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WROUGHT HIGH TEMPERATURE ALLOY

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This invention has to do with an improved high-temperature alloy which is capable of being hot worked into any desired shape and is capable of withstanding prolonged stress at elevated temperature.

The alloy of this invention is especially useful for parts which have to withstand high stresses under elevated temperature conditions such as 1500° F. or higher and at the same time be resistant to oxidation. The alloy uses a minimum of strategic materials. The material of this invention has numerous applications in gas turbines and jet engine components. Some of the uses for which this material is particularly useful are: fabricated nozzle guide vanes, afterburner flame gutters, turbine shrouds, etc. The material of this invention in sheet metal form has better high-temperature properties and much lower strategic rating than materials currently available commercially in sheet form.

The composition of the material of the present invention in its broader aspects consists essentially as follows:

0.03– 0.30%	carbon
13.00–17.00%	chromium
4.00– 6.00%	molybdenum
24.00–55.00%	nickel
14.00–55.00%	iron
1.50– 5.00%	aluminum
1.50– 3.00%	titanium
0.01– 0.20%	boron

The material also may contain silicon ranging up to about 1 percent. Manganese also may be present in amounts up to about 1 percent. In most cases, the manganese ranges between 0.05 and 0.30 percent and the silicon ranges between 0.10 and 0.60 percent. Best results also are obtained when the iron content is not more than about 30 percent and when the material has a boron content of at least .04 percent and preferably at least 0.06 percent. This amount of boron substantially improves the elongation at rupture and with increase in rupture life. Amounts of iron above 30 percent cause a decrease in high-temperature strength.

Usually, the preferred materials will fall within a range of composition as follows:

0.03– 0.30%	carbon
13.00–17.00%	chromium
4.00– 6.00%	molybdenum
14.00–30.00%	iron
1.50– 5.00%	aluminum
1.50– 2.50%	titanium
0.04– 0.20%	boron
Balance nickel	

The following is a typical example of a highly satisfactory alloy in accordance with the invention:

0.05– 0.20%	carbon
0.10% (max.)	manganese
0.60% (max.)	silicon
14.00–17.00%	chromium
4.00– 6.00%	molybdenum
24.00–26.00%	iron
2.75– 3.50%	aluminum
1.75– 2.50%	titanium
5.00– 6.00%	aluminum and titanium combined
0.04– 0.08%	boron
Balance nickel	

All of the compositions of this invention have good hot work-ability at temperatures in the range of about 1750° F. to 2125° F. This is a particular advantage of the present invention since the materials can be readily processed from cast ingots into wrought products such as bar stock, sheets, etc., using conventional rolling mill equipment. The materials have been successfully reduced into sheets having thicknesses as low as 0.03 inch. The sheet materials of this invention may be hot or cold pressed or otherwise formed into desired shapes.

The wrought or hot worked materials of this invention may be subsequently solution treated and aged. A typical treatment for this purpose includes heating for one hour at 2075° F., water quenching, reheating four hours at 1400° F., and thereafter air cooling. Another treatment includes heating at 2000° F. for 20 minutes, air cooling, and thereafter reheating for 20 hours at 1500° F.

Table A below gives the results of typical tests on test bars made from wrought barstock from different heats. The Table A gives the composition of the materials, the heat treating conditions, time to rupture in hours, percent elongation at rupture, and the test conditions including temperature and stress employed in the tests.

Table A

WROUGHT BARSTOCK

Heat No.	C	Mn	Si	Ni	Cr	Mo	Fe	Al	Ti	B	Condition*	Hours to Rupture	Percent Elongation	Test Conditions
1	.19	.05	.11	Bal.	14.7	4.35	23.9	3.67	2.23	ND	1 hr., 2,075° F. WQ 4 hrs., 1,400° F. AC	42	2.1	1,500° F./35,000 p. s. i.
											1 hr., 2,075° F. WQ 4 hrs., 1,500° F. AC	32	2.1	1,500° F./35,000 p. s. i.
											1 hr., 2,075° F. WQ 4 hrs., 1,600° F. AC	47	4.8	1,500° F./35,000 p. s. i.
2	.19	.05	.11	Bal.	14.6	4.17	23.5	3.39	2.31	.041	1 hr., 2,075° F. WQ 4 hrs., 1,500° F. AC	82	13.8	1,500° F./35,000 p. s. i.
											1 hr., 2,075° F. WQ	82	11.6	1,500° F./35,000 p. s. i.
3	.05	.14	-----	Bal.	14.8	4.24	26.0	2.80	2.46	.05	1 hr., 2,075° F. WQ	534	11.1	1,500° F./25,000 p. s. i.

