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NICKEL BASE ALLOYS

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This invention relates to nickel base alloys, and more particularly to such alloys containing substantial amounts of silicon and chromium, as well as significant but lesser amounts of other constituents as will appear presently, which alloys exhibit properties of extreme hardness and resistance to corrosion.

The novel alloys are capable of use in cast form, but their hardness and brittleness render them substantially incapable of being wrought or machined except to a very limited extent. Their general utility may however be greatly extended beyond that in which they can serve in cast form by using the novel alloys in conjunction with a ductile or more readily machinable metal to provide a composite article having a base or core of metal which can be easily worked or shaped, and having a surface or sheath of the novel alloy, whereby to make the article much more resistant to corrosion than is possible when using the base metal alone, while retaining the advantages of greater strength and workability of the base metal.

The foregoing proposal is of course not broadly new. However, the novel alloys here disclosed are particularly suited for application to the surface of a base metal by a method which differs substantially from the more conventional methods heretofore employed, and which offers advantages over those methods. Commonly in prior practice the base metal was sheathed or encased with a resistant alloy by depositing the latter thereon in a conventional welding operation, using welding rods of the alloy as the means of supplying the latter for fusion to the surface of the base metal. Such methods, however, are subject to the distinct disadvantage that dilution of one metal into the other occurs, thereby affecting the properties of both and diminishing the effectiveness of each in serving its intended purpose. Thus, the transfer into the base metal of substantial amounts of the constituents of the coating alloy will tend to render the base metal brittle and hard, weakening it and making it difficult to machine thereafter. Simultaneously, of course, there occurs a change in the composition of the surfacing material, reducing its effectiveness to withstand corrosive attack and rendering it less resistant to wear, which are its primary functions. Also, such prior methods of welding to the base metal generally involve raising the temperature of the base metal to an undesirable extent, not only promoting dilution, but adversely affecting the mechanical properties of the base metal as well.

The present invention eliminates these difficulties. In the cladding method for which the novel alloys here disclosed are particularly suited, the alloys are first reduced to powder form and the powder is then caused to adhere to the base metal by a low temperature metalizing operation. This consists in depositing the powder in a layer on the surface to be covered, in which layer the particles of the powder are still substantially discrete, although they are sufficiently bonded to themselves and the base metal to provide a fair amount of mechanical strength in the layer. The surface of this layer is still quite porous,

however, and unsuited for use under corrosive conditions. The layer is accordingly next subjected to a "torching" operation, whereby the discrete particles of powder are caused rapidly to fuse or coalesce to themselves and the base metal, forming a substantially smooth, nonporous sheath on the base metal without overheating the latter.

It is essential to the practical success of the foregoing method that the coalescence of the powdered metal occur rapidly to avoid prolonged heating. Not only will prolonged heating lead to the difficulties mentioned hereinabove, but it will also cause excessive fluidity of the molten layer of surface metal, introducing problems of run-off from high spots on the surface being covered.

I have discovered that coalescence of the metal powder particles is surprisingly expedited by the inclusion in the novel alloys hereof of a controlled amount of boron. When this element is present in amount presently to be stated more in detail, it has the remarkable property of so materially increasing the "wettability" of the alloy that the individual minute molten globules, to which the powder particles are converted in the torching operation, join or coalesce with adjacent particles at a much lower degree of fluidity than before. Thus a smooth, continuous or homogeneous, dense layer of corrosion resistant metal alloy is formed on and joined to the base metal at a much lower temperature, and in less time, than would otherwise be possible.

The alloys of the present invention and the foregoing method of utilizing them find especial application, for example, in pumps designed to handle highly corrosive liquids. Since some leakage of fluid past the impeller seal of such a pump is bound to occur, that section of the impeller shaft which runs in the seal and adjacent thereto is subject to corrosive attack. For reasons of strength and economy, a shaft of ordinary high tensile strength steel is desirable. The present invention makes it possible to employ such a steel by providing on those sections exposed to the corrosive fluids an integral sheath of one of the relatively low strength but vastly superior corrosion and abrasion resistant alloys of the invention. In an alternate form, there may be provided, in place of the integral sheath, a separate, replaceable shaft sleeve having the corrosion-abrasion resistant alloy applied thereto, which snugly engages the shaft to prevent its exposure to corrosive attack.

Alloys of the present invention consist preponderantly of nickel, but also comprise a high percentage of chromium and silicon, which together impart to the alloys their characteristic high corrosion resistance and extreme hardness. In addition to the foregoing, the alloys include significant amounts of copper and molybdenum, and for the reasons mentioned hereinabove regarding "wettability," a carefully controlled amount of boron is also present. Iron is also present, as are manganese and the usual concomitant impurities, as sulfur and phosphorus. Iron and the other impurities, however, are desirably kept as low as possible. Carbon of course is likewise present in small controlled amount.

