

Dec. 1, 1953

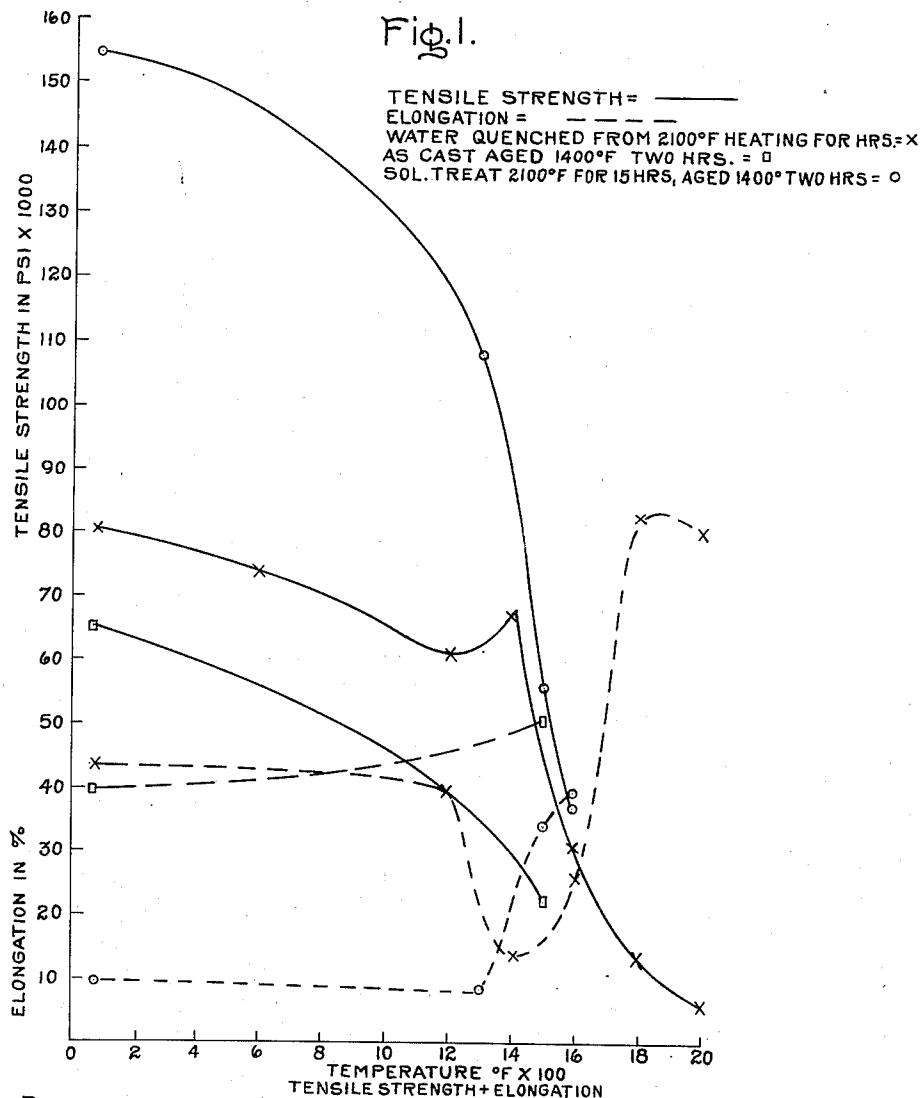
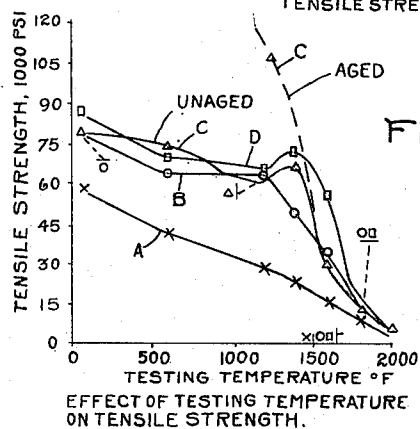
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2,661,284

PRECIPITATION HARDENABLE IRON BASE ALLOY

Filed June 27, 1951

2 Sheets-Sheet 1



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PRECIPITATION HARDENABLE IRON BASE ALLOY

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2 Sheets-Sheet 2

Fig. 3.

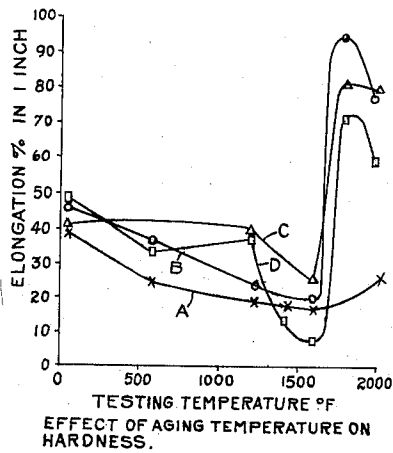


Fig. 4.

