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Walter et al.

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[54] **NICKEL-BASE TANTALUM CARBIDE EUTECTIC ALLOYS**

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[73] Assignee: **General Electric Company**, Schenectady, N.Y.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 138,555, April 29, 1971, abandoned.

[52] **U.S. Cl.** **75/171**, 148/32, 148/32.5

[51] **Int. Cl.** **C22c 19/00**

[58] **Field of Search** 75/171, 170; 148/32, 32.5

[56] **References Cited**

UNITED STATES PATENTS

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[57] **ABSTRACT**

Unidirectionally solidified nickel-base carbide-reinforced cast superalloy bodies having high strength and exceptionally high stress-rupture properties, particularly at elevated temperatures. The reinforcing fibers present in the matrix comprise aligned fibers of single-crystal monocarbide essentially of tantalum. A preferred composition contains the nominal (melt) percentages: 6.7 w/o chromium, 18.25 w/o total tantalum, 1.1 w/o carbon, 5.0 w/o aluminum, 0.84 w/o titanium, 8.4 w/o cobalt and 5.0 w/o molybdenum, balance essentially nickel. The resulting article, after trimming, has the approximate composition: 7.9 w/o chromium, 7.0 w/o tantalum, 0.24 w/o carbon, 6.0 w/o aluminum, 0.38 w/o titanium, 9.6 w/o cobalt, 4.9 w/o molybdenum, balance essentially nickel.

5 Claims, 2 Drawing Figures

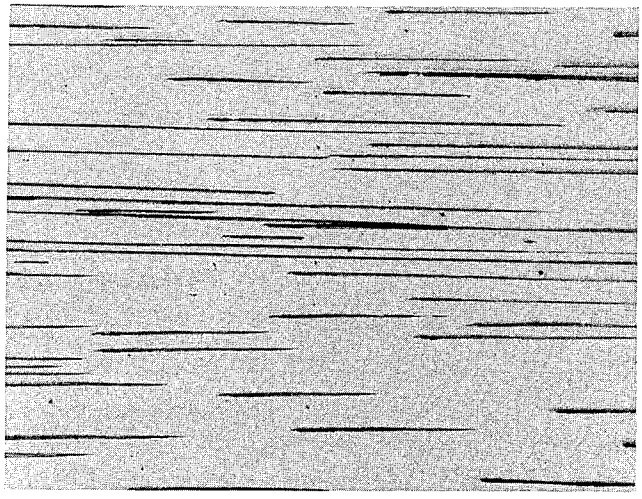


Fig. 1.

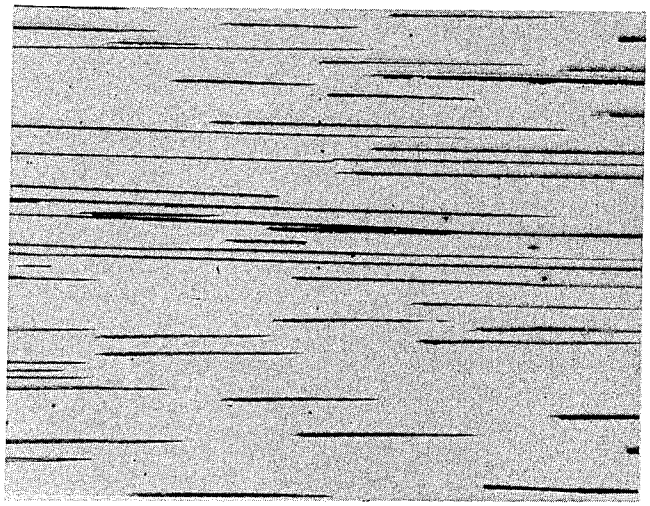
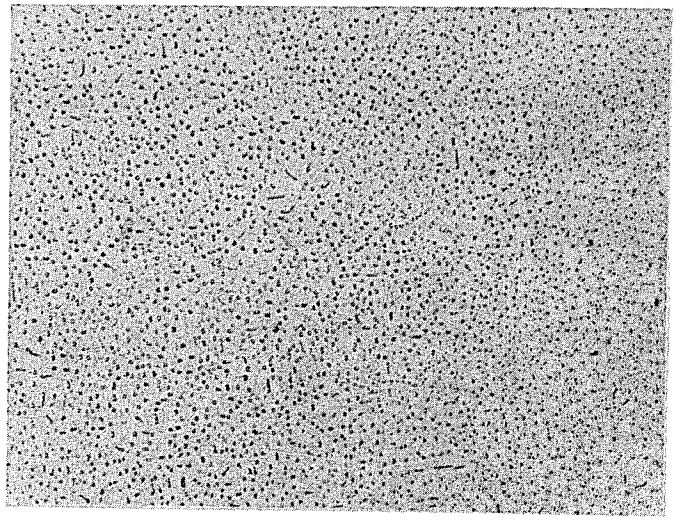


