

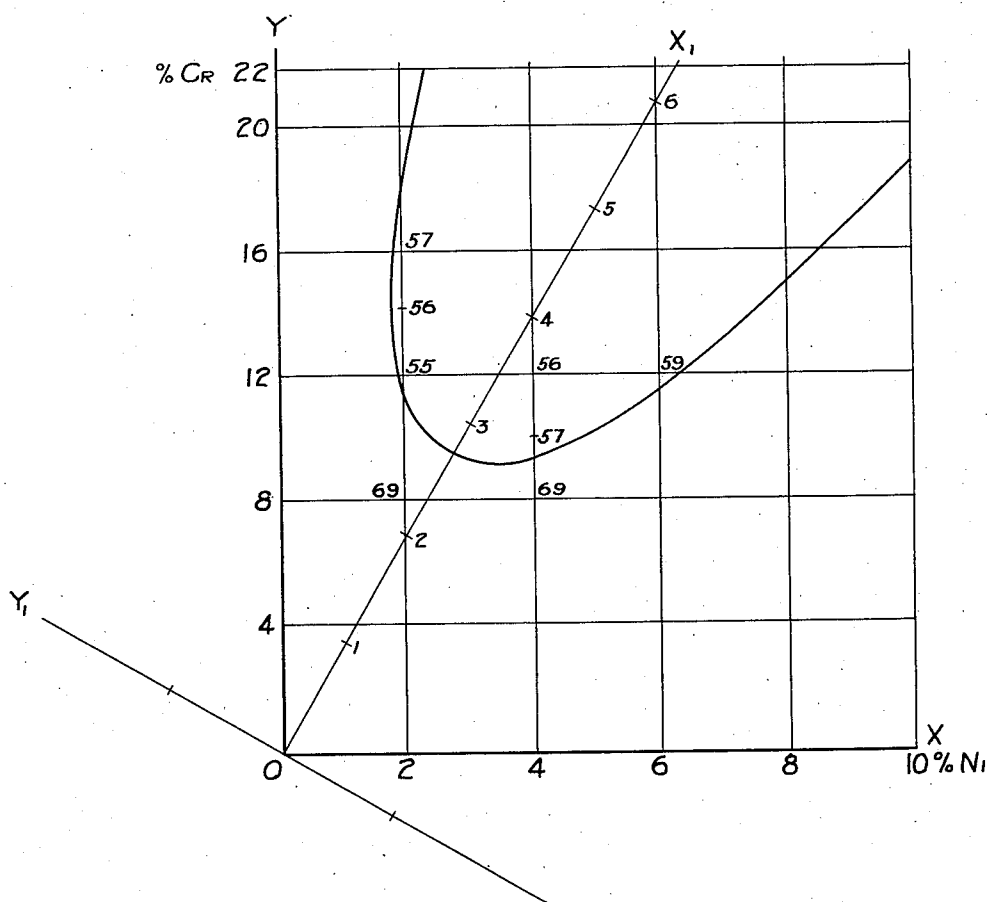
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FERROUS ALLOY

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FERROUS ALLOY

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1 Claim. (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 possesses 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 claim, can be embodied in a plurality and variety of forms.

In order to more clearly visualize the invention, reference may be had to the accompanying drawing, forming a part of the present application, and in which appears a graph containing a curve, all points of which have as their abscissae 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—X₁ (x₁-axis) and O—Y₁ (y₁-axis), that is, both sets have a common origin (O), but the x₁-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 a curve, designated A. Curve A is a parabola, whose principal axis is the x₁-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 of 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

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

The alloys of our invention 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 22% chromium.

The curve passes through points or values where there is a critical change of hardness from the austenitic to the ferritic or more magnetic state. The critical change in hardness from compositions within area No. 1 to those lying outside this area is accompanied by changes in the magnetic values, from a value of 3 inside the curve to 4 just outside the curve, such values being arbitrary but reproducible. 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 espe-

cially 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 these alloys, 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, and about 4%-6% nickel. 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 in area No. 1 preferably contain about 4% carbon, but may contain from about 3% to about 5% carbon.

A distinct feature of the invention consists in the addition to the austenitic compositions in area No. 1 of silicon in amounts sufficient to change these compositions to compositions which are non-magnetic or non-austenitic (ferritic), 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 and 6% nickel, 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. The range of silicon required to effect these changes is from about 2% to about 5.5%, the upper limit being more or less critical in that additional amounts of silicon result in a substantial decrease in the hardness of the metal. In general, the more closely the curve A is approached, the smaller the amount of silicon which is necessary to provide the change in question. We have discovered, as a matter of fact, that silicon should be used in amounts which bear a more or less definite relationship to the amount of nickel in the alloy, as follows:

(a) Where nickel is present in a range, the lower limit of which is represented by the curve A and the upper limit of which is about 3%, silicon in amounts of from about 2% to about 3½% should be used.

(b) Where nickel is present in amounts of from about 3% to about 5%, silicon in amounts of from about 3½% to about 4½% should be used.

(c) Where nickel is present in amounts of from about 5% to about 10%, silicon in amounts of from about 4½% to about 5½% should be used.

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.

The silicon is preferably added to the alloys in the form of zirconium-silicon or a ferro-alloy containing zirconium and silicon.

A particular desirable alloy in this group, which is magnetic and particularly valuable from the standpoint of wear resistance, contains 4% carbon, 16% chromium, 6% nickel and 4½% silicon.

The aforesaid alloys may be rendered corrosion-resistant to a degree which will readily adapt them for use as valves and valve seats in oil refinery apparatus by the addition thereto of copper in amounts of from about .2% to about 5%. The copper-bearing alloys have a hardness when applied to an article as a hard surfacing material ranging from 52 to 62 Rockwell C.

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 in 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
75 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 ele-

ments other than those described, as possible. In other words, silicon (except where specifically 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.

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:

A ferrous alloy consisting of more than 3% but not more than 5% carbon, nickel in amounts of from 1.7% to 10%, chromium in amounts of from 9% to 22%, and silicon in amounts of from 2% to 5.5%, in accordance with the following schedule:

Nickel	Silicon
1.7% - 3%	2% - 3½%
3% - 5%	3½% - 4½%
5% - 10%	4½% - 5½%

the remainder of the alloy being iron, and the silicon being present in an amount which renders the metal in the "as-cast" state no longer austenitic but critically ferritic.

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