(NASA-Case-MFS-26200-1-SB)
HYDROGEN RESISTANT ALLOY - NASA 23
Patent Application (NASA. Marshall
Space Flight Center) 9 p

N95-20068

Unclas

G3/26 0039789

(6)

P. 9

NASA CASE NO. MFS-26200-1

PRINT FIG. None

NOTICE

The invention disclosed in this document resulted from research in aeronautical and space activities performed under programs of the National Aeronautics and Space Administration. The invention is owned by NASA and is, therefore, available for licensing in accordance with the NASA Patent Licensing Regulation (14 Code of Federal Regulations 1245.2).

To encourage commercial utilization of NASA-owned inventions, it is NASA policy to grant licenses to commercial concerns. Although NASA encourages nonexclusive licensing to promote competition and achieve the widest possible utilization, NASA will consider the granting of a limited exclusive license, pursuant to the NASA Patent Licensing Regulations, when such a license will provide the necessary incentive to the licensee to achieve early practical application of the invention.

Address inquiries and all applications for license for this invention to NASA/Marshall Space Flight Center, Patent Counsel, Mail Code CC01, Marshall Space Flight Center, AL 35812. Approved NASA forms for application for nonexclusive or exclusive license are available from the above address.

Serial Number 08/248,611
Filing Date May 10, 1994
NASA/MSFC

TECHNICAL ABSTRACT NASA CASE NO. MFS-26200-1

Hydrogen Resistant Alloy - NASA 23

A high-strength metal alloy that resists hydrogen embrittlement consisting essentially of thirty-seven (37) percent by weight of iron, thirty-two (32) percent by weight of nickel, fifteen (15) percent by weight of cobalt, ten (10) percent by weight of chromium, three (3) percent by weight of niobium, two-and-one-half (2.5) percent by weight titanium, fifteen hundredths (0.15) percent by weight of aluminum, and an amount of carbon that does not exceed four hundredths (0.04) percent by weight.

Inventors: William B. McPherson, NASA/MSFC
A. K. Kuruvilla, IIT Research Institute

Date Filed: 5/10/94

Serial Number: 08/248,611

Serial No. 08/248,611
Date Filed: May 10, 1994

NASA Case No. MFS-26200-1-SB PATENT APPLICATION

HYDROGEN RESISTANT ALLOY - NASA 23

Origin of the Invention: The invention described in this patent was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties.

BACKGROUND OF THE INVENTION

Field of the Invention: The invention pertains to high-strength metal alloys. Specifically, the invention pertains to a high-strength metal alloy that is resistant to a hydrogen environment.

Background Information: Size and weight limitations dictate that rocket engine components be made from high-strength metal alloys. In addition, if a mixture of hydrogen and oxygen is used as rocket fuel, rocket engine components need to be resistant to an environment of high-pressure hydrogen since such an environment can cause many alloys to embrittle with a resulting reduction in ductility, fracture toughness, service life, and safety margins. To avoid embrittlement from hydrogen, engine components are commonly coated with hydrogen barrier coatings (i.e., coatings that are not affected by hydrogen) such as gold or copper. However, such protective coatings are not always practical because of cost, time, and adhesion problems. Thus, there is a great need for a high-strength metal alloy that is naturally resistant to hydrogen under pressure.

In response to this need, the National Aeronautics and Space Administration (NASA) undertook a development effort to produce a high-strength alloy that was resistant to hydrogen. The progress of this development effort was presented at the AIAA/ASME/SAE/ASEE 22nd Joint Propulsion Conference on June 16-18, 1986, in Huntsville, Alabama, in the form of a paper published by the American Institute of Aeronautics and Astronautics (AIAA) entitled "A New High Strength Alloy for Hydrogen Fueled Propulsion Systems" by W. B. McPherson (AIAA-86-1478). At that time, NASA believed the most promising alloy composition was "37% Fe, 32% Ni, 15% Co, 10% Cr, 3% Cb, 2 to 3% Ti and 0.5 to 1% Al" and that increasing the amount of aluminum in the alloy would achieve some desirable results. See McPherson, AIAA-86-1478, page 4.

Subsequent development effort, however, revealed that the aluminum content was not only high, but was excessive by a factor of five (5). In other words, the alloy which proved to be most effective against high-pressure hydrogen contained only 0.1 to 0.2 percent by weight of aluminum.

SUMMARY OF THE INVENTION

The invention is a high-strength metal alloy that resists hydrogen embrittlement consisting essentially of thirty-five (35) to thirty-nine (39) percent by weight of iron, thirty (30) to thirty-four (34) percent by weight of nickel, fourteen (14) to sixteen (16) percent by weight of cobalt, nine (9) to eleven (11) percent by weight of chromium, two-and-one-half (2.5) to three-and-one-half (3.5) percent by weight of niobium, two (2) to three (3) percent by weight titanium, ten hundredths (0.10) to twenty hundredths (0.20) percent by weight of aluminum, and an amount of carbon that does not exceed four hundredths (0.04) percent by weight.

An object of the present invention is to provide a high-strength metal alloy that is resistant to hydrogen.

Another object of the present invention is to provide a hydrogen-resistant, high-strength alloy that can be used to make both cast products and wrought products.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention consists essentially of thirty-seven (37) percent by weight of iron, thirty-two (32) percent by weight of nickel, fifteen (15) percent by weight of cobalt, ten (10) percent by weight of chromium, three (3) percent by weight of niobium, two-and-one-half (2.5) percent by weight titanium, fifteen hundredths (0.15) percent by weight of aluminum, and an amount of carbon that does not exceed four hundredths (0.04) percent by weight.

In a cast condition, the alloy has a yield strength of 130-140 kips per square inch (ksi) or 0.90-0.97 gigapascals (GPa) and an ultimate tensile strength of 170-180 ksi or 1.17-1.24 GPa with 10-12% elongation. To obtain these mechanical properties, the following heat treatment was used:

1. Homogenize at 2100 ^{o}F $\pm$ 25 ^{o}F (1149 ^{o}C $\pm$ 14 ^{o}C) for 24 hours $\pm$ 30 minutes.
2. Hot Isostatic Press (HIP) at 2200 ^{o}F $\pm$ 25 ^{o}F (1204 ^{o}C $\pm$ 14 ^{o}C) and 25 ksi (172.4 MPa) for 5 hours $\pm$ 30 minutes.
3. Solution anneal at 1900 ^{o}F $\pm$ 25 ^{o}F (954 ^{o}C $\pm$ 14 ^{o}C) for about 1 hour per inch of material thickness.
4. Age harden by heating to 1325 ^{o}F $\pm$ 15 ^{o}F (718 ^{o}C $\pm$ 8 ^{o}C) for about 8 hours, cooling to 1150 ^{o}F $\pm$ 15 ^{o}F (621 ^{o}C $\pm$ 8 ^{o}C) and holding for about 8 hours, and air cooling back to room temperature.

In a wrought condition, the alloy has a yield strength of 150-155 ksi or 1.03-1.07 GPa and an ultimate tensile strength of 190-200 ksi or 1.31-1.38 GPa with 20-22% elongation. To obtain these mechanical properties, the following heat treatment was used:

1. Hot roll at 1900-2000 ^{o}F (1038-1093 ^{o}C), then water quench or rapidly air cool.
2. Solution anneal at 1900 ^{o}F $\pm$ 25 ^{o}F (1038 ^{o}C $\pm$ 14 ^{o}C) for about 1 hour per inch of material thickness.
3. Age harden by heating to 1325 ^{o}F $\pm$ 15 ^{o}F (718 ^{o}C $\pm$ 8 ^{o}C) for about 8 hours, cooling to 1150 ^{o}F $\pm$ 15 ^{o}F (621 ^{o}C $\pm$ 8 ^{o}C) and holding for about 8 hours, and air cooling back to room temperature.

In a thermo-mechanically processed condition, the alloy has a yield strength of 173 ksi or 1.19 GPa and an ultimate strength of 206 ksi or 1.42 GPa with 15% elongation. To obtain these properties, the following heat treatment was used:

1. Hot work at 1900-2000 ^{o}F (1038-1093 ^{o}C), then water quench or rapidly air cool.
2. Warm work 1200-1300 ^{o}F (649-704 ^{o}C).
3. Solution anneal at 1750 ^{o}F $\pm$ 25 ^{o}F (954 ^{o}C $\pm$ 14 ^{o}C) for about 1 hour per inch of material thickness.
4. Age harden by heating to 1325 ^{o}F $\pm$ 15 ^{o}F (718 ^{o}C $\pm$ 8 ^{o}C) for about 8 hours, cooling to 1150 ^{o}F $\pm$ 15 ^{o}F (621 ^{o}C $\pm$ 8 ^{o}C) and holding for

about 8 hours, and air cooling back to room temperature.

The resistance of an alloy to a hydrogen environment can be demonstrated by comparing the tensile strength of a notched specimen in a hydrogen environment to the tensile strength of a similarly notched specimen in a helium environment. The ratio of the tensile strength in hydrogen to the tensile strength in helium is referred to as the notch tensile ratio. If an alloy is not affected by hydrogen, the alloy would have a notch tensile ratio of 1.00. The present invention, NASA 23, has a notch tensile ratio that varies from 0.70 to 1.00 depending on which heat treatment method is used. Ratios in the upper end of the range are associated with lower strength and higher ductility.

ABSTRACT

A high-strength metal alloy that resists hydrogen embrittlement consisting essentially of thirty-seven (37) percent by weight of iron, thirty-two (32) percent by weight of nickel, fifteen (15) percent by weight of cobalt, ten (10) percent by weight of chromium, three (3) percent by weight of niobium, two-and-one-half (2.5) percent by weight titanium, fifteen hundredths (0.15) percent by weight of aluminum, and an amount of carbon that does not exceed four hundredths (0.04) percent by weight.