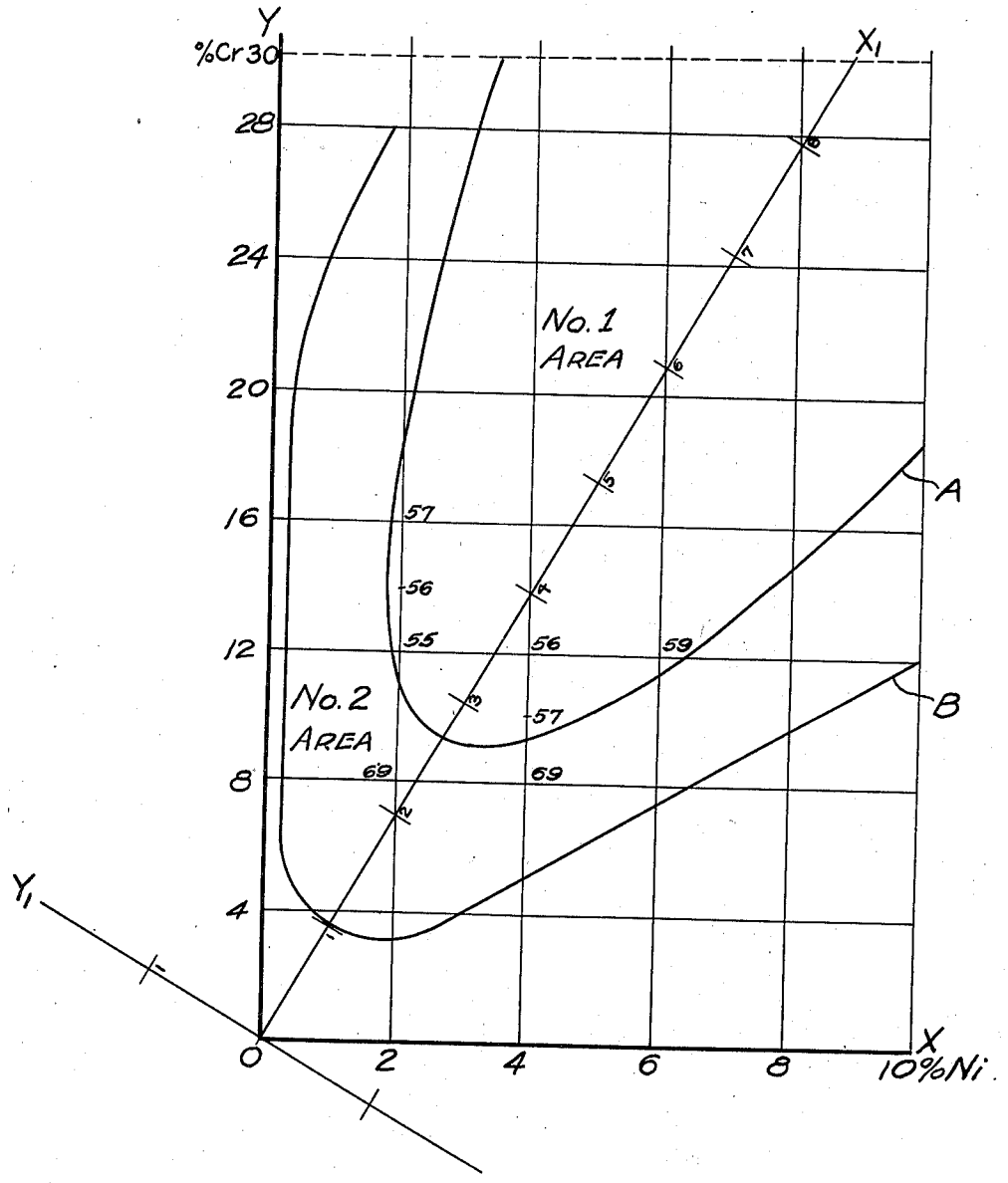
Feb. 6, 1940. A. T. CAPE ET AL 2,189,131

FERROUS ALLOYS

Filed Sept. 6, 1938



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Patented Feb. 6, 1940

2,189,131

UNITED STATES PATENT OFFICE

2,189,131

FERROUS ALLOYS

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Application September 6, 1938, Serial No. 228,528

7 Claims. (Cl. 75—128)

This invention relates to ferrous alloys, but has reference more particularly to ferrous alloys which are especially adapted for hard-facing purposes and for utilization in the form of castings.