Because boron greatly reduces corrosion resistance by combining with chromium, the presence of even relatively small amounts has a large effect on this property of the alloy. Consequently only so much boron is used as is necessary to get effective coalescence of the powdered alloy when fusing or torching is carried out. To counteract the effect of the boron, chromium is always present in substantial amount as indicated hereafter.

Alloys within the broad scope of the present invention show the following constituent ranges upon analysis, the indicated limits of which are substantially critical in the sense that they definitely differentiate the alloys which are useful for the purposes contemplated by the invention from those which are not.

Table 1

Chromium	10 to 25%.
Silicon	5 to 20%.
Boron	0.25 to 4%.
Copper	2% max.
Molybdenum	4% max.
Carbon	0.25% max.
Iron, together with the usual non-essential constituents	Less than 8% of which iron is predominant among these but does not exceed 5%.
Nickel	Balance to make 100%.

In producing alloys within the foregoing range, the charge is prepared by introducing not only nickel into the furnace in its commercially pure metallic state, but also the chromium, silicon and molybdenum in that same form to avoid as much as possible the introduction of iron. While chromium, silicon and molybdenum are more commonly added in the form of their respective ferro compounds in ordinary foundry practice, this is not practical in this instance because too much iron would thus be unavoidably introduced. For the same reason, boron is added in the form of nickel or chrome boride rather than as the ferro compound.

As specific examples of alloys within the above range which have proven exceptionally satisfactory in actual use, the following compositional analyses are illustrative:

Table 2

Heat No.	Percent Composition [1]							
	Cr	Si	Mo	Cu	Fe	Mn	C	B
A	15.12	10.03	------	0.99	------	0.10	0.03	3.85
B	14.20	13.28	1.00	1.14	------	------	0.16	3.62
C	19.05	12.48	1.01	1.05	------	0.49	0.21	3.55
D	17.10	9.35	1.04	0.99	------	0.74	0.20	3.55
E	17.30	10.07	1.24	1.03	------	0.51	0.16	1.78
F	19.90	12.65	1.07	1.26	------	0.66	0.12	0.28
G	19.75	12.75	0.98	1.00	------	0.59	0.13	1.14
H	19.55	12.72	1.10	1.17	------	0.50	0.12	1.45
J	19.85	11.82	1.54	1.08	4.72	1.00	0.13	1.97
K	20.16	12.55	0.72	1.10	2.20	0.60	0.12	2.46
L	19.85	12.80	0.89	1.17	1.60	0.54	0.14	2.88
M	19.15	12.40	0.70	1.14	3.46	0.68	0.12	3.43
N	14.96	12.60	0.95	0.91	1.90	0.02	0.05	3.71

[1] Except for nickel, which makes up the balance to 100% in each heat.

The high degree of corrosion resistance of some of the foregoing alloys is shown by the results in various corrosive media given in the following tabulation:

Table 3

Heat No.	Mils penetration per year			
	65% HNO_3, Boiling	10% H_2SO_4, 80° C.	10% H_2SO_4, Boiling	40% H_2SO_4, 80° C.
B	150.00	59.6	245.4	75.2
C	250.00	139.6	290.1	113.7
D	593.6	31.9	192.3	62.7
E	28.3	33.3	317.9	131.9
F	22.8	40.0	258.0	45.0
G	27.7	46.0	487.0	90.0
H	28.8	66.0	671.0	75.0

For purposes of comparison, the corrosion rate of "Stellite 1" in 10% sulfuric acid at 80° C. is around 300 M. P. Y., whereas "Colmonoy 6" dissolves completely in boiling 10% sulfuric and corrodes at the rate of 256 M. P. Y. in 40% sulfuric at 80° C. The superiority of the new alloy is thus readily apparent.

Within the broader compositional limits heretofore set out, it has been observed that optimum results are generally obtained when compositions lie within the following ranges:

Table 4

Chromium	18 to 20%.
Silicon	8.5% minimum.
Boron	0.5 to 3%.
Copper	Approx. 1% max.
Molybdenum	Approx. 1% max.
Carbon	0.25% max.
Iron, together with the usual non-essential constituents	Less than 8% of which iron is predominant among these but does exceed 5%.
Nickel	Balance to make 100%.

