April 22, 1969 YOSHIRO ARAKI 3,440,038

HIGH TENACITY CHROMIUM-NICKEL MANGANESE AUSTENITIC STEEL

Filed Jan. 18, 1966

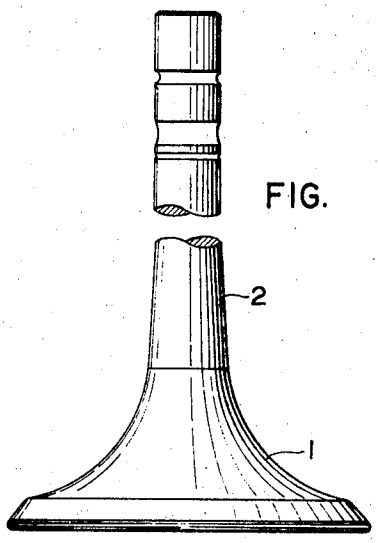


FIG. 1

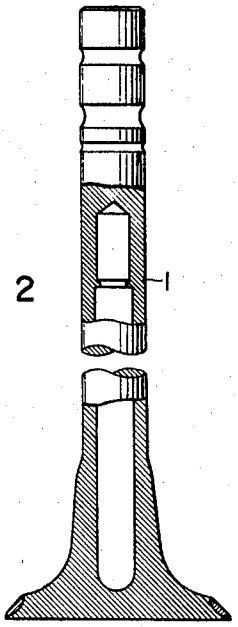


FIG. 2

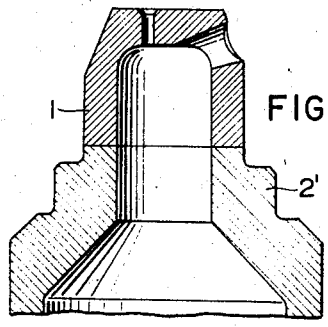


FIG. 3

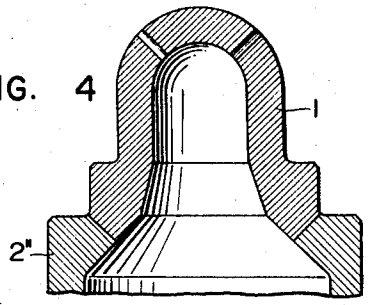


FIG. 4

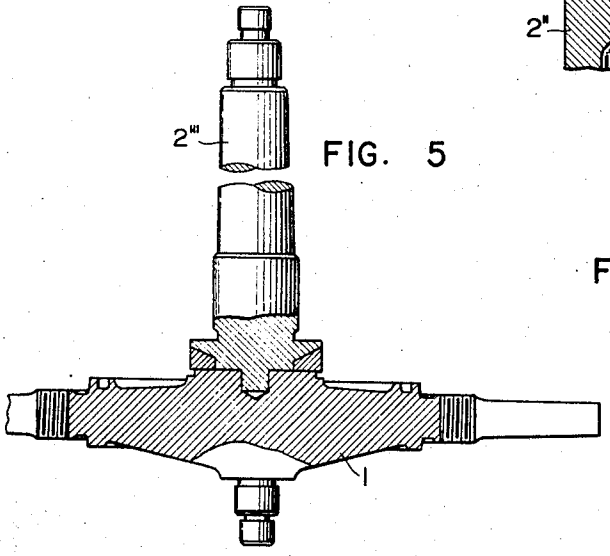


FIG. 5

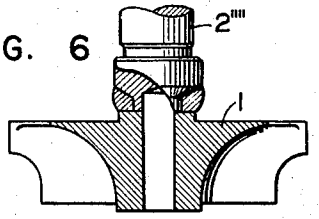


FIG. 6

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HIGH TENACITY CHROMIUM-NICKEL MANGANESE AUSTENITIC STEEL

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Int. Cl. C22c 41/02, 39/26, 39/44
U.S. Cl. 75—128 4 Claims

ABSTRACT OF THE DISCLOSURE

The austenitic steel alloys of high tensile strength contain 0.31 to 0.57% C, 0.11 to 1.91% Si, 6.4–11.9% Mn, 6.1 to 11.1% Ni, 16.0 to 22.0% Cr, 0.40 to 2.10% W, 0.09 to 0.59% N, 0.0051 to 0.22% B, 0.01 to 0.12% S, and Fe, the total of Mn and Ni being 12.0 to 19% and the total of C, Si, W, N, S and B being 1.4 to 4.2%. These alloys are particularly stable with respect to heat and have excellent processability characteristics.

