United States Patent [19]

Dalai et al.

[11] **3,807,993**

[45] **Apr. 30, 1974**

[54] **NICKEL BASE ALLOY CONTAINING HAFNIUM**

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[73] Assignee: **Avco Corporation,** Stratford, Conn.

[22] Filed: **Apr. 12, 1972**

[21] Appl. No.: **243,418**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 189,733, Oct. 15, 1971, abandoned.

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

3,677,331	7/1972	Lund et al.	75/171
3,677,747	7/1972	Lund et al.	75/171

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Attorney, Agent, or Firm—Charles M. Hogan; Irwin P. Garfinkle

[57] **ABSTRACT**

The nickel base, cobalt containing alloys of this invention contain relatively small, but nonetheless significant, amounts of tungsten and molybdenum for solid solution strengthening, chromium for oxidation and sulfidation resistance, tantalum for solid solution and carbide strengthening, aluminum and titanium to enhance the strength by precipitation of a fine dispersed phase, gamma prime $Ni_3(Al, Ti)$, and hafnium for intermediate strength, ductility and improved oxidation resistance.

7 Claims, No Drawings

NICKEL BASE ALLOY CONTAINING HAFNIUM

This application is a continuation-in-part of our U.S. Pat. application Ser. No. 189,733, filed Oct. 15, 1971, now abandoned.

This invention relates to nickel base alloys exhibiting high strength, stability, ductility and resistance to corrosion, sulfidation and oxidation at elevated temperatures and which are useful for blades, vanes and integrally cast turbine wheels.

The nickel base alloys of this invention contain relatively small, but nonetheless significant, amounts of tungsten and molybdenum for solid solution strengthening; chromium for oxidation and sulfidation resistance; tantalum for solid solution and carbide strengthening; aluminum and titanium to enhance the strength by precipitation of a fine dispersed phase, gamma prime $Ni_3(Al, Ti)$, and hafnium for intermediate strength, ductility and improved oxidation resistance.

Compositions of the following analyses are contemplated as within the scope of the present invention the compositions being expressed in weight percent, the balance being Ni except for incidental impurities:

C	0.30 max.	Hf	0.1–3
Cr	11–15	Ti	3.5–4.5
Co	8–12	Al	3–4
Mo	1–2.5	Ti + Al	7–8
W	3–10	B	0.005–0.025
Ta	3.5–10	Zr	0.05–0.4

balance Ni

A more preferred range of compositions is as follows:

C	.25 max.	Hf	0.4–3
Cr	11–13.5	Ti	3.5–4.5
Co	8–11	Al	3–4
Mo	1–2.5	Ti + Al	7–8
W	3–5	B	0.005–0.025
Ta	3.5–8	Zr	0.05–0.4

Balance Ni

A still more preferred range of compositions is as follows (in weight percent):

C	0.10–0.22	Hf	0.75–1.25
Cr	12.2–13.5	Ti	3.9–4.2
Co	8.5–9.5	Al	3.2–3.6
Mo	1.85–2.05	Ti + Al	7.25–7.70
W	3.65–8	B	0.01–0.02
Ta	3.65–8	Zr	.08–.25

balance Ni

Exemplary alloys in accordance with the teachings of this invention had the compositions shown in Table I which follows:

