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2,744,009

Ni-Cr HARD FACING ALLOYS

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No Drawing. Application July 30, 1951,
Serial No. 239,388

4 Claims. (Cl. 75—171)

This invention pertains to nickel base alloys, utilizable principally as a hard facing alloy or in cast form, and containing, to this end, a relatively high carbon content, together with relatively high chromium and boron, as essential constituents.

It is an object of this invention to provide a low melting point, nickel base alloy of high hardness and good corrosion resistance. It is a further object of this invention to provide a corrosion resistant, hard facing alloy which does not require either of the strategic alloying elements cobalt or tungsten, although small amounts of each may be present, as noted below.

It is desirable that the melting point of the alloy be relatively low so that the hard facing deposits of the alloy on a base metal can be applied rapidly and with minimum consumption of fuel. The use of a low melting point alloy also permits deposition on relatively thin sections of a base metal with minimum distortion of the underlying section.

We provide hardness and wear resistance in our alloy by incorporating carbon, boron, and chromium in it so that chromium carbides and boron compounds are present in the cast or deposited alloy. To contain the chromium carbides and boron compounds, we use nickel as a matrix, because nickel is less expensive and more readily available than cobalt, and nickel is much more corrosion resistant than iron.

In addition to providing hard compounds, carbon and boron lower the solidus temperature of the alloy and cause a wide spread between the solidus and liquidus temperatures of the alloy. Boron also makes the alloy self-fluxing. This combination of low melting point, wide range between the solidus and liquidus temperatures, and self-fluxing property, makes it possible for the alloy of this invention to be deposited from a cast rod thereof as a series of beads by means of an electric arc, or gas welding procedure, and then to be molded into a smooth surface of desired configuration, by heating the deposit to about 1900° to 2100° F., and applying pressure by means of a die. The fluxing property of the alloy also makes it adaptable for making deposits by spraying with a metal spray gun.

The alloy of the invention has, for reasons explained below, the following broad, preferred, and optimum range of composition:

Composition	Amount, Percent by Weight		
	Broad Range	Preferred Range	Optimum Range
Carbon ¹	0.5-2.2	0.8-1.8	0.8-1.8
Chromium	15-35	20-27	20-27
Boron	1.3-3.5	1.3-3.0	1.3-2.5
Silicon	0-1.5	0-1.0	0-0.5
Copper	0-10	0-10	0-5
Iron	0-20	0-8	0-5
Cobalt	0-2	0-2	0-2
Tungsten and/or Molybdenum	0-2	0-2	0-2
Nickel	Balance	Balance	Balance

¹ In each case the aggregate amount of carbon and boron is at least 2.2%

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One application for the alloy of this invention is the hard facing of reciprocating engine exhaust valves. Since in this application the alloy comes in contact with the products of combustion of gasoline containing lead compounds, it is essential that the alloy of this invention be highly resistant to corrosion by molten lead compounds. As a test for such resistance we immerse our alloy in liquid lead oxide at 1675° F. and hold it immersed for a period of 1 hour, after which we clean the sample and measure it for weight loss per unit of area. As shown in Table 1, we have found that relatively large amounts of silicon and boron have deleterious effects on the corrosion resistance of the alloy.

Table 1.—Effect of boron and silicon on corrosion resistance of hard facing alloy in molten lead oxide at 1675° F.

Alloy	Analysis, Percent					Loss in 1 hr., gms./sq. in.
	C	Si	Cr	B	Ni	
856	.69	.44	25.3	1.3	Balance	.34-.53
857	.61	.46	25.6	2.2	Balance	.55-.63
852	.52	.46	25.4	3.4	Balance	1.4-3.3
2045	.47	1.22	26.6	3.2	Balance	5.1-6.7
858	1.01	.48	25.4	1.3	Balance	.48-.50
859	1.02	.70	25.4	2.2	Balance	.56-.67
853	1.05	.52	25.7	3.3	Balance	5.6-5.8
862	1.86	.38	25.2	1.3	Balance	.30-.33
863	1.85	.42	24.7	2.0	Balance	.72-1.1
892	1.80	.90	29.2	1.0	Balance	1.0-1.1
2611	1.33	.36	25.1	2.5	Balance	.30-.38
2622	1.41	1.78	24.8	2.7	Balance	5.2-5.6
2623	1.55	3.05	25.9	2.8	Balance	5.2-5.3

On the basis of the above results, we limit the boron content in our alloy to 2.5% maximum and the silicon content to 0.5% maximum when our alloy is to be used in applications where excellent resistance to corrosion in lead oxide is required. However, for other applications where only general resistance to corrosion is required, we may use as much as 3.5% boron and as much as 1.5% silicon in our alloy.

In respect to corrosion in lead oxide, we have found that carbon in the alloy may be varied from about 0.2% to about 2.3% without much effect, as shown in Table 2.

Table 2.—Effect of carbon on corrosion resistance of hard facing alloy in molten lead oxide at 1675° F.

Alloy	Analysis, Percent					Loss in 1 hr., gms./sq. in.
	C	Si	Cr	B	Ni	
2619	.24	.26	26.5	2.2	Balance	.18-.19
2863	.38	.48	26.7	2.2	Balance	.35-.36
2864	.57	.29	26.3	2.5	Balance	.30-.40
2865	.79	.22	25.8	2.7	Balance	.33-.34
2866	.98	.42	25.2	2.5	Balance	.30-.46
2867	1.16	.68	25.4	2.5	Balance	.60-.63
2611	1.38	.36	25.1	2.5	Balance	.30-.38
2620	2.11	.16	25.9	2.7	Balance	.42-.81
2621	2.33	.16	26.3	2.8	Balance	.60-.78

The effects of chromium, copper, and iron on the corrosion resistance of the alloy in molten lead oxide are shown in Table 3.

Table 3.—Effects of chromium, copper, and iron on corrosion resistance of hard facing alloy in molten lead-oxide at 1675° F.

Alloy	Analysis, Percent							Loss in 1 hr., gms./sq. in.
	C	Si	Cr	B	Cu	Fe	Ni	
2615	1.40	.16	15.2	2.6	-----	-----	Balance.	.40-.46
2616	1.48	.18	19.8	2.6	-----	-----	Balance.	.31-.53
2611	1.38	.36	25.1	2.5	-----	-----	Balance.	.30-.38
2617	1.60	.24	29.5	2.8	-----	-----	Balance.	.28-.71
2618	1.61	.26	34.8	2.5	-----	-----	Balance.	.52-1.1
2612	1.47	.28	25.9	2.6	2.6	-----	Balance.	.39-.54
2613	1.45	.26	25.9	2.5	4.8	-----	Balance.	.55-.76
2614	1.53	.24	25.8	2.5	9.5	-----	Balance.	.66-.80
2869	1.32	.76	25.3	2.3	-----	3.0	Balance.	.28-.67
1168	1.30	.30	26.6	2.4	-----	5.2	Balance.	.38-.39
1169	1.33	.22	26.0	2.6	-----	10.0	Balance.	.50-5.9
2872	1.42	.31	25.9	2.7	-----	19.5	Balance.	4.9-5.4

On the basis of the above results, we may have from 15 to 35% chromium in our alloy, but generally we prefer to hold the chromium content to about 27% because the higher chromium alloys are more expensive and also more difficult to weld. These results also show that we may have up to 10% copper in our alloy. Since copper is less expensive than nickel, it is a desirable addition in our alloy. However, when the amount of copper in the alloy exceeds about 10%, the alloy is difficult to deposit satisfactorily by conventional hard-surfacing techniques.

Iron is a desirable addition to our alloy from the viewpoint of cost, first, because iron is much less expensive than nickel; and second, because when the alloy contains iron, ferro-chromium may be used as the means for providing chromium to the alloy rather than the much more expensive chromium metal. However, the results in Table 3 show that the corrosion resistance of the alloy is deleteriously affected when the iron content is as high as 10%. We, therefore, limit the iron content of our alloy to about 8% when the alloy is required to withstand corrosion in lead oxide. However, for applications where only general resistance to corrosion is required we may use up to 20% iron in our alloy.

The melting point of our alloy is appreciably lowered as both the carbon and boron content increase as shown in Table 4.

Table 4.—Effect of carbon and boron on the melting point of hard facing alloy

Alloy	Analysis, Percent					Approximate Melting Point, ° F.
	C	Si	Cr	B	Ni	
891	1.91	.55	25.3	0.5	Balance.	2,325
887	1.53	.87	25.0	1.0	Balance.	2,250
892	1.80	.90	29.2	1.0	Balance.	2,150
858	.69	.44	25.3	1.3	Balance.	2,200
858	1.01	.48	25.4	1.3	Balance.	2,125
860	1.43	.44	25.5	1.3	Balance.	2,125
862	1.86	.38	25.2	1.3	Balance.	2,050
2619	.24	.26	26.5	2.2	Balance.	2,100
2863	.38	.48	26.7	2.2	Balance.	2,100
857	.61	.46	25.6	2.2	Balance.	2,050
859	1.02	.70	25.4	2.2	Balance.	2,050
861	1.26	.42	24.3	2.2	Balance.	2,000
863	1.85	.42	24.7	2.0	Balance.	2,000
2864	.57	.29	26.3	2.5	Balance.	2,050
2866	.98	.42	25.2	2.5	Balance.	1,975
2611	1.38	.36	25.1	2.5	Balance.	1,975
852	.52	.46	25.4	3.4	Balance.	1,975
853	1.05	.52	25.7	3.3	Balance.	1,975
2621	2.33	.16	26.3	2.8	Balance.	1,975

On the basis of these results, we use a minimum of 0.5% carbon and a minimum of 1.3% boron in our hard facing alloy so that its melting point will be under 2150° F. Obviously, when the carbon is as low as 0.70%, the boron in the alloy would have to be about 1.5% in order to have a melting point under 2150° F. We, therefore, set a minimum of 2.2% for the sum of carbon plus boron.

Our hard facing alloy as deposited has a room temperature hardness which may be as low as Rockwell C32 or as high as C62, depending on the carbon and boron contents; the higher the sum of carbon plus boron, the higher the hardness of the alloy as deposited. This room temperature hardness is practically unaffected by heating the alloy to temperatures as high as 1600° F. The hardness of the alloy at elevated temperatures decreases with increasing temperature, but reflects the hardness at room temperature; the higher the room temperature hardness, the higher the hardness at any particular elevated temperature.

Although our alloy is used mainly in the form of cast rods for applying hard surfaces by conventional welding techniques, it may also be used in powder form and applied to the surface to be covered by spraying. Our alloy may also be used in the form of castings made by usual foundry techniques. Such castings would have high hardness, corrosion, and abrasion resistance, although they would be relatively brittle.

What we claim is:

1. A nickel base alloy containing about: 0.8 to 1.8% carbon, 1.3 to 2.5% boron, the sum of carbon and boron aggregating at least 2.2%, 20 to 27% chromium, up to 0.5% silicon, up to 5% each of copper and iron, up to 2% cobalt, up to 2% of metal of the group molybdenum and tungsten, and the balance substantially nickel, characterized in having a melting point under 2150° F., a room temperature hardness within the range of about Rockwell "C" 32 to 62, combined with high corrosion resistance and high hardness at elevated temperatures.

2. An alloy consisting essentially of about: 0.5 to 2.2% carbon, 1.3 to 3.5% boron, the sum of carbon and boron aggregating at least 2.2%; 15 to 35% chromium, up to 1.5% silicon, up to 10% copper, up to 20% iron, up to 2% cobalt, up to 2% of metal of the group tungsten and molybdenum, balance nickel.

3. An alloy consisting of about: 0.8 to 1.8% carbon, 1.3 to 3% boron, the sum of carbon and boron aggregating at least 2.2%, 20 to 27% chromium, up to 1% silicon, up to 10% copper, up to 8% iron, up to 2% cobalt, up to 2% of metal of the group tungsten and molybdenum, balance nickel.

4. An alloy consisting of about: 0.8 to 1.8% carbon, 1.3 to 2.5% boron, the sum of carbon and boron aggregating at least 2.2%, 20 to 27% chromium, up to 0.5% silicon, up to 5% each of copper and iron, up to 2% cobalt, up to 2% of metal of the group tungsten and molybdenum, balance nickel.

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