NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

October 15, 1970

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	:	3,276,866
Corporate Source	:	Lewis Research Center
Supplementary Corporate Source	:	
NASA Patent Case No.	:	XLE-02082

Gayle Parker

Enclosure:
Copy of Patent

FACILITY FORM 602

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3,276,866

Patented Oct. 4, 1966

3,276,866

NICKEL-BASE ALLOY CONTAINING Mo-W-Al-Cr-Ta-Zr-C-Nb-B

John C. Freche, Fairview Park, and William J. Waters, Cleveland, Ohio, assignors to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration

No Drawing. Filed Apr. 14, 1964, Ser. No. 360,180

3 Claims. (Cl. 75—171)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an improved nickel-base alloy having an extremely high load carrying capacity at elevated temperatures. The invention is further concerned with a nickel-base alloy having good resistance to oxidation at elevated temperatures and sufficient ductility to facilitate fabrication of the alloy into a sheet product.

Materials presently available for high load carrying capacity at elevated temperatures around 1900° F. include some of the refractory metals, such as tungsten, tantalum, molybdenum and columbium along with their alloys which have these metals as their base. Nickel- and cobalt-base superalloys are also used for such applications.

There are major disadvantages associated with the use of the above materials for such high-temperature, high-stress applications. The high melting point refractory metals have very poor oxidation resistance at high temperatures. Therefore, these materials must be protected from oxidation in air by a protective coating applied to the material. The problem of providing adherent coatings which will give uniform coverage under operating conditions in which the temperature varies with exposure time or is drastically cycled has not been solved. Examples of such operations occur in turbine engines and in the re-entry to the atmosphere of space vehicles. As a result, the refractory metals, though suitable from a strength standpoint, are inadequate in an air environment insofar as oxidation resistance is concerned. Also, because many of these metals lack ductility they are extremely difficult to work. The lack of oxidation resistance also complicates the working of the refractory metals, and special facilities including inert gas protection are required for fabrication. Because the refractory metals have high densities they are undesirable for many applications, particularly many aerospace applications wherein weight is a major consideration.

The strongest conventional nickel- and cobalt-base alloys presently available have limited ductility and are primarily cast materials. Although there are some nickel- and cobalt-base alloys that are readily workable, their short- and long-time strength properties are considerably lower at temperatures above 1800° F. than the strength properties of the cast material.

It is, therefore, an object of the present invention to provide a nickel-base alloy having improved properties at elevated temperatures.

Another object of the invention is to provide an improved nickel-base alloy having superior stress-rupture properties and oxidation resistance at elevated temperatures.

A further object of the invention is to provide an improved nickel-base alloy having sufficient ductility to enable it to be worked into thin sections and at the same time have superior strength properties.

Still another object of the invention is to provide an improved nickel-base alloy which can readily be cast without the need for closely controlled vacuum techniques and still provide exceptionally high temperature properties.

These and other objects of the invention will be apparent from the specification which follows.

The present invention is embodied in alloys having the following composition range, the amount of each alloying element being listed as a percentage by weight:

	Percent
Nickel	From about 49.49 to about 83.048
Molybdenum	From about 2 to about 6
Tungsten	From about 2 to about 10
Aluminum	From about 4 to about 8
Chromium	From about 4 to about 8
Tantalum	From about 3 to about 12
Zirconium	From about .5 to about 2
Carbon	From about .05 to about 1
Columbium	From about .5 to about 3.5
Boron	From about .002 to about .01

A preferred alloy has the following composition by weight:

	Percent
Nickel	About 68.372
Molybdenum	About 4
Tungsten	About 4
Aluminum	About 6
Chromium	About 6
Tantalum	About 8
Zirconium	About 1
Carbon	About .125
Columbium	About 2.5
Boron	About .003

The percentage of columbium was varied in the above preferred alloy composition. It was found that as the amount of columbium in the alloy was decreased the hardness decreased proportionally in a linear fashion.

This alloy was prepared with one of the simplest possible casting techniques. The alloy was melted in a refractory crucible of stabilized zirconium oxide in a high frequency induction coil. Argon gas was used as a protective cover for the material during the melting operation. During pouring, the inert gas cover was removed, and the melts were hand poured at 350° F. ±50° F. into investment molds heated to 1600° F. Heats were slow cooled to room temperature before removing the castings from the molds.

The alloy may also be prepared by controlled vacuum melting techniques. This can result in further improvements in physical properties, as has been demonstrated with many commercial nickel-base alloys. Vacuum melting allows much closer alloying control, reduces the interaction of such active elements as aluminum and zirconium with oxygen, and permits the drawing off of highly volatile low-melting point tramp element constituents. Reduced gas content and improved cleanliness of the melt also can be achieved by vacuum melting.

The above alloy composition is similar to that of the alloy disclosed in copending U.S. patent application Serial No. 107,866, filed May 4, 1961, now Pat. No. 3,167,426. The present alloy includes columbium as an alloying constituent but contains no vanadium. This results in a major improvement in oxidation resistance as well as high temperature tensile strength. The present alloy also differs from the alloy disclosed in the aforementioned patent in that boron is added for high temperature strength.

The present alloy derives much of its strength from the formation of a fine dispersion of a complex nickel-base intermetallic compound of the Ni_3Al type with substantial amounts of tantalum, chromium and columbium in solution. Complex tantalum-columbium carbides are also present in the alloy of the present invention and serve as additional strengtheners.

The alloy of the present invention compares favorably in high temperature tensile strength, oxidation resistance

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and workability with known advanced temperature nickel-base alloys. Table I sets forth several commercially-available alloys which have similar chemical compositions to those disclosed herein along with the composition of the alloy disclosed in the aforementioned patent.

The alloy of the present invention is identified as the New Alloy in Table I while the alloy disclosed in Pat. No. 3,167,426 is referred to as Alloy I. A comparison of these two alloys in Table I illustrates the similarity as well as the important differences in their compositions pointed out below.

TABLE III

	Time, hr.	Temperature ° F.	Oxidation resistance as measured by weight loss, mg./cm.[2]
New Alloy	50	1,900	1.3
SM 200	50	1,900	1.4
IN 100	64	1,900	1.6
René 41 (bar stock)	50	1,900	4.2
Alloy I	50	1,900	8.0

TABLE I

Nominal chemical compositions

Alloy	C	Mn	Si	Cr	Ni	Co	Ta	Mo	W	Cb	V	Ti	Al	Fe	Zr	B
IN 100	.18			10.0	Bal	15.0		3.0			1.0	5.0	5.5		0.05	0.015
SM 200	.15	.20	.20	9.0	Bal	10.0			12.5	1.0		2.0	5.0	.25	.05	.015
René 41	.09			19.0	Bal	11.0		10.0				3.1	1.5			.005
Alloy 1	.125			6.0	Bal		8	4.0	4		2.5		6.0		1.0	
New Alloy	.125			6.0	Bal		8	4.0	4	2.5			6.0		1.0	.003

The improved high temperature strength of the alloy made in accordance with the present invention is shown in Table II wherein the ultimate tensile strength of the cast New Alloy is compared with those of two commercially-available cast alloys as well as that of the cast nickel-base alloy disclosed in Pat. No. 3,167,426 at 1900° F. Table II also shows the ultimate tensile strength of the New Alloy sheet at 1800° F. together with that of a commercially-available sheet at the same high temperature. The ultimate strength at 1900° F. of a commercially-available powder product is listed in Table II for comparison purposes.

TABLE II

Alloy	Temperature, ° F.	Ultimate tensile strength, p.s.i.
New Alloy (cast)	1,900	63,300
IN 100 (cast)	1,900	60,000
SM 200 (cast)	1,900	60,000
Alloy 1 (cast)	1,900	55,700
René 41 (sheet)	1,800	40,000
New Alloy (sheet)	1,800	64,000
TD Nickel (Powder Product)	1,900	17,000

The improved oxidation resistance of the New Alloy at high temperatures is shown in Table III. The oxidation resistance at 1900° F. is listed for the alloy made in accordance with the present invention, three commercially-available alloys, and the alloy disclosed in the copending application.

It is apparent from the above tables that the nickel-base alloy of the present invention has improved properties at elevated temperatures which make the alloy useful for a number of different applications. For example, this alloy can be utilized in turbojet engines as a turbine bucket or stator vane material, as a high temperature structural member for aerospace vehicles, and as a sheet material for surface panels of re-entry vehicles.

Although the present invention has been described in conjunction with a preferred embodiment, it is to be understood that modifications and variations may be resorted to without departing from the spirit of the invention or the scope of the subjoining claims.

What is claimed is:

1. A nickel-base alloy consisting essentially of from 49.49% to 83.048% nickel, from 2% to 6% molybdenum, from 2% to 10% tungsten, from 4% to 8% aluminum, from 4% to 8% chromium, from 3% to 12% tantalum, from 0.5% to 2% zirconium, from .05% to 1% carbon, from .5% to 3.5% columbium, and from .002% to .01% boron.

2. A nickel-base alloy consisting essentially of 4% molybdenum, 4% tungsten, 6% aluminum, 6% chromium, 8% tantalum, 1% zirconium, .125% carbon, .003 boron, from .5 to 3.5% columbium, and the balance nickel.

3. A nickel-base alloy as claimed in claim 2 including 2.5% columbium.

References Cited by the Examiner

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