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COLD REDUCED TITANIUM-BASE ALLOY

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ABSTRACT OF THE DISCLOSURE

A titanium-base alloy combining strength, ductility and corrosion resistance is adaptable as wire for stranded marine cable. The alloy essentially contains aluminum, chromium, nickel (the ratio of chromium to nickel being correlated under certain conditions), and the balance essentially titanium.

This invention relates to titanium alloys and, more particularly, to novel titanium-base alloys capable of being cold drawn into fine, high strength, corrosion resistant wire.

Materials suitable for use such as stranded wire for cable, particularly in marine environments, must have high strength, a good strength to weight ratio (in long lengths a good portion of the total stress derives from its own weight), ductility sufficient to withstand severe cold reduction, e.g., drafts totaling at least about 50%, i.e., a reduction in cross-sectional area of at least about 50%, without failure during the wire drawing operation, and good corrosion resistance, notably to sea water (both stagnant and flowing). Moreover, such wire must afford residual ductility of a magnitude sufficient to permit fabrication of stranded cable and to withstand bending, flexure and impact while in service.

Heretofore, plain carbon steels have been used for marine cable but, although strength and ductility are adequate, poor corrosion resistance to marine environments requires that they be protected by sacrifical coatings such, for example, as zinc or aluminum. Consequently, the service life of galvanized or aluminized steels is dependent on the life of the coating. Consideration has been given to conventional stainless steels but susceptibility to chloride stress corrosion cracking and crevice or pitting corrosion have imposed severe limitations. Cladding of stainless steel has been advanced to obviate this drawback but, insofar as I am aware, this proposal has not been found entirely satisfactory. The many attributes of the cupro-nickels would render such materials as likely candidates were it not for their inherent low strength and high density.

It has now been discovered that a new titanium-base alloy containing small but carefully controlled or correlated amounts of alloying elements and having an excellent combination of strength, ductility and corrosion resistance especially in marine environments can be cold drawn into fine wire for use in making stranded cable.

It is an object of the present invention to provide a new titanium-base alloy characterized by a ductility sufficient to permit severe cold reduction without failure during the wire drawing operation.

Another object of the invention is to provide a titanium-base alloy for use as stranded wire cable in marine environments.

Other objects and advantages will become apparent from the following description.

Generally speaking ,the present invention contemplates a titanium-base alloy having good wire drawing properties which contains, by weight percent, about 1.5% to 2.5% aluminum, about 1% to 2.5% chromium, about 0.5% to 2% nickel, provided that when the chromium is less than about 2% the ratio of chromium to nickel is at least about 2:1, and the balance essentially titanium.

In carrying the invention into practice, the aluminum content should not be less than about 1.5%, and preferably not below about 1.8%, e.g., about 2%, in order to maintain adequate strength. If the aluminum content is much above about 2.5% the alloy is not satisfactorily cold drawable. Advantageously, the aluminum content does not exceed 2.2%. At least about 1% chromium, and beneficially at least about 1.5% or 1.8%, e.g., about 2%, should be present in the alloy to confer the desired level of strength, e.g., about 150,000 p.s.i. or above. Chromium should not be present in amounts above about 2.5%, and beneficially not above about 2.2%, in order to avoid problems associated with cold drawing. Although for reasons not completely understood, it has been found that nickel which is present in an amount of at least about 0.5% renders the titanium-aluminum-chromium alloy cold drawable, i.e., capable of undergoing drafts totaling at least about 50% without failure. However, nickel levels above about 2% tend to embrittle the alloy. Consequently, the nickel content is advantageously maintained between about 0.5%, e.g., about 1%, and 1.5%. In further respect of nickel content, if the chromium content of the alloy is less than about 2%, the nickel must be present in controlled amounts, i.e., the chromium and nickel must be further correlated such that the chromium:nickel ratio is at least about 2:1, in order to obtain and maintain good drawing properties. In addition advantageous results are achieved when the ratio of aluminum to chromium is maintained between about 0.8 to 2.0. An excellent combination of properties, including cold drawability and strength, is obtainable with aluminum to chromium ratios between 0.8 to 1.2.