Fig. 2.



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NICKEL-BASE TANTALUM CARBIDE EUTECTIC ALLOYS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of co-pending application Ser. No. 138,555, filed Apr. 29, 1971, now abandoned of John L. Walter and Harvey E. Cline entitled NICKEL-BASE TANTALUM CARBIDE EUTECTIC ALLOYS, assigned to the same assignee as the present invention.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates in general to nickel-base eutectic superalloy compositions, and more particularly to bodies of such compositions containing, as reinforcement of their structure, aligned fibers of a carbide.

In particular embodiments of this invention, these alloys have utility in gas turbine engine components.

2. Description of the Prior Art

Superalloy bodies forming components in gas turbine engines are often subjected to temperatures which can approach 1,900°F, under highly oxidizing conditions. Although unidirectional solidification of a number of eutectic superalloys is known to achieve increased strength, heretofore there have been no nickel-base superalloy compositions developed which can be unidirectionally solidified to have a good combination of properties of high strength, high resistance to creep or stress-rupture at room temperature and elevated temperatures, all while retaining adequate ductility.

Among the commerically available cast nickel-base superalloys used for gas turbine engine blades are the following known compositions:

Ni-Base Superalloys

Composition	B-1900 wt. percent	Rene 80 wt. percent
Nickel	64.8	60.3
Chromium	8.0	14.0
Tantalum	4.0	—
Carbon	0.10	0.17
Aluminum	6.0	3.0
Titanium	1.0	5.0
Cobalt	10.0	9.5
Zirconium	0.10	0.03
Boron	0.015	0.015
Molybdenum	6.0	4.0
Tungsten	—	4.0

However, it would be desirable to improve the stress-rupture properties of these and similar alloys at high temperatures.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a range of compositions for nickel-base unidirectionally solidified superalloys which have excellent tensile properties, at room temperature and at temperatures up to2,000°F.

Another object of the invention is to provide cast fiber-strengthened bodies useful as components for turbine engines which have a combination of properties including high yield and tensile strength combined with good creep resistance under static stress at elevated temperatures, together with good engineering ductility.

Still another object of the invention is to provide a cast article having a microstructure which includes a relatively high volume percent of aligned reinforcing fibers in the matrix of the alloy.

In accordance with these and other objects of the invention, a range of nickel-base superalloy compositions is provided which form a composite structure comprising a matrix reinforced with aligned fibers essentially of tantalum carbide. The range of compositions of the unidirectionally solidified castings according to the invention is approximately, in weight percent, 6.5 to 10.0 percent chromium, 14.0 to 23.0 percent total tantalum, 1.0 to 1.5 percent carbon, a trace to 6.0 percent aluminum, a trace to 1.0 percent titanium, a trace to 8.5 percent cobalt, a trace to 5.0 percent molybdenum, balance essentially nickel.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment has the nominal (or melt) composition: 6.71 w/o chromium, 18.25 w/o tantalum of which 16.5 w/o tantalum is present as TaC fibers and an additional 1.75 w/o tantalum may be present in solid solution in the matrix, 1.1 w/o carbon, 5.04 w/o aluminum, 0.84 w/o titanium, 8.4 w/o cobalt and 5.04 w/o molybdenum, balance essentially nickel.

The resulting article, after trimming off portions, has the approximate composition: 7.9 w/o Cr, 7.0 w/o Ta, 0.24 w/o C, 6.0 w/o Al, 0.38 w/o Ti, 9.6 w/o Co, 4.0 w/o Mo, balance essentially Ni.

