United States Patent Office 3,756,809
Patented Sept. 4, 1973

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3,756,809
CHROMIUM-COBALT ALLOY

Kamal Asgar, Ann Arbor, Mich., assignor to The Regents of The University of Michigan, Ann Arbor, Mich.

No Drawing. Filed May 1, 1972, Ser. No. 248,843
Int. Cl. C22c 19/00, 31/00
U.S. Cl. 75—134 F 6 Claims

ABSTRACT OF THE DISCLOSURE

An alloy containing as essential ingredients 18% to 28% chromium, 25% to 50% cobalt, 18% to 40% nickel and 12.3 to 13.5% tantalum has high strength and an improved balance of elongation and toughness, making the alloy particularly useful for partial denture prosthetics.

This invention concerns a chromium-cobalt alloy having high strength, high ductility, and an improved balance of elongation and toughness, which, owing to these properties, is particularly adapted for the production of cast partial denture appliances.

Chromium-cobalt alloys, having come into wide use in the production of castings for partial or complete denture appliances, must meet certain physical properties requirements, e.g., adequate elongation and toughness and the right degree of hardness, to permit the dentist or dental technical to make minor but necessary adjustments at the time of delivery to the patient. The technician or dentist must be able to bend the clasp attachment to more than a ten degree angle without breakage occurring. Counterbalancing such good flexibility, however, the clasp must have sufficient rigidity to retain the shape and position to which it has been adjusted and to resist distortion by the biting forces. In my U.S. Pat. No. 3,544,315, Dec. 1, 1970, was disclosed a chromium-cobalt alloy meeting the requisite standards, wherein the strength and toughness of the alloy are achieved by a critical combination of narrowly defined molybdenum and carbon content. It has been determined that the alloy described in U.S. 3,544,-315 owes its strength to the formation of carbide precipitates. But an alloy strengthened by formation of carbides possesses certain inherent disadvantages. For example, such cobalt alloys show greater variation of mechanical and physical properties from one specimen or casting to another. Not only does the amount of carbide precipitate alter the properties, but, in addition, the location and distribution of the precipitates have a marked effect on mechanical properties. Chromium-cobalt alloys may be cast and recast at temperatures in the range of 2750° F. to 2900° F., and possible variations in these temperatures from one melt to another, and the use in recasting of scrap materials and sprue remnants (generally too expensive to discard), together with the variation in mold temperatures (that is, all or any of the various manipulative conditions to which dental alloys are subjected) have a significant effect on the mechanical properties of the carbide-hardened alloys which eventually reach the mouth of the patient.

In contrast, the present composition, consisting essentially of an alloy composed of chromium, cobalt, nickel and tantalum in specific proportions, gets its strength through a precipitation hardening mechanism, rather than by the formation of carbides. Thus, since there is no carbide precipitation, the foregoing manipulative conditions during casting of the alloy and other processing do not cause a variation in mechanical properties and strength. Remelting of the new alloy, including the recasting of scraps thereof, and variations in casting temperatures do not cause variations in the physical properties of the alloy. Most importantly, loss of ductility as the alloy is strengthened by the precipitation hardening mechanism is kept to a minimum.

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Tantalum has previously been disclosed as an additive to chromium-cobalt alloys to improve certain properties (but not in the unique proportions embodied in the present invention which unexpectedly provide a special combination of strength, toughness, and ductility to the alloy making it particularly useful in dental appliance manufacture). For instance, Canadian Pat. 238,742, Mar. 18, 1924, discloses a chromium-cobalt alloy for cutting tools, containing not more than about 5% tantalum. In the only specific example cited in this Canadian specification, the alloy also contains about 15% tungsten and 2% carbon. Michael et al., U.S. 3,085,005, Apr. 9, 1963, describes an alloy for turbine engines and gas combustion chambers consisting of 15% to 25% chromium, 2% to 15% tungsten, from 3% to 25% of tantalum or columbium, and varying amounts of aluminum, molybdenum and titanium, the remainder being cobalt, and "incidental impurities," including up to about 0.5% carbon. Thielemann, U.S. 2,974,036, Mar. 7, 1961 is concerned with an alloy useful in gas turbine engines composed of 15 to 30% chromium, 5 to 15% tungsten, 0.5 to 20% tantalum, 0.01 to 3% zirconium, 0.1 to 1.3% carbon and the balance cobalt. McQuillan et al., U.S. 3,314,784, Apr. 18, 1967, is concerned with a similar engine alloy consisting essentially of 20 to 35% chromium, 5 to 20% tungsten, 3 to 5% tantalum, 0.7 to 1.3% carbon and the balance cobalt. Wheaton, U.S. 3,366,478, Jan. 30, 1968, describes an alloy for gas turbine engines having excellent resistance to the combined effects of stress and oxidation at elevated temperatures (1400° F.–2000° F.) composed of 0.03% to 0.2% carbon, 15% to 30% chromium, 10% to 30% nickel, 2% to 12% tantalum, 0.1% to 0.5% zirconium, various amounts of other metals, and the balance essentially cobalt. Wheaton cautions that it is essential that the amount of tantalum in his alloy not exceed 12% by weight and that the chromium content not exceed 30% by weight.

The alloy of the present invention consists essentially of 18% to 28% chromium (preferably 23 to 26% Cr), 25% to 50% cobalt (preferably 33 to 36% Co), 18% to 40% nickel (preferably 24 to 30% Ni), and from 12.3% to 13.5% tantalum (preferably about 13%), such amounts of Ta being critical to obtain the properties hereinafter described. (All amounts of constituents of alloys described herein are given in percents by weight.) The alloys of this invention, which are essentially free of carbon to avoid undesired carbide precipitation, have an elongation of at least 10% and a toughness factor of at least about 8000. The yield point of the alloy is greater than about 80,000 p.s.i. and its hardness is not greater than about 330 KHN units.