TABLE I

Heat No.	C	Cr	Co	Mo	W	Ta	Hf	Ti	Al	Ti+Al	B	Zr	Ni
I	.15	12.50	9.35	1.94	3.99	3.86	1.10	3.96	3.57	7.53	.015	.17	Bal
II	.15	12.50	9.35	1.94	3.99	3.86	2.28	3.96	3.57	7.53	.015	.21	Bal
III	.23	12.80	8.68	1.97	4.00	3.77	0.49	4.32	3.28	7.60	.016	.13	Bal
IV	.23	12.38	8.68	1.97	4.00	3.77	1.07	4.32	3.28	7.60	.016	.16	Bal
V	.23	12.38	8.68	1.97	4.00	3.77	1.55	4.32	3.28	7.60	.016	.14	Bal
VI	.23	12.38	8.68	1.97	4.00	3.77	1.80	4.32	3.28	7.60	.016	.20	Bal
VII	.23	12.38	8.68	1.97	4.00	3.77	0.44	4.32	3.28	7.60	.016	.14	Bal
VIII	.20	12.31	9.18	1.94	3.72	4.05	1.06	4.08	3.38	7.46	.014	.15	Bal
IX	.20	12.31	9.18	1.94	3.72	4.05	2.26	4.08	3.38	7.46	.014	.22	Bal
X	.20	12.31	9.18	1.94	3.72	4.05	2.16	4.08	3.38	7.46	.014	.21	Bal
XI	.20	12.31	9.18	1.94	3.72	4.05	1.16	4.08	3.38	7.46	.014	.16	Bal
XII	.19	12.66	9.42	1.92	3.75	3.86	2.40	4.01	3.27	7.28	.015	.22	Bal
XIII	.15	12.50	8.88	2.04	3.95	5.0	1.13	3.96	3.22	7.18	.013	.10	Bal
XIV	.15	12.50	8.88	2.04	3.95	6.0	1.13	3.96	3.22	7.18	.013	.10	Bal
XV	.20	13.35	8.88	1.91	3.87	8.0	1.20	4.18	3.21	7.39	.012	.11	Bal
XVI	.20	13.35	10.88	1.91	3.87	6.0	1.20	4.18	3.21	7.39	.012	.11	Bal
XVII	.20	13.35	10.88	1.91	3.87	7.0	1.20	4.18	3.21	7.39	.012	.11	Bal
XVIII	.20	13.35	10.88	1.91	3.87	8.0	1.20	4.18	3.21	7.39	.012	.11	Bal
XIX	.15	12.87	9.49	2.01	4.01	4.0	1.05	4.10	3.23	7.33	.013	.11	Bal
XX	.15	12.87	9.49	2.01	5.01	7.50	1.05	4.10	3.23	7.33	.013	.11	Bal
XXI	.15	12.87	9.49	2.01	7.50	5.0	1.05	4.10	3.23	7.33	.013	.11	Bal
XXII	.15	12.87	9.49	2.01	10.0	5.0	1.05	4.10	3.23	7.33	.013	.11	Bal
XXIII	.16	12.60	9.40	2.0	3.97	3.85	0.50	4.0	3.55	7.55	.020	.10	Bal
XXIV	.21	12.80	9.40	2.19	4.0	4.08	1.95	4.05	3.25	7.30	.014	.10	Bal
XXV	.21	12.80	9.40	2.19	4.0	4.08	1.95	4.05	3.25	7.30	0.14	.15	Bal
XXVI	.21	12.80	9.40	2.19	4.0	4.08	1.95	4.05	3.25	7.30	.014	.20	Bal
XXVII	.09	12.30	9.10	1.87	7.40	4.94	1.25	4.18	3.35	7.53	.012	.12	Bal
XXVIII	.09	12.30	9.10	1.87	4.90	4.94	1.25	4.18	3.35	7.53	.012	.12	Bal
XXIX	.27	12.40	9.00	1.87	7.40	4.90	1.15	4.06	3.20	7.26	.013	.11	Bal

After vacuum melting, the alloys noted above were vacuum cast into test bars and subjected to stress rupture testing according to ASTM Standard E139. The test bars were heat treated before testing as follows: heated to 2,050° F, held at that temperature for 2 hours then air cooled, then reheated to 1,550° F and held at 1,550° F for 4 hours, then air cooled, then reheated to 1,400° F and held at that temperature for 16 hours then air cooled.