Table A.—Continued

SHEET MATERIAL

3											20 min., 2,000° F. AC	88	25.2	1,600° F./15,000 p. s. i.
											20 min., 2,000° F. AC	102	16.9	1,550° F./20,000 p. s. i.
											20 min., 2,000° F. AC	22	12.4	1,500° F./35,000 p. s. i.
											20 min., 2,000° F. AC	109	9.6	1,500° F./25,000 p. s. i.
											20 min., 2,000° F. AC	281	18.7	1,500° F./25,000 p. s. i.
											20 min., 2,000° F. AC, 4 hrs., 1,500° F. AC, No preheat in S-R test	198	9.2	1,350° F./80,000 p. s. i.
											20 min., 2,000° F. AC	128	6.4	1,350° F./50,000 p. s. i.
											20 min., 2,000° F. AC	153	4.5	1,300° F./60,000 p. s. i.
											20 min., 2,000° F. AC, 4 hrs., 1,500° F. AC, No preheat in S-R test	194	7.0	1,300° F./60,000 p. s. i.

ND—None Detected.
WQ—Water Quench.
AC—Air Cool.

*All test samples aged at test temperature during 20 hour preheat in test machine except as noted.

Table B is generally similar to Table A except that the test bars were made from castings.

The alloy or alloy compositions of this invention may be made by known alloying procedures. Any desired type of melting furnace may be used. Typical examples are indirect arc and induction types. Protective atmospheres preferably are employed during the melting and casting operations. Vacuum melting may be employed.

Table B

Heat No.	C	Mn	Si	Ni	Cr	Mo	Fe	Al	Ti	B	Condition	Hours to Rupture	Percent Elongation	Test Conditions
4	.09			24.9	14.6	5.29	51.3	1.86	2.03		As-cast	14	5.1	1,500° F./23,500 p. s. i.
5	.03			48.0	16.9	5.82	24.5	2.43	2.51		do	148	2.3	1,500° F./23,800 p. s. i.
6	.13	.29	.48	29.3	15.2	5.14	45.2	2.19	1.99	.19	do	8	23.2	1,500° F./23,510 p. s. i.
7	.15	.10	.40	Bal.	15.0	5.25	15.0	3.20	2.20	.06	do	104	7.8	1,500° F./35,000 p. s. i.
												57	6.7	1,500° F./35,000 p. s. i.
												71	10.1	1,500° F./35,000 p. s. i.
8	.18	.11	.56	Bal.	15.5	5.00	14.8	3.19	2.12	.075	do	118.5	11.9	1,500° F./35,000 p. s. i.
												116.4	15.2	1,500° F./35,000 p. s. i.
												123.0	8.63	1,500° F./35,000 p. s. i.
9	.21	.09	.50	Bal.	15.5	5.00	19.8	3.02	2.16	.075	do	108.1	13.0	1,500° F./35,000 p. s. i.
												146.5	9.3	1,500° F./35,000 p. s. i.
10	.20	.05	.20	Bal.	15.5	5.00	22.3	2.85	2.00	.075	do	122.8	12.9	1,500° F./35,000 p. s. i.
												172.2	13.1	1,500° F./35,000 p. s. i.
11	.14	.09	.44	Bal.	15.5	5.00	24.6	3.16	1.97	.075	do	136.0	6.2	1,500° F./35,000 p. s. i.
												107.4	8.7	1,500° F./35,000 p. s. i.
												98.6	6.55	1,500° F./35,000 p. s. i.
												67.0	8.62	1,500° F./35,000 p. s. i.
												45.9	11.6	1,500° F./35,000 p. s. i.
13	.15	.10	.40	Bal.	15.0	5.25	25.0	3.20	2.20	.06	As-cast	42.0	3.8	1,500° F./35,000 p. s. i.
												172.5	4.7	1,500° F./35,000 p. s. i.
												53.9	18.7	1,500° F./35,000 p. s. i.
14	.20	.05	.20	Bal.	15.5	5.00	26.5	2.70	1.78	.075	do	67.9	9.48	1,500° F./35,000 p. s. i.
												39.4	10.62	1,500° F./35,000 p. s. i.
15	.16	.11	.37	Bal.	15.5	5.00	30.6	3.05	2.05	.075	do	29.6	4.8	1,500° F./35,000 p. s. i.
												57.2	6.47	1,500° F./35,000 p. s. i.
16	.19	.05	.20	Bal.	15.5	5.00	32.8	2.72	2.05	.075	do	154.6	10.3	1,500° F./35,000 p. s. i.
												154.0	8.1	1,500° F./35,000 p. s. i.
17	.15	.10	.40	Bal.	15.0	5.25	35.0	3.20	2.20	.06	do	15.8	3.64	1,500° F./35,000 p. s. i.
												16.1	4.22	1,500° F./35,000 p. s. i.
18	.21	.05	.20	Bal.	15.5	5.00	35.0	2.55	2.08	.075	do	24.9	10.5	1,500° F./35,000 p. s. i.
												75.0	12.4	1,500° F./35,000 p. s. i.
												64.0	9.22	1,500° F./35,000 p. s. i.