The alloys of the present invention contain carbide fibers, essentially of tantalum carbide in amounts of from about 2 to about 10 volume percent of the alloy, with the preferred composition containing about 6 volume percent. The carbide fibers are preferably dispersed throughout the matrix of the composite structure, but beyond about 6 volume percent some of the carbide may tend to precipitate out as particles at the bottom of the cast body during the solidification process, particularly in the alloys containing significant amounts of aluminum, molybdenum and cobalt.

Typical compositions according to the invention are shown below in Table I.

TABLE I

Ni-base-TaC Alloys

Alloy Designation	Ni	Cr	Ta	Ta(M)*	C	Al	Ti	Co	Mo
A. TaC-74A	67.8	8.1	22.6		1.5				
B. TaC-67Ti	67.2	9.9	16.3		1.2	4.5	1.0		
C. TaC-60Co	60.2	8.9	16.3		1.2	4.5	1.0	8.0	
D. TaC-59Ta	59.2	8.9	16.3	1.0	1.2	4.5	1.0	8.0	
E. TaC-1900	54.7	6.7	18.3		1.1	5.0	0.84	8.4	5.0

TABLE I

Ni-base-TaC Alloys

Alloy Designation	Ni	Cr	Ta	Ta(M)*	C	Al	Ti	Co	Mo
F. TaC-19Ta	54.61	6.71	16.5	1.75	1.1	5.04	0.84	8.4	5.04
F-1 (Article Portion)	Bal	7.9	7.0		0.24	6.0	0.38	9.6	4.9

*Ta(M) is the amount of tantalum in the matrix, in addition to the Ta as TaC.

The nominal, or melt composition designated F (corresponding to the article portion F-1) in Table I is a preferred embodiment of the invention because of its excellent properties, as shown in Tables II, III and IV.

C. TaC-60Co	31,300	10.0
D. TaC-59Ta	32,600	20.0
E. TaC-1900	48,800	17.4
F. TaC-19Ta	54,500	17.2

TABLE IV

High Temperature Stress-Rupture Properties

Alloy Designation	Stress(psi)	Temp. °F	Life (hrs. to rupture)	% Elong.
A. TaC-74A	20,000	2000	2.3	20.5
B. TaC-67Ti	20,000	2000	2.9	20.2
C. TaC-60Co	20,000	2000	0.04	24.3
D. TaC-59Ta	17,000	2000	1.0	15.5
E. TaC-1900	20,000	2000	7.1	11.7
F. TaC-19Ta	20,000	1832	312	10.4
René 80	20,000	1832	15.8	
	20,000	2000	2.9	
B-1900	20,000	1832	15.8	
		2000	2.9	

The tantalum in this alloy, as indicated in Table I, is 18.25 weight percent total, of which 16.5 percent is present as stoichiometric carbide, plus an additional 1.75 weight percent tantalum presumably present in solid solution in the matrix, where it may serve to inhibit the decomposition of the carbide fibers at high temperatures. The composition of the resulting article portion is that designated F-1 in Table I.

EXAMPLE I

Ingots of the melt composition designated in Table I as composition F were directionally solidified from molten condition at ¼ inch/hr. and in a temperature gradient of up to 200°F per inch. The resulting microstructure, as may be seen in FIGS. 1 and 2, comprised aligned carbide fibers, essentially single crystal tantalum carbide, in a nickel-base alloy matrix. The mechanical properties of the uniform fibrous portion of these alloys, after customary trimming off of redundant segregated portions, had the composition F-1 of Table I, of which specimens tested at a strain rate of 2×10^{-2}/min. are listed in Table II for room temperature, and in Table III at the elevated temperature of 1,832°F.

TABLE II

Mechanical Properties at Room Temperature

Alloy Designation	Ult. stress(psi)	% Elong.
A. TaC-74A	110,600	2.8
B. TaC-67Ti	165,600	4.0
C. TaC-60Co	186,000	25.4
D. TaC-59Ta	174,500	28.0
E. TaC-1900	132,200	16.0
F. TaC-19Ta	158,600	2.4

TABLE III

Mechanical Properties at High Temperature—1832°F (1000°C)

Alloy Designation	Ultimate stress(psi)	% Elongation
A. TaC-74A	36,000	9.0
B. TaC-67Ti	23,800	16.4

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a photomicrograph (250X) of a longitudinal section of typical nickel-base superalloy with carbide fibers according to the invention; and

FIG. 2 is a photomicrograph (250X) of a transverse section of the alloy of FIG. 1.