The alloys of the invention may be cast into various shapes which are useful as-cast, such as pump casings, impellers, piping and the like, but are so extremely hard as to resist any practical machining and working of them once cast. About the most that can be done in the way of further finishing is by grinding to remove flashings or to polish a surface. Their hardness is indicated by the fact that they show Rockwell C readings of 50 minimum. The alloys are also useful in the as-cast form for welding rod to produce hard, corrosion resistant welds, and in depositing a facing upon a base metal by conventional arc or torch welding processes in conventional manner. However, as already mentioned, they are particularly suited for use in providing corrosion and wear resistant surfaces by a metalizing process which offers advantages over the conventional fusion welding process just mentioned and greatly extends the general utility of the alloys.

The foregoing metalizing process consists in first reducing the alloy to a powder, which may be done most conveniently from the molten state by spraying it into an inert atmosphere. The base metal to be coated is grit blasted to provide a roughened surface, and the metal powder is then caused to adhere to this surface in the form of a molten spray. In this process, the powder is air fed to a spray gun having a tip in which the powder emerges from a center port in a stream surrounded by a series of gas jets. When the gas is ignited, the particles of powder are melted sufficiently by the heat of the surrounding jets to cause them to adhere to the base metal surface when they strike the latter. At such time, the particles appear to be in a supercooled state and immediately form agglomerates which lock into the roughened surface so that when solidified they exhibit considerable adherence to the surface of the base metal. In the operation just described, the flame from the gas jets is also played on the base metal surface so that it is likewise heated, which promotes adherence of the particles when they strike. No preheating of the base metal is required, and although this may be done, it is generally not preferred. In this manner, heating of the base metal is confined largely to the surface and overall heating of the base metal is minimized. For example, the temperature of the main body of the base metal may well never exceed 400° F. in the process.

In the metalizing operation, the powder adheres to the base metal in a layer of substantially discrete particles or agglomerates which are bonded by the action of the heat to themselves and to the base metal and produce a layer possessing some mechanical strength as already mentioned. That is, this preliminary layer of alloy powder is sufficiently strong to withstand grinding but is still quite porous and unsuited for providing any degree of corrosion resistance to the base metal.

The alloy layer thus produced is next fused to provide a dense, smooth, firmly adherent sheath or surfacing on the base metal. The fusing of the powder layer is done by "torching," that is by carefully playing a gas torch flame over the surface to cause the coalescence of the

discrete particles. In this step, the individual particles of powder are melted just sufficiently to cause them to run together and form a continuous skin or surface on the base metal. As has been mentioned previously, prolonged heating in this torching step is undesirable, and the presence of the boron in the alloy is important in promoting rapid coalescence at relatively low temperatures.

After the alloy layer is torched to fuse it into its final form on the base metal, the composite metal article or part thus prepared is attempered by furnace cooling at a controlled rate from a suitable temperature. The surface of the composite article is then given a finish by grinding, if this is required.

Because of the brittleness of the novel alloys, as well as any differences in their thermal expansion rates from those of the base metal to which they may be applied, the thickness of the layer which may be produced in this manner is somewhat limited. Experience has shown that for surfaces subjected to working loads or pressures, such as the pump shaft bearing surfaces or sleeves mentioned hereinabove, a layer of about one-sixteenth of an inch is about the upper limit. This provides good mechanical strength and good corrosion resistance life even under the severest conditions. In order to provide a surface or layer of this final thickness, a somewhat thicker layer must initially be applied of course to allow for reduction in size during finish grinding. From a practical standpoint, an unfinished thickness in the alloy layer of around one-eighth of an inch will be ample to provide a final thickness, after grinding, of one-sixteenth inch in the finished layer.

What is claimed is:

1. An alloy characterized by extreme resistance to corrosion and abrasion having in its as-cast state the following composition: chromium 10 to 25%; from 5 to 20% silicon; boron from 0.25 to 4%; copper up to 2%; molybdenum up to 4%; carbon 0.25% maximum; as little iron as possible which together with the usual incidental impurities are always less than 8%, iron being predominant among these but not exceeding 5%; the balance being nickel.

2. An alloy characterized in its as-cast state by extreme brittleness and inability to be machined or forged but having excellent corrosion and abrasion resistance, which comprises in its as-cast state approximately 18 to 20% chromium, at least 8.5% silicon, from 0.5 to 3% boron, up to approximately 1% each of copper and molybdenum, a maximum of 0.25% carbon, less than 8% of iron and the usual concomitant impurities, iron being predominant among these but never over about 5%, the balance being nickel.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 14, Table 4, before "exceed" insert -- not --.

Signed and sealed this 10th day of March 1959.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents