

UNITED STATES PATENT OFFICE

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HIGH TEMPERATURE ALLOY STEEL AND ARTICLES MADE THEREFROM

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The present invention relates to high temperature alloy steels and articles made therefrom and, more particularly, to an alloy steel and articles having good load-carrying ability at high temperatures.

In relatively recent years, various machines have been developed, such as gas turbines, superchargers and jet-propelled aircraft, etc., in which various parts are subjected to dynamic stresses which are fairly high and which must be withstood at high temperatures over a considerable period of time. Such machines will not perform their functions successfully unless they can operate at much higher stresses and/or temperatures than were believed practicable a few years ago. The life of a supercharger or gas turbine, for example, is necessarily limited by the load-carrying ability of the parts which are subjected to stress at high temperatures. Such parts are also required to resist the corrosive attack of combustion gases at the high temperatures encountered in use.

I have discovered an alloy having unique and exceptionally good load-carrying abilities at high temperatures and which, therefore, is exceptionally adapted for the uses mentioned above, and other kindred uses. The alloy which I have provided contains as essential alloying constituents silicon, manganese, chromium, nickel, molybdenum, tungsten and titanium, together with carbon in certain balanced proportions which I have found required to produce the desired load-carrying ability at high temperatures. More specifically, I have discovered that, by employing a balanced combination of three alloying elements, namely, tungsten, molybdenum and titanium, in relatively small amounts in an austenitic matrix, an alloy has resulted which, while possessing exceptionally high resistance to stresses at high temperatures, is, nevertheless, an alloy which can be readily worked both hot and cold and fabricated in the mill with a minimum of loss and which has a considerable ductility and resistance to shock and stability against age hardening. The alloy which I provide has a predominant austenitic matrix with minor percentages of ferrite and carbides. In my novel alloy, the desired balance between the antithetical properties of high resistance to deformation and rupture on the one hand, and of ductility on the other hand, may be controlled by varying the percentages of the austenite formers, carbon, manganese and nickel, on the one hand, and of the ferrite formers, molybdenum, silicon, chromium, tungsten and titanium, on the other hand.

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The steel which I provide has carbon and alloying constituents within the following ranges:

Carbon	.10-.50
Manganese	.20-3.00
5 Silicon	.20-3.00
Chromium	15.00-25.00
Nickel	5.00-25.00
Molybdenum	.50-4.00
10 Tungsten	.50-4.00
Titanium	.10-2.00
Sulphur	.40 max.
Phosphorous	.20 max.

In practice, I prefer that the alloy have constituents within the following preferred ranges:

Carbon	.28-.35
Manganese	.75-1.50
Silicon	.30-.80
Chromium	18.00-21.00
20 Nickel	8.00-11.00
Molybdenum	1.00-2.00
Tungsten	1.00-2.00
Titanium	.40-.90
Sulphur	.40 max.
25 Phosphorous	.20 max.

A typical analysis of my alloy is as follows:

Carbon	.30
Manganese	1.25
30 Silicon	.55
Chromium	19.00
Nickel	9.00
Molybdenum	1.50
Tungsten	1.25
35 Titanium	.60
Sulphur	.04
Phosphorous	.03

The alloy of my invention can be readily formed into desired shapes by forging, rolling and casting.

When properly fabricated and treated, this material has the following properties, among others:

- (a) High temperature load-carrying ability through 1350° F., which, so far as I am aware, is exceeded by no known wrought materials which do not contain at least one other alloying element and which is only equalled by analyses of much higher alloy content.
- (b) High temperature load-carrying ability through 1500° F.
- (c) Suitability for low stress service through 1800° F.
- (d) It is susceptible to the effects of cold-work or hot-cold-work to produce exceptionally high

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strengths. Load-carrying ability is also improved from the hot-worked condition by solution treatments at high temperatures.

(e) It is not susceptible to precipitation hardening effects to any appreciable degree and possesses a high degree of surface and structural stability.

(f) It may be softened, i. e., annealed, by rapid cooling from high temperatures. A stress-relief anneal at intermediate temperatures preserves the as-worked properties and promotes machinability.

(g) It is quite readily machinable, exceeding many of the more familiar austenitic alloys in this characteristic.

(h) Adequate surface oxidation resistance is obtained through 1800° F. It is quite resistant to grain boundary oxidation, and the fine grain structure is retained at elevated temperatures.

(i) It possesses a high degree of resistance to both reducing and oxidizing corroding media and by heat treatment can be made resistant to intergranular attack.

(j) It is readily workable and can be formed into various shapes commonly used.

(k) It possesses a good balance of elastic strength and ductility at both room temperature and at high temperatures. Sufficient ductility is retained even after prolonged exposure under load at elevated temperatures and relatively high impact characteristics are also maintained.

Alloys coming within the composition ranges specified above will vary somewhat as regards physical properties, depending not only on processing variables, but also on the balance of the two general classes of alloying elements within the compositions, namely, carbide and ferrite formers and austenite formers. The carbide and ferrite formers are chromium, molybdenum, tungsten, titanium and silicon. An increase in any or all of these ferrite and carbide formers tends to promote the presence of ferrite which enhances certain of the metallurgical properties. The austenite formers, namely, carbon, nickel and manganese, are effective in forming austenite in the order named. An increase in any or all of these austenite formers tends to inhibit the presence of ferrite and insure a uniform structure of austenite and carbides, and, therefore, enhances certain of the metallurgical properties. The remainder of the various analyses set forth above is substantially iron and elements which are not subversive to the action of the essential alloying elements there enumerated in producing good load-carrying ability at elevated temperatures. The balance may be substantially commercial steel which may contain the usual impurities, residuals or minor amounts of alloying elements coming from the scrap or introduced during the melting, deoxidation, etc. of the alloy. The usual impurities, residuals or minor amounts of alloying elements are not subversive to the action of the essential alloying elements above enumerated in producing good load-carrying ability at elevated temperatures.

The alloy can be made in accordance with the usual melting practice of the alloy steel industry. The usual practice is to cast the metal into ingots and forge or roll it into billets or slabs. The billets and slabs are then hot formed into the desired shapes which are then stress-relieved

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by soaking at intermediate temperatures or annealed by rapid cooling from high temperatures. By stress-relieving is meant the heating through of the entire section to arrive at a uniform temperature. This standard treatment has been found to increase the machinability of the alloy over the as-worked or annealed condition.

While this alloy can be readily forged, rolled and machined in the making of machine parts, it also may be made into castings.

While I have specifically described preferred embodiments of my invention, it is to be understood that the invention is not so limited but may be otherwise embodied or practiced within the scope of the following claims.

I claim:

1. An alloy steel characterized by high load-carrying ability at elevated temperatures and containing carbon .28 to .35%, manganese .75 to 1.5%, silicon .30 to .80%, chromium 18.0 to 21.0%, nickel 8.0 to 11.0%, molybdenum 1.0 to 2.0%, tungsten 1.0 to 2.0%, titanium .40 to .90%, sulphur .40% maximum and phosphorous .20% maximum, the balance being all iron except for incidental impurities.

2. An alloy steel characterized by high load-carrying ability at elevated temperatures and containing carbon .30%, manganese 1.25%, silicon .55%, chromium 19.0%, nickel 9.0%, molybdenum 1.5%, tungsten 1.25%, titanium .60%, sulphur .04% maximum and phosphorous .03% maximum, the balance being all iron except for incidental impurities.

3. An alloy steel characterized by high load-carrying ability at elevated temperatures and containing carbon .28 to .35%, manganese .75 to 1.5%, silicon .30 to .80%, chromium 18.0 to 21.0%, nickel 8.0 to 11.0%, molybdenum 1.0 to 2.0%, tungsten 1.0 to 2.0%, titanium .40 to .90%, sulphur .40% maximum and phosphorous .20% maximum, the balance being all iron except for incidental impurities, said steel having a structure consisting predominantly of an austenitic matrix, together with minor proportions of ferrite and carbide and characterized by great resistance to deformation and rupture under load at high temperatures, together with retention of ductility under load.

4. Articles which require high load-carrying ability at elevated temperatures formed from an alloy containing carbon .28 to .35%, manganese .75 to 1.5%, silicon .30 to .80%, chromium 18.0 to 21.0%, nickel 8.0 to 11.0%, molybdenum 1.0 to 2.0%, tungsten 1.0 to 2.0%, titanium .40 to .90%, sulphur .40% maximum and phosphorous .20% maximum, the balance being all iron except for incidental impurities.

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