It is perhaps well-known that there are, in general, three types of hard-facing metals, which, briefly, are the hard carbides, the non-ferrous type, and the compounds of ferrous materials. In facing a base metal with the hard carbides, the retaining metal flows onto the metal to be faced and becomes welded to it, the carbides not being melted. This type of hard facing alloy is highly resistant to abrasion but it cracks badly and rapidly under repeated impact, and, consequently, its service is limited. Non-ferrous types of hard facing alloys have a relatively good wear resistance, although not as good as the carbides, but are decidedly tougher. The hard-facing alloys of the ferrous type vary greatly and it can be said that the effectiveness of the material can generally be indicated by the market price thereof. In other words, the cheaper the hard facing metals of the ferrous type are, the lower is their effectiveness. That is, these cheaper materials are too soft and they wear rapidly. On the other hand, the more expensive the hard facing alloy of the ferrous type, the greater tendency they have to be brittle, although they are reasonably resistant to wear.

A primary object of the present invention is to provide ferrous alloys for hard-facing and casting purposes which not only have a high resistance to wear and abrasion, but have high resistance, as well, to heavy and repeated impacts, that is to say, they possess high mechanical strength.

Another object of the invention is to provide ferrous alloys for hard-facing and casting purposes, which are resistant to chemical corrosion, to oxidation at high temperatures, and possessing strength at high temperatures.

A further object of the invention is to provide ferrous alloys of the hard-facing type which also possess the quality of being capable of forming a sound bond with the base metal.

A still further object of the invention is to provide ferrous alloys of the hard-facing type, which have a viscosity, in the molten condition, such as to permit exceedingly easy application of the alloys to the base metal.

Other objects of the invention, together with some of the advantageous features thereof, will appear from the following description of the preferred and other embodiments of the invention. It is to be understood, however, that we do not limit ourselves to the embodiments described, since our invention, as defined in the appended claims, can be embodied in a plurality and variety of forms.

The alloys with which we are principally concerned fall into two groups, the alloys in each group having certain properties in common with those of the other group, but having other properties distinct from those of the latter. In order to more clearly visualize these groups, reference may be had to the accompanying drawing, forming a part of the present application, and in which appears a graph containing two curves, all points of which have as their abcissae percentages of nickel, and as their ordinates percentages of chromium.

Referring more particularly to this graph, it may be noted that the graph contains two sets of rectangular coordinates, one set consisting of the axes O—X (x-axis) and O—Y (y-axis), and the other consisting of the axes O—X_1 (x_1-axis) and O—Y_1 (y_1-axis), that is, both sets have a common origin (O), but the x_1-axis is inclined at an angle of 60 degrees, measured in a counter-clockwise direction, to the x-axis. The x-axis denotes percentages of nickel and the y-axis denotes percentages of chromium.

The graph also contains two curves, designated A and B.

Curve A is a parabola, whose principal axis is the x_1-axis and whose equation or formula is $x_1 - cy_1^2 = a$, where a and c are constants, with $a=2.7$ and $c=0.9$. To reduce this formula or equation to concentrations or percentages of chromium and nickel, the following is established:

$x_1 - cy_1^2$ must be greater than a, which equals 2.7, where

$$x_1 = \frac{x}{4} \text{ plus } .217y \text{ and } y_1 = \frac{y}{8} \text{ minus } .433x$$

and x equals the percentage of nickel and y equals the percentage of chromium. The parabola defined in terms of concentration of chromium and nickel is

$$\frac{x}{4} \text{ plus } .217y \text{ minus } c\left(\frac{y}{8} \text{ minus } .433x\right)^2 \text{ equals } a$$

Of the two principal groups which have been referred to, the preferred group comprises all those alloys which lie within the area designated No. 1 in the graph, this area being bounded by the parabola A and the lines representing 10% nickel and 30% chromium. The other group

comprises all of those alloys which lie within the area designated No. 2 in the graph, this area being bounded by the curves A and B and the lines representing 10% nickel and 30% chromium. The curve B is generally parabolic, and somewhat parallel with curve A. No attempt will be made to give the formula or equation of this curve, but it is to be noted that the curve is a dividing line between alloys of different characteristics.