After the heat treatment described above, stress rupture tests were conducted on cast test bars representative of each of the heats in the heat treated condition at 1,400° F/90Ksi, 1,400° F/100Ksi, 1,700° F/39Ksi and 1,800° F/29Ksi. The results are given in Table II, it being noted that thickwall data refers to 0.250 inch diameter solid test bar results. Thinwall data refers to tubular test bar results in which wall thickness is 0.040 inch. Thickwall or solid test bar data reflects mechanical property capability of heavy sections such as might be represented by turbine blade roots. Thin wall or tubular test bar properties reflect the mechanical property capabilities of thin walled sections such as might be represented by cored or hollow turbine blade airfoils. Thinwall data are for tests at 1,700° F/35Ksi.

TABLE II

C103 STRESS RUPTURE TEST results

Heat No.	THICKWALL 1400°F/90Ksi Life (Hrs.)	El (%)	1400°F/95Ksi Life (Hrs.)	El (%)	1400°F/100Ksi Life (Hrs.)	El (%)	1700°F/29Ksi Life (Hrs.)	El (%)	1800°F/29Ksi Life (Hrs.)	El (%)	THINWALL 1700°F/35Ksi Life (Hrs.)	El (%)
I	462	4	163	3			72	5				
	483	5					99	5				
II			382	7			79	9				
III			225	5			99	10				
			87	10			106	10				
IV			211	5			106	10				
			180	5								
V			73	3								
			119	5			48	8				
VI			208	4			77	9				
VII	277	4					65	7				
	419	5					121	3				
VIII	286	5.5					50	8				
	408	6					37	6				
IX	530	3					45	10				
							38	6				
							36	7				
X	505.7	7.5					71	8				
							50	6				
							56	7				
XI	273	4					60	7.5				
							97	8.0				
XII			160	8								
			153	6								
XIII					97	5	88	6	44	5		
									61	6		
XIV					159	5	129	9	61	8		
									58	5		
XV					70	4	53	4	48	6		
					46	3	56	4	49	6		
					49	3						
XVI					104	8	62	7	22	8		
							63	8	27	10		
XVII					130	8	93	7	38	10		
									45	9		
XVIII									35	9		
									37	8		
XIX					130	9	72	9			53	6
					103	8					58	6
XX					149	4			50	6	64.4	6.0
					174	4			28	9	70.6	5.0
											178.0	5.0
XXI					142	4			43	10	129	5
					224	5			79	5	189	5
									81	7	254	5
XXII					224	5			45	5	101	N/A
									51	8	137	6
XXIII	113	4					39	4				
	116	3					67	4				
XXIV					144	9	109	10				
					167	6	88	10				
							99	10				
XXV					181	15	65	N/A				
							71	8				
XXVI					172	6	79	10				
					168	8	83	8				
							80	9				
XXVII					163	5			59	8	60	3
					157	7			58	5	68	4
XXVIII					130	4	119	8	60	10	111	5
					212	6	75	9	61	9	125	5
											125	9
XXIX					110	4			81	5	122	4
					133	5			61	8	184	4
											212	5
INCO 713	16	6	5	4			20	12				
MARM 421	50	3	20	3			15	15				
IN792	255	7.5			75	7	75	9				

Corresponding values for three presently known commercial alloys are appended to Table II for comparison.

INCO 713C is reported to be an alloy with a nominal composition of

C	Cr	Mo	W	Cb	Ti	Al	Zr	B	Ni
0.14	13.0	4.5	0.20	2.0	0.75	5.75	0.05	0.012	Balance

MAR-M-421 is reported to be an alloy with a nominal composition of

C	Cr	Co	Mo	W	Cb	Ti	Al	Zr	B	Ni
0.15	15.8	9.5	2.0	3.8	2.0	1.8	4.3	0.05	0.015	Balance

INCO IN792 is reported to be the alloy described in U.S. Pat. No. 3,619,182.

Table III presents the room temperature tensile properties of the alloy of this invention, heat treated as before, after casting into test bars.