In the drawings, FIG. 1 is a photomicrograph (250X) of a longitudinal section of a nickel-base superalloy with carbide fibers and having the nominal (melt) composition F (corresponding to article composition F-1) of Table I. In FIG. 1 it may be seen that the carbide fibers are relatively long and mutually aligned, thus contributing to the maximum strength of the alloy in the direction of their alignment. Transmission electron microscopy results show that these fibers are cubic and single crystal.

FIG. 2 is a photomicrograph (250X) showing a transverse section of the alloy body of FIG. 1, illustrating that the carbide fibers are generally uniformly distributed throughout the alloy matrix. The carbide fibers form a high volume fraction of the alloy, namely about 2 to 10 volume percent of the total alloy, and preferably about 6 volume percent. The TaC preferably forms about 15 to 20 weight percent of the alloy.

Table IV shows the stress-rupture properties of typical alloys of the present invention at various elevated temperatures, as compared to the known nickel-base alloys René 80 and B-1900, both with relatively high creep resistance.

As may be seen from the data of Table IV, the carbide reinforced nickel-base alloys of the present invention have comparable or superior high temperature creep resistance, as compared to the known nickel-base superalloys B-1900 and René 80. For example, at a temperature of 1,832°F and 20,000 psi stress, the René 80 alloy of the prior art withstood the stress for only 15.8 hours before rupture; whereas under the same conditions the nickel-base alloy with tantalum carbide according to composition F withstood the stress for 312 hours before rupture.

In addition to tantalum carbide, other monocarbides such as zirconium carbide, titanium carbide, niobium carbide and hafnium carbide, or combinations of these, may also produce composite structures consisting of an aligned phase of a monocarbide in the nickel-base alloy matrix. Of these carbides, both ZrC and TiC form aligned fibrous composites in the nickel-base alloy in a manner similar to tantalum carbide, with consequent improvement in mechanical properties over the non-reinforced matrix alloy. The TiC, NbC and ZrC monocarbides would be considered for their lower densities as compared with tantalum carbide. However, on the basis of the melting temperatures of the zirconium and titanium carbides in relation to strength, it would be expected that these latter carbides would impart less strength to the nickel-base alloy than does tantalum carbide.

Thus, the nickel-base carbide-reinforced alloys of the present invention exhibit a combination of desirable properties.

It will be obvious to those skilled in the art upon reading the foregoing disclosure that many modifications and alterations in the specific compositions and microstructures disclosed as non-limiting examples may be made within the general context of the invention, and that numerous modifications, alterations and addtions may be made thereto within the true spirit and scope of the invention as set forth in the appended claims.

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

1. An article of manufacture comprising a unidirectionally solidified casting of a nominal composition consisting essentially in weight percent of about 6.7 percent chromium, 18.3 percent tantalum, 1.1 percent carbon, 5.0 percent aluminum, 0.84 percent titanium, 8.4 percent cobalt, 5.0 percent molybdenum and the balance nickel, said casting having a nickel base alloy matrix reinforced with tantalum monocarbide fibers.

2. An article according to claim **1**, said casting being characterized by having high strength and resistance to creep and a chemistry which consists essentially of a nickel-base alloy containing at least a portion of said tantalum and carbon in the form of about 15 to 20 weight percent monocarbide of tantalum.

3. An article according to claim **1**, a major portion of said tantalum being present as a monocarbide of tantalum comprising fibers forming from about 2 to 10 volume percent of the alloy.

4. An article according to claim **1**, a minor proportion of the tantalum being present as a solid solution in the matrix of the alloy in addition to said tantalum present as TaC fibers.

5. An article according to claim **1**, said carbide of tantalum consisting essentially of tantalum monocarbide and comprising aligned fibers in the form of single crystals of tantalum carbide of cubic form.

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