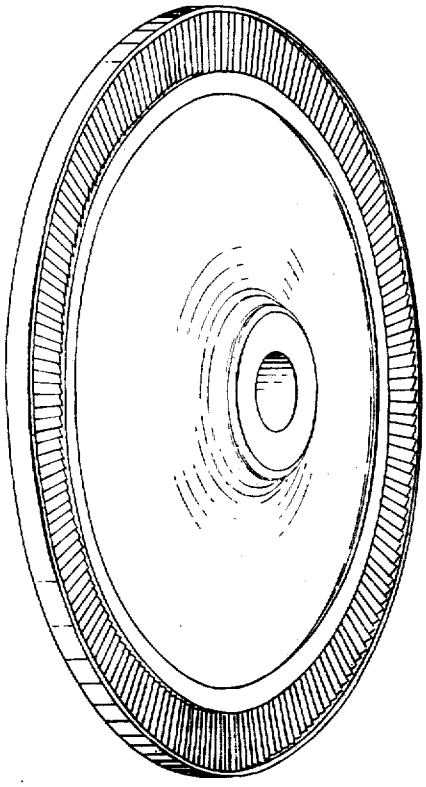
Dec. 3, 1957 W. C. CLARKE, JR 2,815,280

ALLOY STEEL AND ARTICLE MADE THEREFROM

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Chromium 9%—14%
Manganese 4%—20%
Nickle 4%—10%
Phosphorus .15%—.35%
Carbon .10%—.40%
Iron, Remainder

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ALLOY STEEL AND ARTICLE MADE THEREFROM

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This invention relates to stainless steel and more particularly to stainless steel employing a low content of strategic alloy elements. It also relates to certain articles of manufacture fashioned of the same.

Among the objects of my invention is the possession of a stainless steel which is strong and tough, both at room temperatures and at high temperatures, which avoids the necessity for hot-cold forging operations, and which is hardenable by heat treatment to achieve the desired great strength and hardness at high temperatures and yet which employs a minimum strategic alloying ingredients such as chromium, nickel and the full saving of the high temperature alloying ingredients cobalt and columbium.

Another object is the provision of an austenitic stainless steel which is sufficiently ductile and malleable as to lend itself to ready working into a host of articles of ultimate use which may be precipitation-hardened to great strength and hardness throughout a wide temperature range of use.

A further object of my invention is the provision of jet engine turbine discs and the like of great high temperature strength and hardness, employing a minimum of strategic alloying ingredients, and which develop high strength without going to hot-cold forging operations.

Other objects of my invention in part will be obvious and in part pointed out in the description which follows.

The invention accordingly consists in the combination of elements, composition of ingredients and in various articles fashioned of the same as described herein. The scope of the application of which is indicated in the claims at the end of this specification.

In the single figure of the accompanying drawing I give a perspective view of a turbine disc and alloy steel according to my invention.

As conducive to a better understanding of certain features of my invention it may be here noted that stainless steel generally is considered to contain about 10% to 35% chromium with or without nickel and with or without other additions for special purposes. The remainder of the steel, of course, is substantially all iron. Such steels, of course, are well known and are employed in the fabrication of a variety of useful products and articles.

Now in the manufacture of jet engines the necessary turbine requires discs, which are large and heavy. They must be strong. Heretofore the requirements have been answered by alloys high in chromium, cobalt and nickel. Very often tungsten is a substantial constituent.

The turbine discs which are made through the hot-cold forging operation do not have uniform properties throughout. And the yield strengths, which are achieved, are not entirely satisfactory. Similarly, those discs wherein strength is had, not by hot-cold forging operation, but by precipitation hardening methods, require excessive amounts of strategic materials.

In an effort to use less of the strategically important elements, chromium, cobalt, nickel, columbium and tungsten, the prior art has directed its attention to the ferritic grades of stainless steel. Unfortunately this steel, although readily forgeable, lacks the required strength at the high temperatures prevailing under actual turbine operating conditions. Moreover, resistance to the wash, scour and corrosion of the hot gases and vapors encountered is not particularly satisfactory. The ferritic grades of stainless steel, therefore, leave much to be desired.