The alloys of this invention when drawn to wire are characterized by ultimate tensile strengths of at least about 150,000 p.s.i., and as high as about 225,000 p.s.i. for fine wire (about 0.010 inch) undergoing cold reductions on the order of about 50%, a good strength to weight ratio, ductility sufficient to be bent around its own diameter several times, and good corrosion resistance especially to sea water.

In conducting a cold drawing operation in accordance herewith it is quite advantageous to employ intermediate annealing treatments. It has been found that the maximum subsequent cold reduction can be achieved if the annealing treatment is carried out between about 1000° F. and 1450° F., e.g., about 1300° F., for about one-quarter hour to two hours, e.g., about one-half hour. Such annealing operations in air are sufficient to form a thin surface layer of titanium oxide. The oxide so formed serves to facilitate the cold drawing operation particularly when molybdenum disulfide is used as a lubricant. Care should be exercised to avoid unnecessary exposure of the alloy to air at annealing temperatures in order to avoid problems associated with the absorption of oxygen.

For the purpose of giving those skilled in the art a better understanding of the invention, there is given herein data illustrative of the markedly improved combination of properties characteristic of the alloys within this invention. In Table I there is presented a series of titanium-base alloy compositions in weight percent with mechanical properties of the cold drawn wire. Alloys 1 to 4 are within the scope of the invention while Alloys A, B, C and D are beyond the compositional scope of the invention and are included for comparative purposes with Alloys 1 to 4.

TABLE I

Alloy	Percent Al	Cr	Ni	Cold reduction during final draw	Final wire diameter (inches)	Y.S. (K s.i.)	U.T.S. (K s.i.)	Elongation (percent)
1	2	1	0.5	(a) 90	0.036	190	208	0.7
1	2	1	0.5	88	0.010	----------	170	----------
2	2	2	0.5	87	0.051	174	190	0.6
2	2	2	0.5	72	0.036	178	198	0.5
2	2	2	0.5	88	0.010	----------	222	----------
3	2	2	1	(a) 87	0.051	180	204	0.3
3	2	2	1	72	0.036	177	199	0.6
4	2	2	2	83	0.058	173	180	0.5
4	2	2	2	56	0.040	----------	151	0.2
4	2	2	2	88	0.010	----------	224	----------
A	2	2	------	22	0.098	----------	----------	----------
B	2	1	------	33	0.084	----------	----------	----------
C	2	1	1	22	0.098	----------	----------	----------
D	2	1	2	(b)	0.125	----------	----------	----------

[a] Maximum cold reduction during final draw without failure.
[b] Alloy not drawable.

All alloys were arc melted under a reduced pressure of about 20 inches of argon using a thoria doped tungsten electrode and then cast into ingots. The ingots were hot forged in the beta field at 1700° F. to 1800° F., hot swaged to about 0.2 inch diameter rod in the alpha-beta field at 1500° F. to 1600° F., cold rolled to about 0.125 inch square, annealed at about 1300° F. for about one-half hour, and then cold swaged to about 0.125 inch round.

In Table I there is also included data showing the amenability to, and the effect of, cold drawing. Alloys 1 to 4 were cold drawn from 0.125 inch round rod to wire using molybdenum disulfide and the oxide film formed during annealing as lubricants. The rods were reduced to the wire sizes shown in Table I in several draws followed by an annealing treatment at about 1300° F. for about one-half hour after substantial amounts of cold reduction. Alloys A, B and C could only be drawn to the wire diameters indicated in Table I without failure. Alloy D failed during the initial draw. The mechanical property measurements shown in Table I were made on the as-drawn wire.

