United States Patent Office

2,805,153

Patented Sept. 3, 1957

2,805,153

HIGH TENSILE VANADIUM ALLOYS

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No Drawing. Application April 4, 1955, Serial No. 499,229

8 Claims. (Cl. 75—134)

The present invention is directed to improvements in high tensile alloys, and is more specifically directed to alloys containing substantial amounts of vanadium.

Substantially pure vanadium metal has only a fair tensile strength and only a fair amount of ductility, as evidenced from the following table which illustrates typical mechanical properties of substantially pure vanadium:

TABLE I

At room temperature:

Ultimate tensile strength	49,100 p. s. i.
Reduction in area	2.4%.
Elongation	6.0%.
Modulus of elasticity	19.7×10^6 p. s. i.
Hardness	182 VHN.
Ultimate tensile strength at 700° C.	25,500 p. s. i.
Ultimate tensile strength at 900° C.	15,320 p. s. i.

The tensile strength of substantially pure vanadium is considerably lower than other metals and alloys used for structural elements, as evidenced from the following comparison with various commonly employed alloys:

TABLE II

Composition	Temp., °C.	Ultimate Tensile Strength, p. s. i.
Steel containing 13% Ni, 13% Cr, 2.5% W, 2% Mo, 3% Cb, 1% C, 0.4% C	700	56,000
	900	28,000
Steel containing 25% Cr, 15% Ni	700	44,600
Steel containing 20% Cr, 30% Ni, 1.5% Ti	700	58,600
60% Co, 28% Cr, 6% Mo, 3% Ni, 2% Fe, 0.25% C	732	79,300
	926	32,900
45% Co, 20% Ni, 20% Cr, 4% Cb, 4% W, 4% Fe, 3% Mo, 0.47% C	732	98,900
	926	48,180
80% Co, 28% Cr, 9% Ta	900	25,000
63% Co, 28% Cr, 9% Ta	900	38,800
45% Ni, 24% Fe, 22% Cr, 0.15% C	700	70,000
	900	28,000
76% Ni, 20% Cr, 2.5% Ti, 1.25% Al	700	50,000
Mo	700	42,000
	900	33,000

It has now been determined that the addition of substantial amounts of titanium, and lesser amounts of chromium, silicon, or aluminum very substantially increases the tensile strength of the vanadium both at room temperature and at elevated temperatures. The alloys of the present invention, in their broader ranges, provide a titanium content of from about 20 to about 50% by weight, an amount of silicon, chromium, or aluminum in amounts up to 10% by weight, and the balance being substantially all vanadium, with the usual impurities.

Preferably, the titanium content is in the range from about 40% to 50%, the chromium content is preferably from 5 to 10%, the aluminum content is preferably 5 to 10%, and the silicon content is preferably from 1 to 5%.

An object of the present invention is to provide an improved series of vanadium base alloys having excellent tensile strength properties.

Another object of the invention is to provide vanadium base alloys containing substantial amounts of titanium, together with other additives which increase the tensile strength of the alloy without substantially reducing its ductility.

Another object of the invention is to provide vanadium-titanium alloys which have good tensile strength properties even at highly elevated temperatures, making them useful for structural elements in jet engines, and in similar high temperature environments.

The metallic vanadium employed in making the alloys of the present invention was produced by the calcium reduction of vanadium pentoxide. The metal employed had a sufficiently low concentration of interstitial compounds and metallic impurities to permit severe mechanical deformation, both in the hot and cold condition. The chemical analysis of the vanadium indicated that the carbon content was about 0.077%, oxygen 0.056%, nitrogen 0.086%, and hydrogen 0.002%.

All alloys were produced by melting of the elemental components in the proper proportions in a non-consumable electrode, water cooled, copper crucible arc melting furnace. Cast ingots of the alloy were forged to one-half inch diameter rods for machining directly to tensile test pieces.

Shoulder type tensile test pieces were machined from one-half inch diameter forged rods to a test diameter of 0.252 inch, a gauge length of one inch, and an overall length of three inches. Testing was performed in a conventional Baldwin-Southwark, hydraulically operated, universal testing machine. At temperatures above 500° C., the alloys were protected from oxidation by providing an upward current of argon gas around the test piece.

In substantially all cases, the addition of small, controlled amounts of chromium, silicon, or aluminum significantly increased the tensile strength of the vanadium-titanium alloy without significantly decreasing the ductility of the alloy. In many cases, the ductility was significantly improved by the addition of one of more of the three named elements.

As an example of the foregoing, an alloy consisting solely of 80% vanadium and 20% titanium had a measured ultimate tensile strength of about 95,000 pounds per square inch at room temperature. The addition of 5% aluminum, in replacement of a corresponding amount of vanadium, brought the ultimate tensile strength, at room temperature to about 130,000 pounds per square inch. Similarly, an alloy of 70% vanadium and 30% titanium had an ultimate tensile strength of 112,000 pounds per square inch which was raised to a value of 140,000 pounds per square inch upon the addition of 5% aluminum in replacement of a corresponding amount of the vanadium. In the case of chromium, the addition of 5% chromium to a vanadium-titanium alloy containing 20% titanium raised the tensile strength to 114,600 p. s. i. at room temperature. The addition of only 1% silicon to a vanadium-titanium alloy containing 30% titanium was effective to raise the ultimate tensile strength at room temperature to 126,400 p. s. i.

The substantial improvements achieved in the tensile properties of the alloys of the present invention are illustrated in the following table at various titanium contents, and at various contents of the third metal, the balance of the alloy in each case being substantially pure vanadium:

TABLE III

Composition	T.° C.	Ultimate Tensile Strength, p. s. i.	Elongation, percent	Reduction in Area, percent
20Ti-5Cr	Room Temp.	114,600	28.1	21.8
20Ti-5Cr	700	91,800	18.3	18.8
20Ti-5Cr	900	56,000	14.1	12.7
30Ti-5Cr	900	43,200	29.7	10.0
40Ti-5Cr	Room Temp.	131,000	12.5	6.0
40Ti-5Cr	700	90,200	14.1	8.8
40Ti-5Cr	900	38,000	17.2	11.1
50Ti-5Cr	Room Temp.	130,000	9.4	9.6
50Ti-5Cr	700	66,200	17.2	7.2
50Ti-10Cr	Room Temp.	153,600	4.0	7.1
50Ti-10Cr	700	82,900	7.0	4.2
50Ti-10Cr	900	31,800	31.3	15.5
30Ti-1Si	Room Temp.	126,400	12.5	10.8
40Ti-1Si	Room Temp.	131,000	18.8	25.0
50Ti-1Si	Room Temp.	132,000	14.0	15.4
50Ti-2Si	Room Temp.	150,000	12.5	17.5
50Ti-5Si	Room Temp.	160,200	4.7	2.8
50Ti-5Si	700	94,400	60.9	36.9
50Ti-5Al	Room Temp.	126,000	17.2	25.2
50Ti-5Al	700	84,600	12.5	15.3
50Ti-5Al	900	19,200	96.8	>95
50Ti-10Al	700	104,000	26.2	46.1
50Ti-10Al	900	20,200	103.1	>95
40Ti-5Al	700	96,600	9.4	16.7
40Ti-5Al	900	35,200	28.2	25.2

From the foregoing, it will be evident that the alloys of the present invention exhibit excellent tensile strength both at room temperatures and at elevated temperatures on the order of 700 or 900° C. At the same time, the ductility of the vanadium alloy does not appear to be adversely affected by the addition of the elements aluminum, silicon, or chromium, and in many cases the ductility is improved by the addition.

It will be evident that various modifications can be made to the described embodiments without departing from the scope of the present invention.

I claim as my invention:

1. A high tensile strength alloy containing titanium in amounts from 20 to 50% by weight, a significant amount of a metal selected from the group consisting of aluminum, silicon, and chromium in amounts up to 10% by weight, and the balance being substantially all vanadium.

2. A high tensile strength alloy containing titanium in amounts from about 40% to about 50% by weight, a significant amount of a metal selected from the group consisting of aluminum, silicon, and chromium in amounts up to 10% by weight, and the balance being substantially all vanadium.

3. A high tensile strength alloy containing titanium in amounts from 20 to 50% by weight, chromium in amounts from 5 to 10% by weight, and the balance being substantially all vanadium.

4. A high tensile strength alloy containing titanium in amounts from 20 to 50% by weight, aluminum in amounts from 5 to 10% by weight, and the balance being substantially all vanadium.

5. A high tensile strength alloy containing titanium in amounts from 20 to 50% by weight, silicon in amounts from 1 to 5% by weight, and the balance being substantially all vanadium.

6. A high tensile strength alloy containing titanium in amounts from 40 to 50% by weight, chromium in amounts from 5 to 10% by weight, and the balance being substantially all vanadium.

7. A high tensile strength alloy containing titanium in amouts from 40 to 50% by weight, aluminum in amounts from 5 to 10% by weight, and the balance being substantially all vanadium.

8. A high tensile strength alloy containing titanium in amounts from 40 to 50% by weight, silicon in amounts from 1 to 5% by weight, and the balance being substantially all vanadium.

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