This invention relates to new and improved high tenacity austenitic steels.

The heat-resistant steels of the prior art, to be employed for exhaust valves of internal combustion engines, for turbine blades and for the like are generally deficient in at least one respect. Among the shortcomings of the heat-resistant steels of the prior art are the following: extreme lowering of the mechanical properties at high temperatures, especially at temperatures of about 750° C.; poor processability, especially machinability, forgeability and weldability; only a few of these steels are both very highly oxidation-resistant at high temperatures and very highly corrosion-resistant to PbO; the steels possessing a convenient hardness have poor tenacity and low elongation; and poor fatigue resistance at high temperatures. Furthermore, previous solutions of the foregoing shortcomings have been highly uneconomical. A major object of this invention is to provide a highly economical, high tenacity austenitic steel of general utility, which is also heat-resistant, and which has none of the shortcomings referred to above.

In the description of the invention which follows and in the claims, all proportions are given by weight based on the total weight of the steel and all elements and compounds are referred to by their common chemical abbreviation (such as Mn for manganese, Ni for nickel, Cr for chromium, NiS for nickel sulfide, etc.) rather than by their full name. Since the steels of the present invention are alloys they will frequently herein so be referred to.

FIGS. 1 and 2 each show an engine valve incorporating alloy of the present invention;

FIGS. 3 and 4 each show a precombustion chamber mouth piece of a diesel engine incorporating alloy of the present invention;

FIG. 5 shows a turbine rotor made of an alloy of the present invention, mounted on a shaft;

FIG. 6 shows a turbocharger blade made of an alloy of the present invention, mounted on a shaft.

According to the present invention, Mn is found to be desirable to elevate the stability of the austenite and simultaneously to increase the solid solubility of other elements added. By incorporating Mn in an amount not higher than 6.4% the formation of carbide is aided and the tenacity and heat-rollability of the product are improved. Ni is found to be desirable in an amount of 6.1%–11.1%, as by the presence thereof jointly with Mn the favorable effects of the Mn are augmented and

the strength at both high and low temperatures is substantially improved. Because of the presence of the Ni, the amount of Mn used is less than 11.9%.

Cr forms double carbides. However, it is found desirable to incorporate only 16.0–22.0% Cr, which is sufficient for the attainment of good oxidation resistance.

W forms the M_6C, $M_{23}C_6$ series of carbides, where the metallic (M) portion includes Fe.Cr.W or Fe.Cr.W.Mo or the like, when the steel is heat treated. It is found desirable to incorporate an amount of W of up to 2.1%.

It is found that N and C together increase the hardness and strength of the steel and that the presence of Mn elevates the solid solubility of the N. It is found that suitable amounts of N are 0.09 to 0.59% and of C are 0.31 to 0.57%.

As Si greatly increases the acid-resistance at high temperatures, the addition of a small amount thereof is found to be desirable; however, because it has the tendency to substantially reduce the strength of the steel at high temperatures and, generally, when the amount of Si is great, the resistance to PbO corrosion, which resistance is necessary for a valve steel, is greatly lowered, in the alloy of this invention it is found that a suitable amount of Si is low, only 0.11–1.91%, so that the resistance to PbO corrosion is not reduced.

B greatly improves the hardenability of the steel. In the alloy of this invention, it is found desirable to use more B than in common heat resistant steel; however, it is also found desirable that the amount of B should not be so great as to cause excessive hardness and brittleness upon heat treatment of the steel. Accordingly, the amount of B found desirable is 0.0051–0.22%. Good carbide formation also results.

The incorporation of 0.01–0.12% S is found to give good machinability to the alloys of this invention after the heat-treatment, and by the presence of Mn the formation of noxious sulfides, such as CrS, FeS, NiS and the like, is prevented and innoxious MnS is stably produced.

Mo, with W, is found to efficiently form fine carbides; but, as it is found to have a tendency to greatly reduce the acid-resistance of the steel at temperatures above 800° C., less than 1.2% of Mo is used.

Below 0.45% total of Nb and/or Ta may be used according to the present invention because they promote the stabilization of the carbides and regulation of the crystal grains.

By the addition of a small amount of other elements according to the invention, namely, of Ti, Al, Cu and V, the hardening of the steel may be improved and, as Al also increases the oxidation-resistance, the addition of less than 3% total of these elements is advantageous.

In order to best coordinate the effect of the added elements, it is found that the following relations should obtain: Mn+Ni=12.0–19.0% and

$$C+Si+W+N+S+B=1.4\text{–}4.2\%$$

The balance of the steel of the present invention is Fe.

By a convenient heat-treating of the alloy of this invention excellent tenacity and processability thereof are obtained. The heat-treatment constitutes heating the alloy to a temperature of 1020–1180° C. and holding it at this elevated temperature for about one hour and thereafter cooling it, for example with water, to 700–780° C. and holding it at that temperature for 4–24 hours.

In the drawings **1** indicates steel of this invention and 2, 2′, 2″, 2‴, and 2⁗ indicate heat-resistant steels of the prior art.

FIGURE 1 shows an engine valve joined by resistance welding to a valve body made of an alloy of this invention **1** with a valve rod made of a prior art heat-resistant steel **2**, such as SEH 3 or the like. SEH 3 is the Japanese

code for a steel which is 0.35–0.45% C., 1.80–2.50% Si, no more than about 0.6% Mn, 10–13% Cr, 0.70–1.30% Mo, no more than about 0.03% P, no more than about 0.03% S and the balance Fe.

FIGURE 2 represents an engine valve made of an alloy of this invention, applied with a stellite padding on a valve rod end, and a valve body working surface, the valve body also being made of an alloy of this invention.

FIGURES 3 and 4 show a precombustion chamber mouth piece of a disesel engine made by resistance welding a mouth piece composed of alloy of this invention to a base seat of low alloy steel such as S 45C, SCM 3 or the like and by adjoining the other parts therewith.

FIGURE 5 shows a turbine rotor made of the alloy of this invention with a shaft of low alloy steel such as S 45C, SCM 3 or the like. FIGURE 6 is a turbocharger blade obtained by fixing a blade made of the alloy of this invention to a shaft of S 45C, SCM 3 or the like. The alloy of the present invention is useful for all types of service, such as for use as a non-magnetic material or as a heat-resistant material. S 45C and SCM 3 are Japanese codes for steels. S 45C is 0.50–0.60% C, 0.15–0.40% Si, 0.40–0.80% Mn, no more than 0.45% P, no more than 0.45% S and the balance Fe. SCM 3 is 0.33–0.38% C, 0.15–0.35% Si, 0.60–0.85% Mn, 0.90 to 1.20% Cr, 0.15–0.35% Mo, no more than 0.03% P, no more than about 0.03% S and the balance Fe.

SEH 4 is the Japanese code for an austenitic heat-resistant steel which is 0.35–0.45% C, 1.50–2.50% Si, no more about 0.6% Mn, 13.0–15.0% Ni, 14.0–16.0% Cr, 2.0–3.0% W, no more than 0.03% P, no more than about 0.03% S and the balance Fe.

In perfect austenitic steel, fissures are easily originated at high temperatures by the production of CrS; but in the alloys of the present invention, even if the amount of S is increased, CrS is not produced, that is, although they are not ferrite, the alloys of this invention are fissure-resistant. Furthermore, the alloys of this invention contain no sigma phase, the presence of which would be detrimental. They also possess good mechinability due to the presence of MnS instead of CrS.

The alloys of this invention possess good processability in all respects and the machinability thereof is so good that they are able to be turned at the rate of 160 m./min. Also, their weldability is good and friction welding thereof is possible. Furthermore, surface-treatment thereof, such as metal plating, nitriding, cementation and the like, is easy, and they are excellent also in their ability to be heat-rolled.

The compositions and properties of seven specific alloys according to this invention (*a* to *g*) are set forth separately in Tables 1 and 2 respectively. In Table 1, the proportions of elements are by weight percentage of the total and the unlisted balance to make 100% is Fe.

TABLE 1

	C	Si	Mn	Ni	Cr	W	N	S	Mo	Nb+Ta	P	B
(a)	0.34	0.19	9.01	8.10	21.2	0.71	0.34	0.021			0.031	0.007
(b)	0.43	0.24	7.08	7.27	18.8	0.55	0.33	0.036			0.020	0.009
(c)	0.51	0.26	8.70	6.31	19.9	1.02	0.24	0.045			0.031	0.016
(d)	0.53	0.57	8.93	6.84	20.1	1.46	0.36	0.036		0.29	0.022	0.102
(e)	0.49	0.17	9.55	7.51	20.5	0.99	0.35	0.124	0.52	0.38	0.014	0.189
(f)	0.46	1.12	7.90	9.21	20.2	1.01	0.40	0.050	0.85		0.019	0.011
(g)	0.46	1.90	8.11	7.96	21.3	1.11	0.19	0.013	1.12		0.020	0.009

TABLE 2

	Tensile strength, kg./mm.²		Elongation, percent, 20° C.	Impact value, kgm./cm.², 20° C.	Hardness (Rc), 20° C.	Oxidation weight increase, gr./m². 900 °C./100 h.	PbO weight decrease, gr./dm.²/h. 920° C.	Creep rupture strength, kg./mm.², 700° C./1,000 h.
	20° C.	800° C.						
(a)	97.1	39.8	36.0	6.1	27.2	21.1	12.2	12.9
(b)	101.3	40.3	33.4	5.5	29.6	22.2	13.0	13.8
(c)	103.1	40.6	33.6	4.6	30.3	19.3	13.1	13.5
(d)	101.8	40.2	31.2	4.3	31.7	16.1	28.9	12.9
(e)	101.1	41.2	35.1	5.2	32.1	15.9	10.2	13.9
(f)	99.1	40.8	32.1	5.1	30.0	14.8	48.2	13.6
(g)	98.2	39.0	32.9	5.2	28.1	16.7	49.7	11.0

Alloys of the present invention, heat-treated as described above, have a tensile strength of about 99±4 kg./mm.² at room temperature, a tensile strength of about 40±3 kg./mm.² at 800° C., an impact value of above 4 kgm./cm.², and an elongation of above 25%, and can be stretched at room temperature.

The carbide formed by the heat-treatment, having $M_{23}C_6$ as a core, is very stable; the properties thereof undergo essentially no change even if it is heated up to 750° C. for 1000 hours.

Alloys of the present invention are perhaps lower in hardness than heat-resistant valve steels of the prior art; however, the strength and hardness of the alloys of this invention decrease little at high temperatures and they have outstanding abrasion-resistance.

Alloys of this invention undergo only a small increase of oxidation in the atmosphere at 800° C. as compared with room temperature; thus, for example, this increase is only one-half that which the austenitic heat-resistant valve steel disclosed in U.S. Patent No. 2,657,130 undergoes. Also, the alloys of this invention undergo only a very small loss by corrosion into molten PbO at 1000° C.; for example, the loss is as small as one-twentieth that of SEH 4 heat-resistant steel. Furthermore, in the alloys of this invention, although the oxidation-resistance is notably elevated by the presence of Si, the lowering of corrosion-resistance to PbO caused thereby is very small.

The invention is not to be construed as limited to the particular forms described herein, since these are to be regarded as illustrative rather than restrictive.

What I claim and desire to secure by Letters Patent is:

1. A high tenacity austenitic steel consisting essentially of 0.31 to 0.57% C, 0.11 to 1.91% Si, 6.4–11.9% Mn, 6.1 to 11.1% Ni, 16.0 to 22.0% Cr, 0.40 to 2.10% W, 0.09 to 0.59% N, 0.0051 to 0.22% B, 0.01 to 0.12% S, and Fe, the total of Mn and Ni being 12.0 to 19% and the total of C, Si, W, N, S and B being 1.4 to 4.2%.

2. A high tenacity austenitic steel according to claim **1**, further containing Mo in an amount no greater than 1.2%.

3. A high tenacity austenitic steel according to claim **1**, further containing at least one of Nb and Ta, in a total amount no greater than 0.45%.

4. A high tenacity austenitic steel according to claim **1**, further containing at least one of Ti, Al, Cu and V in a total amount no greater than 3%.

References Cited

UNITED STATES PATENTS

2,602,738	7/1952	Jennings.	
2,801,916	8/1957	Harris	75—128.4
3,306,736	2/1967	Rundell.	

HYLAND BIZOT, *Primary Examiner.*