The data shown in Table I indicate that small amounts of nickel, i.e., up to about 2%, render the titanium-base alloys of this invention drawable. In this regard, the alloys of this invention can be cold drawn at least 50% and upwards to 90% and can be cold drawn to wire of 0.010 inch diameter and smaller. In addition, each of the alloys of the invention when drawn to wire possesses sufficient ductility to be bent around its own diameter at least five times.

Nickel-free Alloy A (also nickel-free Alloy B) has poor drawing properties. Alloys 2, 3 and 4 have compositions otherwise identical to Alloy A except that they contain nickel additions of 0.5%, 1% or 2% which greatly improve their drawing properties. Alloys C and D have less than 2% chromium and illustrate the poor drawing properties resulting when the alloy contains uncorrelated amounts of chromium to nickel of 1:1 (Alloy C) and 1:2 (Alloy D) whereas, in accordance with this invention, the ratio should be at least about 2:1 with chromium contents less than 2%. Alloy 1, although containing less than 2% chromium, illustrates the markedly enhanced properties resulting from proper correlation of chromium to nickel.

The alloys of the present invention display excellent corrosion resistance, especially to sea water, and are suitable for a wide variety of applications. These alloys are particularly adaptable for drawing into fine wire from which stranded marine wire cable can be made.

The alloys of this invention can be commercially prepared and processed into wire by conventional techniques.

As will be readily understood by those skilled in the art, the term, "balance," when used to indicate the amount of titanium in the alloy, does not exclude the presence of other incidental elements or impurities which do not ordinarily affect the basic characteristics of the alloys. Elements deleterious to the ductility of titanium-base alloys, e.g., oxygen, nitrogen and hydrogen should be kept as low as possible.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

What is claimed is:

1. A cold reduced titanium-base alloy having been cold reduced at least about 50%, and characterized in the cold reduced state by an ultimate tensile strength of at least about 150,000 p.s.i., said alloy consisting of about 1.5% to 2.5% aluminum, about 1% to 2.5% chromium, about 0.5% to about 2% nickel and the balance essentially titanium, provided that when the chromium content is less than about 2%, the chromium:nickel ratio is at least about 2:1.

2. A titanium-base alloy in accordance with claim **1** wherein the aluminum is about 1.5% to 2.2%, the chromium is about 1.8% to 2.2% and the nickel is about 0.5% to 1.5%.

3. A titanium-base alloy in accordance with claim **1** wherein the aluminum is about 1.8% to 2.2%, the chromium is about 1.8% to 2.2% and the nickel is about 1% to 1.5%.

4. A titanium-base alloy in accordance with claim **3** wherein the ratio of alumnium to chromium is about 0.8 to 2.0.

5. A titanium-base alloy in accordance with claim **3** wherein the ratio of aluminum to chromium is about 0.8 to 1.2.

6. A titanium-base alloy wire in accordance with claim **1.**

7. A titanium-base alloy wire in accordance with claim **2.**

8. A titanium-base alloy wire in accordance with claim **4.**

9. A stranded marine cable comprised of a titanium-base alloy wire in accordance with claim **6.**

10. A titanium-base alloy wire in accordance with claim **6** wherein the aluminum is about 2%, the chromium is about 2% and the nickel is about 0.5%.

11. A titanium-base alloy wire in accordance with claim **6** wherein the aluminum is about 2%, the chromium is about 2% and the nickel is about 2%.

12. A titanium-base alloy wire in accordance with claim

6 wherein the aluminum is about 2%, the chromium is about 2% and the nickel is about 1%.

13. A process for improving the cold drawing properties of a titanium-base alloy containing about 1.5% to 2.5% aluminum, about 1% to 2.5% chromium, about 0.5% to about 2% nickel, provided that when the chromium content is less than about 2%, the chromium:nickel ratio is at least about 2:1, and the balance essentially titanium which comprises annealing in the temperature range of about 1000° F. to 1450° F. for about one-quarter hour to about two hours to permit a maximum degree of cold reduction and thereafter cold drawing the alloy at least about 50% to produce a wire product.

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