The percentage of elongation is a measure of the extent an alloy will increase in length as it is drawn from a zero load to the breaking point. Percentage of elongation has a direct relationship to cold shaping of an alloy as in the use of pliers to shape wire into clasps. The yield point (Y.S.) is an indication of the behavior of a clasp, as well as the entire denture frame, under biting forces, which forces can easily produce stresses above the yield strength of an alloy deficient in that property, causing the denture to shift out of the proper occlusal relationship to which it was originally designed. Toughness is the ability of an alloy to withstand sudden shocks and blows that stress the alloy beyond its yield point but within its breaking point. It is also the measure of the reserve strength of an alloy in a dental structure such as would be required if the piece were dropped on a tile floor. The "toughness factor" is defined as the product obtained by multiplying the percentage of elongation (as a decimal fraction) by the ultimate tensile strength of the alloy in pounds per square inch. Ultimate tensile strength (U.T.S.) is the greatest unit stress an alloy will stand in tension to the point of breaking. Hardness is the resistance of an alloy to surface penetration, and is a measure of surface wear effects. Extreme hardness is undesirable because of the wear a hard denture causes to opposing teeth in contact therewith.

The physical and mechanical properties of alloys described herein were determined using an Instron Universal Testing Machine and a strain gauge estensometer. The microhardness was determined using a Tukon Microhardness Tester and a Knoop indenter with a 500 gram load. Specimens for microhardness testing were longitudinal sections from test bars polished with conventional metallurgical procedures.

The representative alloys described below were prepared under argon atmosphere using induction type heating units. After melting together the chromium, cobalt and nickel, the measured amount of tantalum was added and blended into the molten alloy. It was observed that the tantalum actually dissolves in the ternary alloy of chromium of Cr-Co-Ni. The alloying temperatures ranged from 2800° F. to 2850° F. The quaternary alloy was remelted under argon for homogenization in the same temperature range, and then cast at 2750 to 2800° F. using a centrifugal induction unit.

Wax patterns were prepared using a modified split brass mold into which molten wax was injected, and the wax patterns were sprued horizontally. The mold supplied the tensile specimen, feeding sprue and venting sprue, all in one piece. The dimensions of the wax patterns to produce tensile specimens were the same as those specified by the American Dental Association Specification No. 14 for dental chromium-cobalt casting alloys. The wax patterns were then invested using a phosphate-bonded investment. The investment was then heated to 1800° F. and heat soaked for one and one-half hours before the castings were made. The constituents of representative alloy compositions are shown in Table 1 below, and the physical properties of these alloys are set forth in Table 2.

TABLE 1

Representative Alloy Compositions, Constituents in Percent by Weight

	Cr	Co	Ni	Ta
Example number:				
A	30	40	30	0
B	29.4	39.2	29.4	2.0
C	28.8	38.4	28.8	3.9
D	28.6	38.1	28.6	4.8
E	28.3	37.7	28.3	5.7
F	27.8	37.0	27.8	7.4
G	27.3	36.3	27.3	9.1
H	26.8	35.7	26.8	10.7
I	26.3	35.1	26.3	12.3
J	26.2	34.9	26.2	12.7
K	26.1	34.8	26.1	13.0
L	26.0	34.6	26.0	13.4
M	25.9	34.5	25.9	13.8
N	25.4	33.9	25.4	15.2

TABLE 2

Physical Properties of Representative Alloys

	Y.S. (0.2%), p.s.i.×10³	U.T.S., p.s.i.×10³	Elongation percent	Hardness, KHN
Example number:				
A	44.0	80.3	31	230
B	48.3	78.0	30.6	228
C	55.0	82.6	28	285
D	56.0	84.0	28.5	285
E	60.0	102.0	28	290
F	60.0	102.0	26.5	310
G	70.0	106.0	21	307
H	74.0	106.5	21	320
I	80	121.0	18	320
J	82.4	122.0	13	325
K	91.0	124.5	10.0	328
L	97.0	127.0	6.5	330
M	99	126.0	5.5	350
N	100	136	4.6	375

NOTE.—Y.S.=Yield strength; U.T.S.=Ultimate tensile strength; KHN=Knoop hardness units.

The foregoing results establish the criticality of the tantalum content of the alloy, as embodied in Examples I, J, K and L. More specifically, there is a marked increase in ultimate tensile strength as the tantalum level increased to 12.3% from lesser amounts. When the upper limit of about 13.5% tantalum concentration is exceeded, however, there is a significant and undesirable increase in hardness coupled with a disadvantageous decrease in elongation.

I claim:

1. An alloy consisting essentially of 18% to 28% chromium, 25% to 50% cobalt, 18% to 40% nickel, and 12.3% to 13.5% tantalum.

2. A denture casting made from the alloy of claim **1**.

3. An alloy in accordance with claim **1** wherein the tantalum is about 13%.

4. An alloy in accordance with claim **1** wherein the chromium is 23% to 26%, the cobalt is 33% to 36%, and the nickel is 24% to 30%.

5. A denture casting made from the alloy of claim **4**.

6. An alloy in accordance with claim **4** where the tantalum is about 13%.

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L. DEWAYNE RUTLEDGE, Primary Examiner

E. L. WEISE, Assistant Examiner

U.S. Cl. X.R.

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