Table C below shows that a typical material in accordance with the present invention identified as GMR-236 is superior to three conventional alloys commercially available in sheet form.

Table C

	Cr	Ni	Mo	Co	Fe	W	Cb	Al	Ti	B	Stress for 100 Hour Rupture Life at 1,500° F., p. s. i.	Strategic Material Rating, 1955 Index
GMR-236	15	Balance (About 50%.)	5		25.0			3	2.5	.07	25,500	2.30
N-155	21	20	3	20	30.0	2.50	1.00				17,000	10.18
L-605	20	10		51	1.5	15.00					23,000	19.93
S-816	20	20	4	42	3.5	4.25	3.75				24,000	34.83

Various changes and modifications of the embodiments of our invention described herein may be made without departing from the spirit and principles of the invention.

We claim:

1. An alloy capable of being hot worked and withstanding high and prolonged stress at elevated temperature consisting essentially as follows:

0.03–0.30% carbon
0.00–1.00% silicon
0.00–1.00% manganese
13.00–17.00% chromium
4.00–6.00% molybdenum
24.00–55.00% nickel
14.00–55.00% iron
1.50–5.00% aluminum
1.50–3.00% titanium
0.01–0.20% boron

2. A wrought-metal product capable of withstanding high and prolonged stress at elevated temperature consisting essentially as follows:

0.03–0.30% carbon
0.00–1.00% silicon
0.00–1.00% manganese
13.00–17.00% chromium
4.00–6.00% molybdenum
24.00–55.00% nickel
14.00–55.00% iron
1.50–5.00% aluminum
1.50–3.00% titanium
0.01–0.20% boron

3. The product of claim 2 which has been solution treated and aged.

4. A wrought-metal product capable of withstanding high and prolonged stress at elevated temperature consisting essentially as follows:

0.03–0.30% carbon
13.00–17.00% chromium
4.00–6.00% molybdenum
14.00–30.00% iron
1.50–5.00% aluminum
1.50–3.00% titanium
0.04–0.20% boron
Balance nickel

5. An alloy capable of being hot worked and withstanding high and prolonged stress at elevated temperature consisting essentially as follows:

0.05–0.20% carbon
0.10% (max.) manganese
0.60% (max.) silicon
14.00–17.00% chromium
4.00–6.00% molybdenum

24.00–26.0% iron
2.75–3.50% aluminum
1.75–2.50% titanium
5.00–6.00% aluminum and titanium combined
0.04–0.08% boron
Balance nickel

6. A sheet metal product capable of withstanding high and prolonged stress at elevated temperature consisting essentially as follows:

0.05–0.20% carbon
0.10% (max.) manganese
0.60% (max.) silicon
14.00–17.00% chromium
4.00–6.00% molybdenum
24.00–26.00% iron
2.75–3.50% aluminum
1.75–2.50% titanium
5.00–6.00% aluminum and titanium combined
0.04–0.08% boron
Balance nickel

7. A hot rolled sheet metal capable of withstanding high and prolonged stress at elevated temperature consisting essentially as follows:

0.03–0.30% carbon
13.00–17.00% chromium
4.00–6.00% molybdenum
14.00–30.00% iron
1.50–5.00% aluminum
1.50–2.50% titanium
0.04–0.20% boron
Balance nickel

8. A wrought-metal product capable of withstanding high and prolonged stress at elevated temperature consisting essentially as follows:

0.03–0.30% carbon
13.00–17.00% chromium
4.00–6.00% molybdenum
14.00–30.00% iron
1.50–5.00% aluminum
1.50–2.50% titanium
0.06–0.08% boron
Balance nickel

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