The curve A passes through points or values where there is a critical change of hardness from the austenitic to the ferritic or more magnetic state. The curve B passes through points or values where the effect of the critical change represented by curve A no longer exists and the hardnesses begin to decrease rapidly. The critical change in hardness from compositions above A to those lying between A and B is accompanied by changes in the magnetic values, from a value of 3 inside the curve to 4 just below curve A, such values being arbitrary but reproduceable. The method used for determining these arbitrary values consists in balancing the metal to be tested, bringing a magnet to a fixed point and noting the deflection. Such a test readily designates the general physical characteristics of an unknown chromium nickel composition or a known composition to which other alloying elements have been added.

The alloys lying within area No. 1 are especially adapted for hard-facing applications, where softness from the point of view of indentation hardness is of advantage, for resistance to impact. At the same time, the complex chromium carbide plates distributed through the matrix in alloys of this group, plus the fact that the matrix itself is austenitic, and therefore hardens as soon as any work is done, imparts to this group a resistance to wear which is remarkable. In practice, we have been able to lay down deposits as soft as 30 Rockwell C (approximately 290 Brinell) which are file hard. A preferred alloy of this group contains about 4.20% carbon, about 14%–18% chromium, about 4%–6% nickel and about .40% vanadium. This alloy is particularly useful in the form of weld rods for hard facing applications for cement mill machinery, agricultural equipment, brick, clay and tile machines, including muller tires; hammer mill parts, and coke handling equipment.

The alloys lying within area No. 2 have a substantially greater initial indentation hardness than the alloys in area No. 1, this being due to the tendency of such alloys to change from the austenitic to the ferritic states. In other words, some of the austenite formed at higher temperatures decomposes during cooling, and the critical precipitation of carbides gives increased hardness. This occurs in the cast material, and does not require heat treatment to bring it about. Just how critically the hardness values change will appear from the graph, wherein, for example, an alloy containing 10% chromium and 4% nickel has a hardness of 57 Rockwell C, while an alloy containing 8% chromium and 4% nickel has a hardness of 69 Rockwell C, in the as-cast state.

The alloys in both groups, that is, in the group within area No. 1, and the group within area No. 2, preferably contain about 4% carbon, but may contain from about 3% to about 5% carbon.

In order to produce resistance to oxidation at high temperatures in the aforesaid basic alloys, molybdenum, in amounts of from about 6% to about 10%, is added. A preferred alloy of this type contains about 4% carbon, about 16% chromium, about 2% nickel, about 8% molybdenum and about 1% vanadium. This alloy is particularly valuable in the form of welding rods for hard-facing applications where high temperatures are encountered or where considerable "edge" strength is required. Typical uses are valve seat inserts and valves, hot shear knives, steel mill guides, forging dies, tobacco and ensilage cutters, etc. The vanadium, which may be added in quantities of from about .20% to about 1%, apparently imparts to the alloy increased toughness, and in the welding rod, a degree of "stickability", which is definitely advantageous. This term defines the property or ability of the weld metal, deposited by the melting welding rod, to resist separation from the base metal, under severe impact.

The addition of silicon, in appreciable amounts up to about 5.5% to the aforesaid basic alloys, particularly to the compositions in area No. 1, changes the magnetic characteristics of the metal, with a consequent increase in the hardness of the metal in the "as-cast" state. For example, the normal hardness of an alloy containing 4.20% carbon, 16% chromium, 6% nickel and .40% vanadium, in the "as-cast" state, is 50 Rockwell C, whereas, when silicon to the extent of 5.5% is added to such alloy, the hardness increases to 65 Rockwell C. In general, the more closely the curve A is approached, the smaller the amount of silicon which is necessary to produce the change in question. In the following table, the arbitrary magnetic values and the hardness for a range of silicon additions is given:

Silicon	Magnetic values	Hardness
2	4	60
3	5	
4	8	
5	11	65

The silicon-containing material, in the as-welded state, is extremely hard, and has an extremely high wear resistance.

Titanium may be added in amounts of from about .10% to about 1%, for securing increased abrasion resistance. A preferred titanium-containing composition is one containing about 4% carbon, about 16% chromium, about 6% nickel, about 8% molybdenum, and about .60% titanium. This alloy has very great resistance to wear, has substantial impact resistance, and will not flake off when used in such applications as Bradley pulverizer rings, Griffin rings, etc.

