

UNITED STATES PATENT OFFICE

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CHROMIUM-NICKEL TITANIUM BASE ALLOYS

Schuyler A. Herres, Albany, and Thomas K. Redden, Cohoes, N. Y., assignors to Allegheny Ludlum Steel Corporation, a corporation of Pennsylvania

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This invention pertains to a new and improved type of titanium-base alloy containing chromium and nickel in combination and to heat-conditioning treatment therefore. An important phase of the invention relates to the provision of a titanium-base alloy having an improved crystal structure.

Although the use of nickel and chromium in iron-base alloys is common, they have not heretofore been successfully employed in titanium-base alloys. We have been able to produce an alloy suitable for many uses employing chromium and nickel in proportioned amounts with titanium as the base metal. Oxygen and nitrogen in combination provide additional alloying elements. A superior titanium-base metal alloy results.

It has thus been an object of our invention to provide a new and improved form of titanium base alloy;

Another object has been to successfully devise a chromium-nickel titanium base alloy which will meet the need of the industry for an alloy having a moderate tensile strength, an excellent corrosion resistance, a good hardness and a relatively high elongation;

Another object has been to produce a titanium-base alloy with improved strength in service at temperatures of 700°-1000° F.;

These and many other objects of our invention will appear to those skilled in the art from the illustrated embodiments thereof.

An alloy of the type here involved can be produced by a commercial method of production such as disclosed in Herres application, Serial Nos. 109,885, 115,454, or 122,717. Where a reducing material or a gas is used in connection with the melting operation, chromium or nickel oxides can be used.

The alloys of our present invention, in their broader aspect, contain elements within the following representative ranges:

Table I

	Per cent
Oxygen	.02- .40
Nitrogen	.02- .25
Nickel	1.0 - 5.0
Chromium	10.0 -18.0
The remainder titanium.	

The preferred ratio of chromium to nickel is at least 2 to 1, and for best results, about 6 to 1.

Within the ranges of Table I a preferred alloy has the following composition: (1) oxygen about .10%, nitrogen about .05%, chromium about 15.0%, nickel about 2.5%, and the remainder sub-

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stantially all titanium. When hot-forged and annealed, it has a BHN hardness of 315, a tensile strength of 162,400, a relatively high yield strength, and an elongation of 18%.

Our investigations indicate that nickel promotes retention of the beta or body-centered cubic crystal structure of titanium when used in combination with chromium. Nickel also forms intermetallic compounds with the titanium which in certain proportions and with suitable heat treatment, has a strengthening effect on both hexagonal, closely packed and body-centered cubic crystal structures of titanium. When used without chromium, nickel (with oxygen and nitrogen as indicated in Table I) does not appear to be a very effective addition as shown by the following:

Table II

Alloy Addition, Percent	Hardness, BHN	Tensile Str., p. s. i.	Yield Str., p. s. i.	Elong., Percent
None	160	70,000	60,000	30
1% Ni	190	87,300	76,000	15
2.5% Ni	197	92,500	71,000	10
7.5% Ni	250	100,000	84,500	1

However, when nickel is used with chromium in accordance with Table I (see also, example (1)), it appears highly beneficial. The alloy of example (1) may be compared with an alloy of the same element composition, but having no nickel; in such case, the BHN hardness is 311, the tensile strength is 152,000 and the elongation is 13%.

The alloys of Table I have the basic characteristic of retaining the body-centered cubic structure on being cooled at a rate that may be less, the lower the total content of chromium and nickel. Controlled oxygen and nitrogen additions are effective in bringing about a further increase in strength of the alloys by solution hardening and precipitation hardening mechanisms.

Alloys of our present invention may be employed in various conditions of heat treatment depending upon the specific properties desired. On heating to a temperature above about 1600° F. and cooling at a relatively rapid rate, depending upon the amount of chromium and nickel, the high-temperature, body-centered cubic lattice structure of titanium is stabilized and retained at room temperature. This produces a softer and more ductile metal than if the same alloy is allowed to transform to its normal hexagonal, close-packed, lattice structure. If the total content of nickel and chromium is in the lower part

of the ranges shown in Table I, very rapid cooling as by water quenching is required to retain the body-centered cubic structure which is a characteristic of pure titanium metal only at temperatures above 1625° F. The same effect may be obtained by a more moderate cooling rate such as air cooling, when the chromium and nickel contents are higher, for example 15% chromium and 2½% nickel. For alloys within the middle and upper part of the composition range given in Table I, hot working within a temperature range of 1700°-1900° F. followed by cooling in air, produces desirable properties for most structural uses. The subsequent anneal or solution treatment has also been used to obtain uniformity of properties. This is accomplished by reheating to a temperature within the range of about 1600°-1850° F. and cooling at a moderate rate. When desired a very high hardness may be obtained in alloys within the lower part of the composition range shown in Table I by cooling at a sufficiently slow rate to allow partial or complete transformation in the temperature range of 1200°-1500° F.

These alloys in the solution-treated condition may be hardened, followed by moderately rapid cooling from a temperature above about 1200° F., by aging or precipitation hardening on reheating and holding for various periods in the temperature range of 700° to 1200° F. The time of holding is less, the higher the aging temperature in this range and the effect is reversible so that the alloy may again be softened by reheating to a higher temperature. The alloys may also be hardened by cold working, i. e., a mechanical reduction in cross-sectional area at temperatures below 1200° F., and may be softened again by heating to temperatures above 1200° F. and holding for various periods. The temperature and time for softening depends upon the degree of cold work accomplished.

The alloys may be surface hardened by heating in air, or in atmospheres, mixtures, or fused baths which provide nitrogen or oxygen to combine with the titanium-base metal. For example, an alloy heated in the presence of oxygen for one hour at 1900° F. will be hardened for a depth of about .05 inches below the surface, with a maximum surface hardness of 400 Brinell. Somewhat similar surface hardening effects are produced by heating the alloy in nitrogen-rich atmospheres, such as one containing ammonia gas at temperatures as low as 950° F., the depth and degree of hardness produced is controlled by the time and temperature of exposure as well as the composition of the atmosphere or bath used.

What we claim is:

1. A heat-treatable titanium-base alloy consisting of about .02 to .40% oxygen, about .02 to .25% nitrogen, about 1 to 5% nickel, about 10 to 18% chromium, and the remainder titanium.

2. A heat-treatable titanium-base alloy characterized by its improved strength at service temperatures of about 700° to 1000° F., its good hardness without brittleness, and its basic characteristic of retaining a body-centered cubic structure on being cooled from an elevated temperature above about 1200° F., in which oxygen, nitrogen, nickel and chromium are critical within the ranges specified, which contains about .02 to .40% oxygen, about .02 to .25% nitrogen, about 1 to 5% nickel, about 10 to 18% chromium, and the remainder titanium.

3. A heat-treatable titanium-base alloy which contains about .10% oxygen, about .05% nitrogen, about 2.5% nickel, about 15% chromium, and the remainder titanium; the alloy being characterized by a BHN hardness of about 315, a tensile strength of about 162,400, an elongation of about 18%, and an improved strength in service at temperatures of about 700° to 1000° F.

SCHUYLER A. HERRES.
THOMAS K. REDDEN.

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