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2,968,549

HIGH STRENGTH ALLOY FOR USE AT ELEVATED TEMPERATURES

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4 Claims. (Cl. 75-126)

This invention relates to alloy steel possessing high strength at high temperatures and more particularly to alloys having high creep-rupture strengths at 1100° F. In certain industries such as steam-power generating and oil-refining, equipment is subjected to stress at temperatures of the order of 1100° F. for extended periods of time. While alloy steels suitable for such use have heretofore been made, the desired long-time (1000 hours) creep-rupture strength in excess of 40,000 p.s.i. at 1100° F. have only been obtainable by using a large proportion of expensive alloying elements or boron. In addition to the foregoing creep-rupture strength, steels for such use must possess a relatively good rupture ductility, i.e. of the order of 5 to 10% elongation per inch and also be readily forgeable by conventional methods into plates, bars, tubes, etc. While boron is beneficial for obtaining improved elevated temperature strength, it is necessary to use such quantities that the forgeability of the steels is reduced to such extent that such steels cannot be used for most applications. Accordingly it is an object of this invention to produce a high strength steel having good creep-rupture properties at elevated temperatures combined with good rupture ductility. It is another object of this invention to produce a high strength steel for use at elevated temperatures which is characterized by being readily forgeable. It is a further object to produce a steel having the foregoing with a minimum amount of alloying elements. We have discovered that a steel possessing the foregoing properties can be produced by combining with iron and carbon, chromium, molybdenum, vanadium, columbium and either tungsten or titanium as essential ingredients. The composition of our invention is balanced so that the steel will transform to martensite upon air cooling from austenitizing temperatures. The molybdenum, vanadium, columbium and a metal of the group consisting of tungsten or titanium are further balanced so that tempering of the martensitic microstructure produces a steel having a 1000-hour creep-rupture strength in excess of 40,000 p.s.i. at 110° F. Along with the fore-

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going elements, the steel contains sufficient chromium to provide good resistance to elevated temperature oxidation together with fair resistance to atmospheric corrosion.

In its broadest aspects, our steel should fall within the following chemical composition limits:

Carbon	0.05 to 0.30%.
Manganese	0.25 to 0.75%.
Phosphorus	0.04% max.
Sulphur	0.03% max.
Silicon	0.15 to 1.0%.
Chromium	1.0 to 5.0%.
Nickel	Up to 0.75%.
Molybdenum	0.50 to 3.50%.
Vanadium	0.15 to 1.0%.
Tungsten	0.15 to 1.0%.
or titanium	0.15 to 0.75%.
Columbium	0.15 to 0.75%.
Balance iron and residual amounts of other elements.	

We have found that preferably the molybdenum should be maintained at about 1.0% and when the steel contains more than about 0.35% titanium, the vanadium should be maintained below about .50%. Thus in its preferred form, the steel should fall within either of the following composition ranges:

Carbon	.18 to .27%.
Manganese	.35 to .65%.
Silicon	.35 to .65%.
Chromium	2.70 to 3.25%.
Nickel	.50% max.
Molybdenum	.85 to 1.15%.
Vanadium	.25 to .95%.
Columbium	.35 to .65%.
Tungsten	.55 to .90%.
or titanium	.35 to .65%.
Balance iron and residual amounts of other elements.	

For optimum properties, the above ranges should be more restricted as follows:

	A, percent	B, percent
Carbon	20/.25	.18/.22
Manganese	35/.55	.35/.55
Silicon	35/.55	.35/.55
Chromium	2.80/3.20	2.80/3.20
Nickel	.50 max.	.50 max.
Molybdenum	.80/1.10	.80/1.10
Vanadium	.73/.87	.19/.23
Columbium	.45/.55	.45/.55
Tungsten	.65/.85	0.
Titanium	0.	.45/.55
Balance iron and residual amounts of other elements.		

The composition of two steels conforming to the teachings of our invention are shown in the following Table I:

TABLE I
Composition of the new steel—percent
CHECK ANALYSES

Steel	C	Mn	P	S	Si	Cr	Mo	V	Ti	W	Cb
1	0.24	0.51	0.018	0.020	0.38	2.92	1.10	0.94	-----	0.77	0.47
2	0.21	0.55	0.018	0.020	0.49	2.98	1.13	0.44	0.32	-----	0.54

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The average room temperature properties of these steels are shown in Table II and the creep-rupture properties at 1100° F. are shown in Table III:

TABLE II

Average room temperature tensile properties of the new steel

Steel	Yield Strength (0.2% Offset), p.s.i.	Tensile Strength, p.s.i.	Elongation in 1 Inch, Percent	Reduction of Area, Percent
1.....	177,405	203,340	13.5	48.8
2.....	191,000	219,190	9.5	29.6

NOTE.—The steels were austenitized for ½ hour at 2,100° F., air-cooled to room temperature; tempered for one hour at 1,200° F. and water quenched to room temperature.

TABLE III

Creep rupture tests results for the new steel at 1100° F.

Steel	Stress, p.s.i., to Produce Rupture in—			Elongation in 1 Inch, Percent ²
	100 hr.	1,000 hr.	10,000 hr. ¹	
1.....	72,000	44,000	27,500	5.5
2.....	70,000	43,000	27,000	9.5

¹ Extrapolated data.

² Obtained from the specimen that ruptured after the longest exposure time at 1,100° F.

NOTE.—The steels were austenitized for ½ hour at 2,100° F., air-cooled to room temperature; tempered for one hour at 1,200° F. and water quenched to room temperature.

The data presented in Tables II and III show that after tempering at 1200° F., the steel of our invention exhibits room temperature tensile strengths in the range of 166,000 to 203,000 p.s.i., elongations in the range of 9 to 15 percent, and a 1000-hour creep-rupture strength in excess of 40,000 p.s.i., at 1100° F. The rupture ductility of the steels after creep-rupture testing at 1100° F. are in the range of 5 to 1 percent.

As was mentioned earlier, our steel contains either tungsten or titanium. However, when the steels contain both tungsten and titanium, they do not develop the minimum desired properties. For example, the compositions of two steels investigated that contain both tungsten and titanium are shown in Table IV, and their creep-rupture strengths at 1100° F. are shown in Table V.

TABLE IV

Chemical composition of the steels investigated—percent

CHECK ANALYSES

Steel	C	Mn	P	S	Si	Cr	Mo	V	W	Ti	Cb
A.....	0.25	0.50	0.032	0.020	0.58	2.90	0.94	0.27	0.70	0.63	0.51
B.....	0.21	0.56	0.020	0.020	0.59	2.88	1.13	0.89	0.74	0.52	0.49

TABLE V

Creep-rupture test results for the new steels

Steel	Stress, p.s.i. for Rupture in—		Elongation in 1 Inch, percent ²
	100 hr.	1,000 hr. ¹	
A.....	41,000	35,000	25.0
B.....	34,000	27,000	30.0

¹ Extrapolated data.

² Obtained from the specimen that ruptured after the longest exposure time at 1100° F.

NOTE.—The steels were austenitized for ½ hour at 2100° F., air cooled to room temperature, tempered for one hour at 1100° F., and water quenched to room temperature.

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While we have shown and described several specific embodiments of our invention, it will be understood that these embodiments are merely for the purpose of illustration and description and that various other forms may be devised within the scope of our invention, as defined in the appended claims.

We claim:

1. A steel alloy characterized by high creep-rupture properties at 1100° F., and said steel containing

	Percent
Carbon	0.05 to 0.30
Manganese	0.25 to 0.75
Phosphorus	0.04 max.
15 Sulphur	0.03 max.
Silicon	0.15 to 1.0
Chromium	1.0 to 5.0
Nickel	Up to 0.75
Molybdenum	0.50 to 3.50
20 Vanadium	0.15 to 1.0
Columbium	0.15 to 0.75

and an element selected from the group consisting of titanium and tungsten, said element being present in an amount between 0.15 and 0.75 when said element is titanium and between 0.15 and 1.0 when said element is tungsten.

Balance iron and residual amounts of other elements.

2. A steel alloy characterized by high creep-rupture properties at 1100° F., said steel containing

	Percent
Carbon	.18 to .27
Manganese	.35 to .65
35 Silicon	.35 to .65
Chromium	2.70 to 3.25
Nickel	.50 max.
Molybdenum	.85 to 1.15
Vanadium	.25 to .95
40 Columbium	.35 to .65

and an element of the group consisting of tungsten and titanium, said element being present in an amount between 0.35 to 0.65 when said element is titanium and between 0.55 and 0.90 when said element is tungsten.

Balance iron and residual amounts of other elements.

3. A steel alloy characterized by high creep-rupture properties at 1100° F., said steel containing

	Percent
Carbon	.20 to .25
65 Manganese	.35 to .55
Silicon	.35 to .55
Chromium	2.80 to 3.20
Nickel	.50 max.
Molybdenum	.80 to 1.10
70 Vanadium	.73 to .87
Columbium	.45 to .55
Tungsten	.65 to .85
Titanium	0

75 Balance iron and residual amounts of other elements.

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4. A steel alloy characterized by high creep-rupture properties at 1100° F., said steel containing

	Percent	
Carbon -----	.18 to .22	
Manganese -----	.35 to .55	5
Silicon -----	.35 to .55	
Chromium -----	2.80 to 3.20	
Nickel -----	.50 max.	
Molybdenum -----	.90 to 1.10	
Vanadium -----	.19 to .28	10
Columbium -----	.45 to .55	
Tungsten -----	0	
Titanium -----	.45 to .55	
Balance iron and residual amounts of other elements.		

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References Cited in the file of this patent

Smith: Chromium-Molybdenum and Chromium-Molybdenum-Vanadium Steels for Power Plant and Refinery Service up to 1100° F.: An Appraisal of the Literature. Reprint of 1956 ASME paper by Climax Molybdenum Co., New York, N.Y.

UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 2,968,549

January 17, 1961

Richard R. Brady et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 55, for "110° F." read -- 1100° F. --;
column 3, line 40, for "1 percent" read -- 10 percent --;
column 4, line 24, for "amont" read -- amount --; line 43,
for "to" read -- and --.

Signed and sealed this 6th day of June 1961.

(SEAL)

Attest:

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