One of the objects of my invention, therefore, is to provide a metal of low strategic alloy content which readily lends itself to forging or other deformation into jet engine turbine discs or like large heavy parts which are strong and hard at high temperatures, and which also readily lends itself to precipitation heat treatment at temperatures which are not objectionably high to give great hardness and strength at high temperatures with uniformity of properties throughout the full cross-section.

Having reference now more particularly to the practice of my invention I employ a chromium-manganese-nickel stainless steel of high critical phosphorous content. The steel is entirely austenitic, the ferrite content amounting to no more than 2% by volume. The phosphorous content is in every sense critical as appears more fully below, ranging from .15% to .35% .

The stainless steel of my invention contains 9% to 14% chromium, 4% to 20% manganese, 4% to 10% nickel, .15% to .35% phosphorus, .10% to .40% carbon, nitrogen up to .30% with the sum of the carbon and nitrogen contents being at least .15% and preferably .15% to .20%. The remainder is substantially all iron.

A turbine disc according to my invention is illustratively shown in the single figure of the drawing.

Where desired in the steel of my invention sulphur may be present in amounts up to .15% and one or both of the ingredients molybdenum and tungsten may be employed in total amount up to 3.5%.

The composition of my chromium-manganese-nickel steel of high phosphorous content is in every sense critical. The desired high temperature properties are had where the chromium content amounts to 9%, but I find that these suffer where any lower chromium content is used. And likewise I find that while excellent properties are had with 14% chromium higher values in chromium lead to a waste of this strategic element.

In the steel of my invention both the manganese content and the nickel content must amount to at least 4%. At least 4% nickel is required in order that the steel may be wholly austenitic. And any lower quantity of manganese represents an unnecessary waste of nickel in order to establish a fully austenitic structure. Manganese in excess of 20% must be avoided in order to present excessive corrosion of refractories during melting and teeming of the metal and nickel in excess of 10% must be avoided because it is an unnecessary waste of this strategic element.

The phosphorous content of .15% to .35% is highly critical, as mentioned above, because I find that with phosphorous content less than .15% there is inadequate precipitation hardening effect. And with values exceeding .35% there apparently are formed eutectic phosphides which lower the malleability of the steel and adversely effect its hot-working properties, especially hot-rolling and forging characteristics.

The amount of carbon employed likewise is highly critical because with less than .10% carbon the high temperature hardness materially suffers and with greater than .40% carbon the hot-working properties are adversely effected. Nitrogen is employed in incidental amounts on up to .30%. With greater amounts of nitrogen there is some likelihood of the metal being gassy. The sum of the carbon and nitrogen contents must be at least .15% in order to achieve the desired high temperature hardness.

Where desired, in order to improve the machining characteristics of the steel, sulphur may be employed in amounts up to .15%; greater amounts are not safely had because of the high manganese content. And likewise where molybdenum and/or tungsten are employed the amount should not exceed 3.5% because with any greater amount there is a significant loss of malleability.

The workability of the steel of my invention may be improved somewhat through the addition of boron in amounts up to .005%. Any substantially greater figure, however, is to be avoided because of the consequent hot-working difficulties. Also, where desired, my steel may contain vanadium in amounts up to .75% for the purpose of increasing the hot hardness of the steel and its high temperature strength. Here again, however, excessive values should be avoided since it represents a waste of this alloying agent and adversely effects the working characteristics of the steel.

A specific steel illustrative of my invention analyzed 12.21% chromium, 7.70% manganese, 7.99% nickel, .178% carbon, .261% phosphorous, 2.25% molybdenum, .013% sulphur, .35% silicon and remainder substantially all iron. And samples of this steel when annealed, water quenched, reheated to precipitation hardening temperature and quenched have the room temperature properties as given in Table I below and the elevated temperature properties as given in Table II below.