In manufacturing the aforesaid alloys, it is desirable to produce sound castings or good welding material. For this purpose, the original charge in the furnace must be kept free from silicon, or as reasonably low in silicon as is possible, and also free from titanium. Additions of silicon and titanium should be made as close to the end of the melting operations as possible. If these conditions are not observed, the material, whether used as castings or as acetylene welding rods, is porous. For arc welding, these factors are not quite as important, because the gases present in the welding rod are removed during the arc welding process. In order to control the acetylene welding property of the material and also to some extent the arc welding characteristics, a small quantity of alkaline earth or alkali metal is added to the melt. The addition of minutely small quantities of these elements increases the wetting properties of all

of the varieties. Without them, during acetylene welding, the metal tends to form into balls, the surface is improperly covered and the adherence is not satisfactory. With an immeasurably small amount of sodium, potassium or calcium, the metal melted by the acetylene torch spreads over the surface and covers it excellently. This is a most valuable property, and distinguishes the present alloys from all other welding materials. The addition of calcium to the metal is preferably as calcium silicide. The addition of these elements increases the fluidity of the metal, as well as merely changing the surface tension. The quantity of calcium silicide used is about .07 ounce per pound of metal. The amount used is well in excess of that required.

The arc welding rods are coated with a mixture of plumbago and sodium silicate, to which a small quantity of bentonite sometimes is added, or they may be coated with a mixture of graphite (in the form of crushed arc furnace electrodes) and sodium silicate, to which bentonite sometimes is added. The use of these coatings is of considerable interest. Where the rods are coated with plumbago, the deposits are soft; where the rods are coated with graphite, the deposits are hard. Differences as great as 30 Rockwell C to 55 Rockwell C can be produced by the selective use of these coatings. The normal mixtures employed in these coatings are as follows, the rods being coated by simply dipping them in the mixture and drying them:

Soft coat

	Grams
Plumbago	3000
Sodium silicate	2600
Bentonite	90
Water	950

Hard coat

	Grams
Graphite	3000
Sodium silicate	1800
Bentonite	90
Water	1290

This peculiar effect of plumbago as against graphite is of interest not only in connection with the present alloys, but also in connection with the coating of welding rods formed of other alloys and compositions.

It has been found that where the problem of porosity arises, the addition of fluoride either to the metal itself in the case of castings, or as a thin layer over the graphite coating of the welding rod can be used effectively in eliminating the gas pockets. All of the fluorides are effective in removing gases from the molten metal and in the event of unduly humid conditions causing an absorption of the gases can be eliminated during the freezing process by the addition of the fluoride to the molten metal. In many cases where it is necessary to weld on dirty or gassy cast iron or cast steel the addition of fluoride either with the graphite or plumbago coating, or as a thin layer superimposed upon the coating, will prevent porosity in the welded deposit.

The alloys should be kept as free from elements other than those described, as possible. In other words, silicon (except where specifiaclly required), manganese, phosphorus and sulphur should be kept to a minimum. For certain specific uses the addition of manganese and phosphorus may have an advantage and these will be described in a later application.

The alloys can be increased in hardness by heating them to 1650° F., and up and cooling them fairly slowly. This is a true precipitation hardening phenomenon.

We claim:

1. A ferrous alloy containing about 4.20% carbon, about 14%–18% chromium, and about 4%–6% nickel, the remainder of said alloy being iron.

2. A ferrous alloy containing more than 3.5% but less than about 5% carbon, nickel in amounts of from about .25% to about 10%, and chromium in amounts of from about 4% to about 30%, the remainder of said alloy being iron.

3. A ferrous alloy containing more than 3.5% but less than about 5% carbon, nickel in amounts of from about 2% to about 10% and chromium in amounts of from about 9% to about 30%, the remainder of said alloy being iron.

4. A ferrous alloy containing more than about 3% but not more than about 5% carbon, nickel in amounts of from about .25% to about 10%, and chromium in amounts of from about 4% to about 30%, the remainder of said alloy being iron.

5. A ferrous alloy containing not less than about 3% but not more than about 5% carbon, nickel in amounts of from about 2% to about 10%, and chromium in amounts of from about 9% to about 30%, the remainder of said alloy being iron.

6. A ferrous alloy containing more than 4% but less than about 5% carbon, nickel in amounts of from about .25% to about 10%, and chromium in amounts of from about 3% to about 30%, the remainder of said alloy being iron.

7. A ferrous alloy containing more than 4% but less than about 5% carbon, nickel in amounts of from about 2% to about 10%, and chromium in amounts of from about 9% to about 30%, the remainder of said alloy being iron.

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