts to produce alloys of cobalt embodying these desirable properties have heretofore not been successful due to a loss in forgeability or in extensive brittleness on additional alloying.

Accordingly, it is an object of the present invention to provide an alloy of cobalt that is strong and ductile while retaining sufficient forgeability to be workable after additional alloying.

A further object of the present invention is to provide an oxidation resistant alloy of cobalt that embodies the aforementioned properties.

Yet another object of the present invention is the provision of cobalt alloys that exhibit significant increases in rupture life, are oxidation resistant, and display short time tensile strength in the range of 60,000 to 85,000 p.s.i. at 1700° F.

Yet another object of the present invention is to provide novel, wrought cobalt-base alloys that are superior in properties to those presently used for high-temperature applications.

Still another object of the present invention is the provision of alloys of cobalt having a 1000 hour rupture life at 10,000 p.s.i. and 1700° F.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying tables and graphs wherein:

FIG. 1 is a graphical presentation of the effect of tungsten addition on the properties of the base composition Co-15Cr;

FIG. 2 is a graphical presentation of the effect of tungsten addition on the properties of the base composition Co-20Cr; and

FIG. 3 is a graphical presentation of the effect of tungsten addition on the 1700° F. short-time yield strength of Co-Cr base alloys.

The above objects are accomplished by the preparation of alloys of the desired properties. Initially basic ternary alloys of cobalt, chromium and tungsten were prepared which exhibited good tensile strength, forgeability, ductility, and oxidation resistance. These ternary alloys were adopted among others as the basis for the search for an alloy of cobalt having improved stress rupture life while

not sacrificing any of the properties of the parent alloy.

The stress rupture properties are improved primarily through dispersion strengthening. For this purpose small additions of at least one metal from the group consisting of titanium, tantalum and columbium is made.

The composition limits within which forgeability is maintained in binary cobalt-chromium alloys have been established. These alloys may be alloyed to the solubility limit (~38 w/o Cr) before loss of forgeability occurs. The addition of 20% or more chromium to cobalt produces alloys having excellent strength at 1700° F. The yield strength of these alloys rises continuously from 18,000 p.s.i. at 20% Cr to 43,500 p.s.i. to 35% Cr.

It has been found that alloys based on Co-Cr are strengthened appreciably at 1700° F. by the addition of tungsten. The effect is illustrated in FIGS. 1, 2 and 3. These alloys have the following properties.

TABLE I

Tensile properties of ternary cobalt base alloys at room temperature

Ex.	Alloy Addition (wt. percent)	Yield Strength (p.s.i.)	Ultimate Tensile Strength (p.s.i.)	Percent RA	Elong. (percent in 0.625 in.)
1	15Cr-10W	90,500	157,000	25	17
2	15Cr-20W	116,000	164,000	21	23
3	20Cr-5W	97,000	149,000	17	16
4	20Cr-10W	78,000	148,000	30	37
5	20Cr-15W	141,000	175,000	13	13
6	25Cr-10W	95,000	160,000	33	36

At 1,700° F.

Ex.	Yield Strength (p.s.i.)	Ultimate Tensile Strength (p.s.i.)	Percent RA	Elong. (percent in 0.625 in.)
1	27,000	32,000	28	15
2	49,500	52,000	35	36
3	21,000	27,500	41	39
4	29,500	36,000	37	34
5	42,500	47,000	45	40
6	58,000	59,000	1	2

Significant quantities of tungsten can be added to cobalt at the 15 and 20 w/o levels without causing embrittlement at room temperature or 1700° F.

Based on this ternary alloy containing 15 to 35% chromium, 5 to 20% tungsten, balance cobalt, additional alloying elements were investigated to obtain maximum stress rupture properties. Selective additions of titanium, niobium and tantalum accomplished these objectives. The addition of titanium or niobium to the Co-Cr base alloys should be restricted to about 1 to 2% to minimize loss of forgeability. However, tantalum may be added in percentages of 2 to 4% to the ternary Co-Cr-W alloy or to the quaternary alloy containing titanium or niobium or combinations thereof. The stress rupture properties

of the ternary base alloy and the alloys containing the additional elements is shown in Table II.

TABLE II

Stress-rupture properties of Co-15Cr-*base alloys*

Ex.	Alloy Addition (wt. percent)	Test* Temp. (° F.)	Stress (p.s.i.)	Time to Failure (hr.)	Percent Elong.	Percent RA
1	15Cr-20W	1,700	10,000	5.3	3	19
2	15Cr-20W-1Nb	1,700	10,000	177	20	28
3	15Cr-20W-1Nb	1,700	15,000	52	20	32
4	15Cr-20W-2Ta	1,700	10,000	166	18	25
5	15Cr-20W-2Ta	1,700	15,000	13	28	35
6	15Cr-20W-4Ta	1,700	10,000	22	42	63
7	15Cr-20W-1Ti	1,700	10,000	922	10	17
8	15Cr-20W-1Ti	1,700	15,000	73	12	18

*Each alloy was heat treated as follows, prior to testing: 2200° F.—15 hrs.—AC+1700° F.—16 hrs.—AC.

The significant increases in strength obtained by the small addition of reactive metals is probably due to reaction with interstitial elements in the base alloy, i.e. through dispersion strengthening.

The most notable improvement in rupture life occurred in alloys based on Co-15Cr-20W. Addition of 1% Cb, 2% Ta or 1% Ti caused a 30 to 175 fold increase in rupture life at 1700° F. and under a stress of 10,000 p.s.i. In each instance more uniform elongation was noted than occurred in the base alloy.

The alloy Co-15Cr-20W-1Ti had a rupture life of 922 hours at 10,000 p.s.i. and 1700° F. compared to approximately 100 hours under these conditions for one of the better commercial wrought alloys. The stress to rupture is about 35% higher at this temperature for the alloys of this invention.

Alloys were prepared as 250-gram pancake-shaped ingots approximately ½ inch x 3 inch diameter. These ingots were arc melted using a water-cooled, tungsten-tipped electrode in a water-cooled copper crucible in an argon atmosphere. The ingots were then hammer forged to ½ inch diameter rod from which test specimens were prepared. Two different heat treatments were employed, consisting of a stabilizing anneal after forging or a solution treatment followed by a stabilizing anneal. The latter invariably resulted in superior rupture life.

Tensile tests were performed at room temperature and at 1700° F. at a strain of approximately 0.12 inch/inch/minute. Before testing, all specimens were sealed in evacuated bulbs, treated at 1700° F. for 24 hours, and then air cooled.

It is now apparent that the novel alloys of the present invention display an unusual and valuable combination of properties making them useful for various critically needed applications in the jet engine and aero-space fields.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In a forgeable, oxidation resistant alloy consisting of 45–80% cobalt, 15–35% chromium, 5–20% tungsten, the addition of 2–4% tantalum and 1–2% titanium characterized by a 30–170 fold increase in rupture life at 1700° F. and under a stress of 10,000 p.s.i.

2. In a forgeable, oxidation resistant alloy consisting of 45–80% cobalt, 15–35% chromium, 5–20% tungsten, the addition of 2–4% tantalum and 1–2% niobium characterized by a 30–170 fold increase in rupture life at 1700° F. and under a stress of 10,000 p.s.i.

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