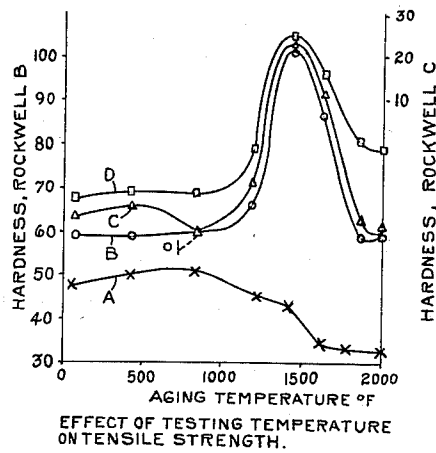
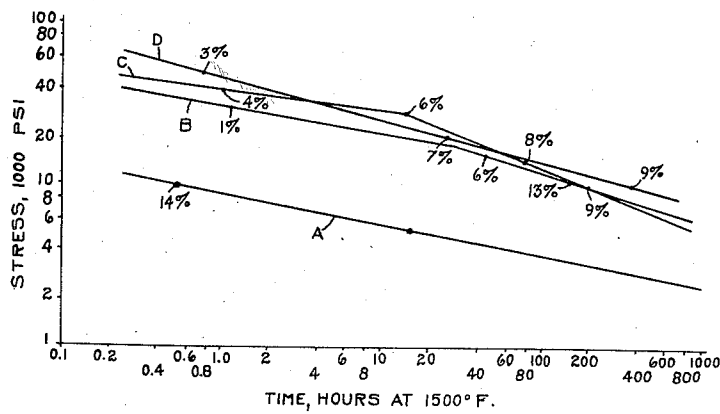


Fig. 5.



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UNITED STATES PATENT OFFICE

2,661,284

PRECIPITATION HARDENABLE IRON
BASE ALLOYJames D. Nisbet, Schenectady, N. Y., assignor to
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Application June 27, 1951, Serial No. 233,842

3 Claims. (Cl. 75—128)

1

The present invention relates to a precipitation hardenable iron base alloy. It is particularly concerned with an iron base alloy containing chromium, nickel, titanium and carbon as essential alloying ingredients, the alloy being further characterized by a substantial freedom from combined and uncombined oxygen and nitrogen.

A primary object of the invention is to provide an iron base alloy which can be solution heat-treated to a soft machinable condition and which can be precipitation hardened by suitable aging treatment.

Additional objects of the invention will become apparent from the following description thereof when taken in connection with the accompanying drawing in which the various figures are plots illustrating the unusual characteristics of the alloy.

In general, the alloy of the present invention will consist essentially of from 15 to 25% by weight chromium, 25 to 35% by weight nickel, 2.4 to 6% titanium, 0.05 to 0.75% carbon, balance iron. A preferred alloy is one containing from 15 to 20% chromium, 29 to 33% nickel, 2.5 to 3.5% titanium, 0.05 to 0.15% carbon, balance iron. Optimum properties have been obtained in an alloy consisting essentially of about 17.5% chromium, 31% nickel, 2.5% titanium, 0.1% carbon, balance iron. All of the alloys of the present invention are characterized by the substantial freedom from oxygen or nitrogen in either the free or combined state, that is, the alloys contain only traces of these two elements in amounts totaling not more than 0.02%. The usual scavenger elements or deoxidizing elements, such as manganese and silicon, are not present except as they may constitute impurities in the essential ingredients of the alloy.

As will be shown by the data given hereinafter, these novel alloys are particularly useful for high temperature applications, as, for example, gas turbine buckets, or other parts for gas turbines, or valves for internal combustion engines. They possess good corrosion resistance and hence can be used as valves, pipe material, etc. in chemical plant equipment where a hardened, stainless or corrosion-resistant material is required to withstand temperatures up to about 1500° F. Lower temperature applications include dairy and laundry equipment, railroad equipment, cutlery and plumbing equipment or similar uses which require a hardenable stainless alloy.

In manufacturing the alloys care should be taken to keep the oxygen and nitrogen impurity content of the alloys below the specified amount.

2

A suitable process is that described in my co-pending application, Serial No. 112,558, filed August 25, 1949, now Patent 2,564,498, assigned to the same assignee as the present invention.

Briefly described, this process comprises the use of a vacuum melting furnace in which the base alloy of iron, chromium and nickel is melted in a vacuum after which the melt is purged with hydrogen to remove, by reduction, the oxides present in the melt. The titanium and carbon are then added to the melt and the alloy is cast in the vacuum.

As a specific example of how the present invention can be carried into effect, a mixture of 17.5 parts by weight chromium, 31 parts nickel and 50 parts iron are melted together in a vacuum chamber with pressure in the chamber reduced to less than 1 mm. This melting may be accomplished by induction heating. After the charge has melted, the chamber pressure is reduced to about 10 microns for the removal of most of the oxygen, nitrogen and carbon monoxide present in the melt. Thereafter, pure dry hydrogen is bubbled into the melt or introduced into the chamber above the melt while maintaining the chamber pressure below about 40 mm. The hydrogen serves to reduce the metal oxides present in the melt. At the end of the hydrogen treatment the oxygen and nitrogen contents combined are usually less than about 0.004%. Thereafter, there are added to the melt sufficient titanium and carbon to provide in the final alloy about 2.5% titanium and 0.1% carbon. The flow of hydrogen is discontinued and at a pressure less than about 10 microns any carbon monoxide formed by reaction of the carbon with residual oxygen is removed from the melt after which the melt is cast at this reduced pressure.

The presence of large quantities of reactive elements such as titanium and chromium, through gettering action and crucible reaction, tend to increase the oxygen and nitrogen contents in the final alloy containing these elements. The final oxygen and nitrogen content can consistently be maintained at values less than 0.02% if these alloys are manufactured by the above described process. Control of the oxidation and nitridation of the reactive titanium and chromium, for example, in air-melted alloys is impractical.

The results obtained by subjecting the cast product to various heat treatments are plotted in Fig. 1 of the accompanying drawing in which the various curves illustrate the tensile strength

and elongation characteristics of the alloy as heat-treated in various ways. The tests plotted in Fig. 1 were made over a temperature range from room temperature to 2000° F. The alloy possesses good elongation characteristics in the cast and aged condition as well as in the solution-treated and water-quenched condition showing that the alloy is rollable and drawable at ordinary temperatures. For maximum tensile strength characteristics, both at room and elevated temperatures up to around 1200° F. to 1500° F., the alloy is preferably solution-treated at a temperature of around 2100° F., water-quenched and thereafter precipitation hardened at an aging temperature of around 1400° F.

The results plotted in Fig. 1 also show the relatively high elongation and low tensile strength of the alloy at about 2000 to 2300° F. which makes the alloy shapable by forging at such temperatures. After forging, the alloy can be precipitation hardened at temperatures from 1300 to 1600° F. for two hours or more, one of the more remarkable properties of this alloy being the great increase in strength and hardness which can be obtained by such treatment. The alloy also possesses good corrosion resistance particularly in the precipitation-hardened state.

Figs. 2 to 5, inclusive, are plots of the tensile strength, elongation, hardness and rupture strength characteristics of a series of similar alloys including the alloys of the present invention. These alloys include alloy A consisting of 17.5% chromium, 31% nickel, balance iron and alloy B containing 17.5% chromium, 31% nickel, 0.1% carbon and 1.4% titanium, which alloys are to be compared with alloys C and D which are within the scope of the present invention. Alloys C and D differed respectively from alloy B in containing respectively 2.5 and 4.1% titanium instead of the 1.4% titanium in alloy B. With reference to Figs. 2 to 4, inclusive, it will be seen that a substantial increase in tensile strength and hardness and a decrease in elongation at elevated temperatures is obtained by the additions of the designated quantities of carbon and titanium to the base alloy A. The best high temperature characteristics in the neighborhood of 1500° F. are obtained when the alloy contains at least 2.5% titanium in addition to the 0.1% carbon. All of the alloys containing both carbon and titanium show exceptionally good hardness at elevated temperatures in the neighborhood of 1500° F. The alloys of Fig. 2 were all prepared by the vacuum casting technique described hereinbefore and were thereafter solution heat-treated at 2100° F. for 15 hours and water-quenched. Elongation tests

plotted in Fig. 3 are for the same alloys. The hardness values plotted in Fig. 4 are for samples of the materials aged at the indicated temperatures. The aging treatment was for two hours followed by air cooling.

Fig. 5 is a plot of the long time stress-rupture characteristics of the alloys A, B, C and D in the solution-treated and water-quenched (but unaged) condition. These test results further indicate the improved high temperature properties of the present alloys. In this figure the per cent elongation at rupture is shown for each rupture point.

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

1. An alloy consisting essentially by weight of 15 to 25% chromium, 25 to 35% nickel, 2.4 to 6% titanium, 0.05 to 0.75% carbon, balance iron, said alloy being free of oxygen and nitrogen in the combined or free state in amounts exceeding the total of 0.02%, characterized by having a 1500° F. stress rupture life of more than 100 hours at 15,000 p. s. i. stress as contrasted with a 1500° F. stress rupture life of less than 25 hours for the same alloy containing more than a total of 0.02 per cent of oxygen and nitrogen in the free or combined state.

2. An alloy consisting essentially, by weight, of 15 to 25% chromium, 25 to 35% nickel, 2.5 to 3.5% titanium, 0.05 to 0.15% carbon, balance iron, oxygen and nitrogen contents of said alloy totaling less than 0.02%, characterized by having a 1500° F. stress rupture life of more than 100 hours at 15,000 p. s. i. stress as contrasted with a 1500° F. stress rupture life of less than 25 hours for the same alloy containing more than a total of 0.02 per cent of oxygen and nitrogen in the free or combined state.

3. An alloy consisting essentially, by weight, of about 17.5% chromium, 31% nickel, 2.5% titanium, 0.1% carbon, balance iron, said alloy containing less than 0.02% combined or free oxygen and nitrogen, characterized by having a 1500° F. stress rupture life of more than 100 hours at 15,000 p. s. i. stress as contrasted with a 1500° F. stress rupture life of less than 25 hours for the same alloy containing more than a total of 0.02 per cent of oxygen and nitrogen in the free or combined state.

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Number	Name	Date
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2,564,498	Nisbet -----	Aug. 14, 1951