TABLE III

C103 ROOM TEMPERATURE TENSILE TEST RESULTS

Heat No.	Uts. (Ksi)	0.2% Y.S.(Ksi)	El (%)	R.A. (%)
VIII	181.4	169.2	3.5	3.2
	172.5	163.9	3.5	3.2
INCO-713C	123	106	7.9	11.6
MAR-M-421	150	130	3.5	5

Comparable values for the same commercial alloys are appended to the table for comparison.

In the Tables IV and V respectively, data is presented on cyclic oxidation test results conducted at 1,750° F and hot corrosion test conducted at 1,650° F.

TABLE IV

COMPARATIVE C103 CYCLIC OXIDATION TEST RESULTS

Material	Weight Change (Mg/Cm^2) After 240 Hours at 1750°F
Heat VIII	1.15
Heat IX	0.95
INCO 713C	−4.40
MAR-M-421	−2.20

TABLE V

COMPARATIVE C103 HOT CORROSION TEST RESULTS

Material	Depth of Attack (Mils) After 150 Hours at 1650°F with 6 ppm Salt
Heat VIII	4.2
INCO 713C	26.0
MAR-M-421	15.0

It is not intended that the invention sought to be patented be limited by the foregoing description, but merely by the scope of the appended claims.

We claim:

1. A nickel base alloy exhibiting high strength, ductility, sulfidation and oxidation resistance and stability at elevated temperature and consisting essentially of the following in weight percent:

C	.30 max
Cr	11–15
Co	8–12
Mo	1–2.5
W	3–10
Ta	3.5–10
Hf	0.1–3
Ti	3.5–4.5
Al	3.2–3.6
Ti+Al	7–8
B	0.005–0.025
Zr	.05–.40
Ni	Balance

2. A nickel base alloy exhibiting high strength, ductility, sulfidation and oxidation resistance and stability at elevated temperature and consisting essentially of the following in weight percent:

C	.25 max
Cr	11–13.5
Co	8–10
Mo	1–2.5
W	3–5
Ta	3.5–5
Hf	0.4–3.0
Ti	3.5–4.5
Al	3.2–3.6
Ti+Al	7–8
B	0.005–0.025
Zr	.05–.40
Ni	Balance

3. A nickel base alloy exhibiting high strength, ductility, sulfidation and oxidation resistance and stability at elevated temperature and consisting essentially of the following in weight percent:

C	.10–22
Cr	12.20–13.00
Co	8.50–9.50
Mo	1.85–2.05
W	3.65–4.05
Ta	3.65–4.05
Hf	0.50–2.50
Ti	3.90–4.20
Al	3.20–3.60
Ti+Al	7.25–7.70
B	.010–.020
Zr	0.08–0.25
Ni	Balance

4. A nickel base alloy exhibiting, high strength, ductility, sulfidation and oxidation resistance and stability at elevated temperature and consisting essentially of the following in weight percent:

C	.10–.22
Cr	12.2–13.5
Co	8.5–9.5
Mo	1.85–2.05
W	3.65–8
Ta	3.65–8
Hf	0.75–1.25
Ti	3.9–4.2
Al	3.2–3.6
Ti+Al	7.25–7.70
B	0.010–0.020
Zr	0.08–0.25
Ni	Balance

5. A nickel base alloy according to claim 1 which has been heat treated to produce a desired morphology of carbides and gamma prime.

6. An article formed of the alloy of claim 1.

7. A vacuum cast article consisting of the alloy of claim 1.

* * * * *

PO-1050
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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,807,993 Dated April 30, 1974

Inventor(s) Ranes P. Dalal, Jeremy J. Walters, Bruce A. Ewing

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Item 19 - Dalai et al. should read --- Dalal et al. ---.

Item 75 - Ranes P. Dalai should read --- Ranes P. Dalal ---.

Table II, under THICKWALL, the heading 1700°F/29Ksi should read --- 1700°F/39Ksi ---.

Signed and sealed this 27th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents