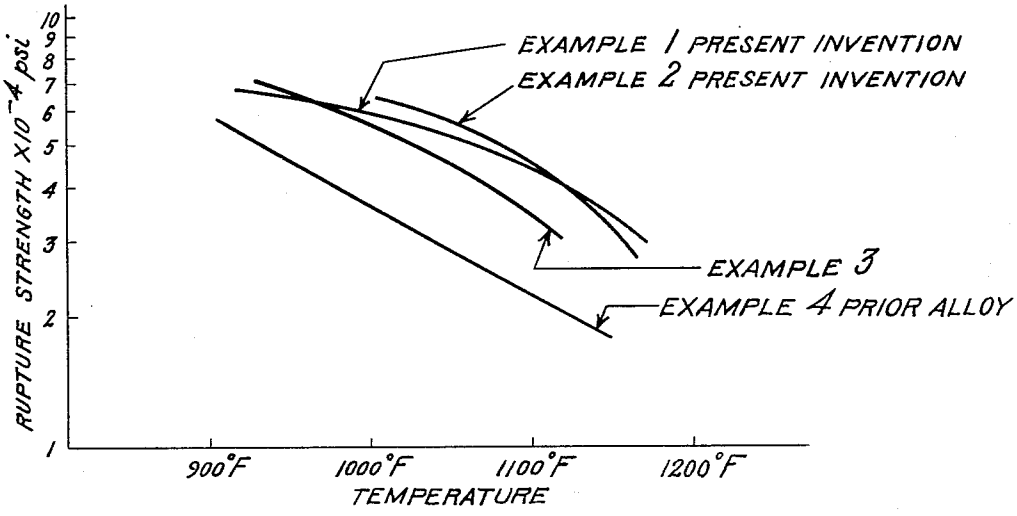
Aug. 1, 1961 R. F. GILL ET AL 2,994,605

HIGH TEMPERATURE ALLOYS

Filed March 30, 1959




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United States Patent Office

2,994,605

Patented Aug. 1, 1961



2,994,605

# HIGH TEMPERATURE ALLOYS

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Filed Mar. 30, 1959, Ser. No. 802,783

6 Claims. (Cl. 75—171)

This invention relates to high temperature alloys for use at temperatures of over 1000° F. and to a process for improving the characteristics of such alloys. More particularly, it relates to alloys which have desirable high temperature, tensile, yield and creep-rupture strengths, and high creep-rupture ductilities, which are structurally stable and have low embrittlement in service, are readily fabricated by welding, are resistant to steam corrosion and have a coefficient of thermal expansion which will match that of ferritic materials.

The family of alloys containing 40 to 80 percent nickel, 10 to 25 percent chromium, balance—iron, is well known. Also known is the improvement of the creep-rupture strength of such alloys by the addition of combinations of columbium (niobium) and titanium and aluminum to produce an age hardening reaction which requires a two-step heat treatment such as a high temperature treatment to dissolve the titanium bearing constituents followed by a lower temperature treatment to reprecipitate the titanium containing component in a controlled manner to achieve high strengths. Alloys so constituted and treated have high tensile, yield and creep-rupture strengths and low creep-rupture ductilities. Omission of the titanium and aluminum results in improved creep-rupture ductility but substantially lowered tensile, yield, and creep-rupture strengths. Table I below shows the rupture stress at 1100° F. and 100,000 hours and the creep-rupture ductility in 1,000 hours at 1100° F. for three alloys of the above family.

*Table I*

| Percent Composition | Rupture Stress (p.s.i.), 100,000 Hrs., 1,100° F. | Creep-Rupture Ductility, percent |
|---|---|---|
| 16 Cr, 7 Fe, 77 Ni | 15,000 | 50 |
| 16 Cr, 8 Fe, 72 Ni, 2.4 Cb | 23,000 | 50 |
| 15 Cr, 7 Fe, 73 Ni, 2.4 Ti, 0.6 Al, 1 Cb | 55,000 | 5 |

The first of the above alloys was heat treated for one hour at 1800° F. and air-cooled and the second alloy was heated at 2050° F. for one hour and air-cooled. The third alloy was heated at 2100° F. for from two to four hours, water quenched and then aged for 24 hours at 1550° F. and for 20 hours at 1300° F.

While the above alloys have suitable properties for some purposes, it is desirable in many applications such as in steam turbine partitions or nozzles to provide creep-rupture strength of the order of 43,000 p.s.i. along with a creep-rupture ductility of at least 10 percent so that lighter structural members can be used with not only a saving of material, but increased efficiency as where the alloy is to be used in steam turbine partitions and similar applications. The relatively complex heat treatment required to produce the characteristics of the above alloys is also time consuming and costly and where the alloys are to be fabricated by welding and require a stress relief heat treatment, the properties developed by the solution treating and aging cycle are often destroyed in the process.

From the above it will be evident that there is a definite need for alloys of the above general type which will have desirable high temperature characteristics which can be developed by a simple heat treatment and which



will not be degraded by subsequent treatment such as by welding or by stress relief heat treatments during fabrication. A principal object, therefore, of the invention is to provide such alloys.

Briefly, the invention comprises alloys for high temperature service which are readily and simply heat treated, have high tensile and yield strength, high creep-rupture strength and high creep-rupture ductility. Furthermore, the alloys are readily malleable and are stress relief annealed without destruction of their desirable physical properties, low tendency toward embrittlement, resistance to corrosion and a thermal coefficient of expansion which will closely match that of ferritic materials. The alloys have the following percent by weight composition:

| | Range (Percent) | Specific Examples (Percent) | |
|---|---|---|---|
| | | 1 | 2 |
| Nickel | 40–80 | 69.5 | 49.86 |
| Chromium | 10–25 | 14.05 | 14.63 |
| Columbium and/or Tantalum | 0.25–5.0 | 1.9 | 1.97 |
| Molybdenum and/or Tungsten | 0.5–8.0 | 2.75 | 3.22 |
| | 0.5–8.0 | 3.42 | 3.27 |
| Titanium | 0.75 max. | 0.024 | .093 |
| Aluminum | 0.25–3.0 | 0.88 | 1.19 |
| Manganese | 2.0 max. | 0.35 | 0.30 |
| Silicon | 2.0 max. | 0.72 | 0.51 |
| Carbon | 0.2 max. | 0.03 | 0.035 |
| Iron | remainder | remainder | remainder |

The alloys are annealed at 1920° F. for about one-half hour and air cooled. A typical annealing temperature range for such alloys is from 1600° F. to 2100° F. at times varying from about one-half hour to one hour per inch thickness of the piece.

Those features of the invention which are believed to be patentable are set forth specifically in the claims appended hereto. The invention will, however, be better understood and further objects and advantages thereof revealed from a consideration of the following description and the drawing in which the single figure is a plot showing the improved high temperature creep-rupture strength of the present alloys.

The alloys of the invention are prepared by melting in any usual manner the prescribed constituents under an inert gas such as argon, krypton, etc. under vacuum or in air, small amounts of titanium and magnesium being added, typically in the amount of the order of 0.2 percent each and boron typically in the amount of 0.005 percent for deoxidation and desulfurization. The ingots as cast were about 4 inches by 4 inches by 11 inches and were swaged at 1900° F. to 2100° F. to round bars one-half to three-quarters of an inch in diameter.

Shown in Table II below are indicated room temperature properties of various alloys. The present preferred alloys are designated Examples 1 and 2. Example 3 is essentially the same as Example 1 except that the aluminum was omitted and Example 4 is a prior art alloy having 72 percent nickel, 16 percent chromium, 8 percent iron, 0.14 percent titanium, 0.17 percent manganese, 0.36 percent silicon, 0.04 percent carbon and 2.4 percent columbium.

*Table II*

| Alloy | Tensile Strength (p.s.i.) | Yield Strength | | Percent Elongation | Percent Reduction in Area |
|---|---|---|---|---|---|
| | | 0.2% O.S. | 0.02% O.S. | | |
| Ex. 1 | 115,000 | 46,750 | 41,250 | 53 | 56 |
| Ex. 2 | 101,500 | 38,000 | 31,000 | 55 | 65 |
| Ex. 3 | 111,500 | 44,000 | 38,500 | 51 | 59 |
| Ex. 4 | 99,500 | 40,500 | 32,500 | 52 | 65 |

Shown in the drawing are the rupture strengths of the alloys of the above examples after 100,000 hours at various temperatures. It will be noted that at 1100° F. the present preferred alloys have creep-rupture strengths of 43,000 to 45,000 p.s.i. whereas the alloy of Example 3 which is substantially the same except for the absence of aluminum has a corresponding value of only about 34,000 p.s.i. A typical prior art alloy (Example 4) containing columbium and titanium among its constituents has a creep-rupture strength under the same conditions of only about 23,000 p.s.i.