TABLE I

Room temperature properties of low strategic alloy chromium-nickel stainless steel of high phosphorous content under three conditions of heat treatment

Treatment	Rockwell Hardness	Ult. Tens. Strength, 1,000 p. s. i.	.2% Yld. Strength, 1,000 p. s. i.	Elon. 2", percent	Red. Area, percent
A	C31–35	152.5	97.5	20.5	31.2
B	C29–33	146.2	91.9	23.5	34.4
C	C29–34	149.0	97.0	24.0	33.0

TABLE II

Elevated temperature properties of low strategic alloy chromium-nickel strainless steel of high phosphorous content under three conditions of heat treatment

Treatment	Test Temperature, °F.	Stress Rupture Test	
		Load, p. s. i.	Time to fracture, hrs.
A	1,200	55,000	100.4
A	1,200	50,000	176.4
A	1,200	43,000	581.4
B	1,200	52,000	164.7
B	1,200	41,000	1,200.0
C	1,200	55,000	60.5

NOTE.—The treatment employed in A, B and C of Tables I and II is given as follows:

A—2,050°F.—½ hr. W.Q.+1,300°F.—24 hrs.—W.Q.
B—1,950°F.—½ hr. W.Q.+1,300°F.—24 hrs.—W.Q.
C—2,000°F.—½ hr. W.Q.+1,300°F.—24 hrs.—W.Q.

It will be seen from Tables I and II above that I provide a steel which has the combination of excellent ductility at room temperatures in combination with good high temperature strength, that is good strength at temperatures of 1200° F. or more. This combination of properties is particularly important in turbine discs or jet engines because these discs do not operate at uniform temperatures. On the contrary, the rim temperature is much greater than at the hub. My steel is well calculated to withstand the thermal stresses which arise from this temperature difference as well as the rotation stresses encountered in actual practical use.

Thus it will be seen that I have provided in my invention a stainless steel and various articles or products of manufacture fashioned of the same in which the various objects hereinbefore set forth together with many thorough practical advantages are successfully had. The steel and the products fashioned thereof are well suited to high temperature applications and yet they employ a minimum of strategic alloy ingredients. Particularly the chromium content is low and in the turbine discs of my invention there is a complete absence of the ingredient cobalt, which has so commonly been used in the turbine discs of the prior art.

As many possible embodiments may be made of my invention and as many changes may be made in the embodiment hereinbefore set forth it is to be understood that all matter described herein or shown in the accompanying drawing is to be interpreted as illustrative and not by way of limitation.

I claim as my invention:

1. Austenitic stainless steel of low strategic material content comprising 9% to 14% chromium, 4% to 20% manganese, 4% to 10% nickel, .15% to .35% phosphorous, .10% to .40% carbon and remainder substantially all iron.

2. Austenitic stainless steel of low strategic material content comprising 9% to 14% chromium, 4% to 20% manganese, 4% to 10% nickel, .15% to .35% phosphorous, .10% to .40% carbon, nitrogen up to .30%, with the sum of the carbon and nitrogen contents being at least .15%, sulphur up to .15%, material of the group consisting of tungsten and molybdenum up to 3.5%, boron up to .005%, vanadium up to .75% and remainder substantially all iron.

3. Austenitic stainless steel comprising about 12% chromium, 8% manganese, 8% nickel, .10% to .40% carbon, .15% to .35% phosphorous, molybdenum up to 3.5% and remainder substantially all iron.

4. Turbine disc of great strength and great resistance to stress rupture at high temperatures comprising 9% to 14% chromium, 4% to 20% manganese, 4% to 10% nickel, .15% to .35% phosphorous, .10% to .40% carbon, nitrogen up to .30%, with the sum of the carbon and nitrogen contents being at least .15%, sulphur up to .15%, material of the group consisting of tungsten and molybdenum up to 3.5%, boron up to .005%, vanadium up to .75% and remainder substantially all iron.

5. Turbine disc of great strength and great resistance to stress rupture at high temperatures comprising 12% chromium, 8% manganese, 8% nickel, .10% to .40% carbon, .15% to .35% phosphorous, molybdenum up to 3.5% and remainder substantially all iron.

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