Not only is the creep-rupture strength of the present alloys much improved but the creep-rupture ductility is an efficacious 10 percent. Steam turbine partitions and other parts made of the present alloy which is simply annealed as described are readily welded without loss of desirable physical characteristics. Furthermore, their relatively low thermal coefficient of expansion permits the making of fabricated or welded structures using such alloys in composition with ferritic alloys which have a similar thermal coefficient of expansion. The present alloys further resist any tendency toward embrittlement which is commonly present in alloys of similar strength in high temperature service.

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

1. An alloy for high temperature service consisting essentially of, by weight, from about 40 to 80 percent nickel, about 10 to 25 percent chromium, about 0.25 to 5 percent of a material selected from the group consisting of columbium and tantalum and mixtures thereof, about 0.5 to 8 percent of a material selected from the group consisting of molybdenum, tungsten and mixtures thereof, a maximum of about 0.75 percent titanium, about 0.25 to 3.0 percent aluminum, a maximum of about 2.0 percent manganese, a maximum of about 2.0 percent silicon, a maximum of about 0.2 percent carbon, with the remainder iron.

2. An alloy for high temperature service consisting essentially of, by weight, about 69.5 percent nickel, about 14.05 percent chromium, about 1.9 percent of a material selected from the group consisting of columbium and tantalum and mixtures thereof, about 2.75 percent molybdenum, about 3.42 percent tungsten, about 0.024 percent titanium, about 0.88 percent aluminum, about 0.35 percent manganese, about 0.72 percent silicon, about 0.03 percent carbon, with the remainder iron.

3. An alloy for high temperature service consisting essentially of, by weight, about 49.86 percent nickel, about 14.63 percent chromium, about 1.97 percent of a material selected from the group consisting of columbium and tantalum and mixtures thereof, about 3.22 percent molybdenum, about 3.27 percent tungsten, about 0.093 percent titanium, about 1.19 percent aluminum, about 0.30 percent manganese, about 0.51 percent silicon, about 0.035 percent carbon, with the remainder iron.



4. An alloy for high temperature service consisting essentially of, by weight, from about 40 to 80 percent nickel, about 10 to 25 percent chromium, about 0.25 to 5 percent of a material selected from the group consisting of columbium and tantalum and mixtures thereof, from about 0.5 to 8 percent of a material selected from the group consisting of molybdenum, tungsten and mixtures thereof, a maximum of about 0.75 percent titanium, about 0.25 to 3.0 percent aluminum, a maximum of about 2.0 percent manganese, a maximum of about 2.0 percent silicon, a maximum of about 0.2 percent carbon, with the remainder iron, said alloy being capable of being heat treated, in a one-step process, at temperatures of from about 1600° F. to about 2100° F.

5. An alloy for high temperature service consisting essentially of, by weight, about 69.5 percent nickel, about 14.05 percent chromium, about 1.9 percent of a material selected from the group consisting of columbium and tantalum and mixtures thereof, about 2.75 percent molybdenum, about 3.42 percent tungsten, about 0.024 percent titanium, about 0.88 percent aluminum, about 0.35 percent manganese, about 0.72 percent silicon, about 0.03 percent carbon, with the remainder iron, said alloy being annealed at about 1920° F. for from about one-half hour to one hour per inch of thickness.

6. An alloy for high temperature service consisting essentially of, by weight, about 49.86 percent nickel, about 14.63 percent chromium, about 1.97 percent of a material selected from the group consisting of columbium and tantalum and mixtures thereof, about 3.22 percent molybdenum, about 3.27 percent tungsten, about 0.093 percent titanium, about 1.19 percent aluminum, about 0.30 percent manganese, about 0.51 percent silicon, about 0.035 percent carbon, with the remainder iron, said alloy being annealed at about 1920° F. for from about one-half hour to one hour per inch of thickness.

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