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SPRAY-WELD ALLOYS OF THE BORON-SILICON-NICKEL TYPE

Sam Tour, New York, N. Y., assignor to Metallizing Engineering Co., Inc., a corporation of New Jersey

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This invention relates to an improvement in spray-weld alloys of the boron-silicon-nickel type. Alloys of this type are known in the art, and comprise a nickel base to which is added relatively small percentages of boron and silicon to improve the fluxing characteristics of the nickel base alloy. Other elements, such as chromium, are frequently included in nickel base alloys of this type.

Such alloys are used for welding and brazing and particularly for coating materials applied as a fused or welded over-lay on base materials, such as steel or steel alloys.

The elements boron and silicon, when added to nickel or nickel base alloys, act as fluxer of the alloy and of the surface to be alloyed during the fusing of the alloy when performing the brazing, welding or coating operation. For this reason such alloys are known as "self-fluxing alloys."

One process frequently used for applying fused coatings of boron-silicon-nickel alloys is known as "spray-welding." Spray-welding comprises the steps of first metal spraying the alloy onto the surface to be coated, and second, fusing the coating in place. The metal spraying operation can be carried out by any of the known metal spraying techniques, in which the material to be sprayed is fed into a heating zone where it is melted or heat-softened and from which it is, in finely divided form, propelled in molten or heat-plastic condition onto the surface to be coated. The material being fed to the heating zone may be in the form of a rod or in the form of a powder, or in some cases, in the form of a powder bonded together by a plastic material to form a wire, said plastic material being of a nature such that it disintegrates in the heat of the flame, releasing the metal particles. In metal spraying methods where the material is fed in the form of a rod or wire, the tip of the wire is melted in the heating zone and sufficient energy is applied to the tip of the molten wire by a blast of air or other gas, to cause the molten metal at the tip to subdivide into a fine spray.

After coatings have been applied by the metal spraying process, they are thereafter fused in the carrying out of the spray-welding process. Such fusing may be done in a furnace or, alternatively, by means of heating torches applied directly to the coated surface.

Only alloys which have certain properties are suitable and practical for the spray-weld process. Some of the properties required for such alloys are:

(1) The property of a melting point appreciably below the melting point of the base to which they are applied, which is usually steel;

(2) The property of wetting the surface to which they are applied (usually steel);

(3) The property of having a relatively wide viscous fluid range with respect to temperature variation so that the coatings will not run or drip during the fusing operation;

(4) The property of having a relatively low surface

tension to avoid retraction from edges during the fusing operation;

(5) The property of having sufficient plasticity at temperatures below but near the melting point, to avoid undue cracking due to shrinkage during freezing;

(6) The property of having sufficient ductility or toughness to avoid cracking due to temperature variations during cooling;

(7) The property of forming an oxide-dissolving slag separable from the molten metal to remove the oxides therefrom, since such oxides formed during spraying or fusing interfere seriously with the coalescence during fusing and adversely affect the physical properties of the fused coatings;

(8) The property of resisting corrosive attack of various environments.

The best self-fluxing alloys for the spray-welding process that have heretofore been known comprise nickel base alloys of the boron-silicon type and of the boron-silicon-chromium type.

The extent to which the base spray-welding properties of the boron-silicon-nickel base alloy can remain essentially unaffected is exemplified by the fact that they may contain from 0% up to 20% Cr by weight of total alloy. This component imparts increasing corrosion and oxidation-resistance properties without interfering with or displacing the essential properties of the alloy enumerated in (1) to (7) above.

On the other hand, such element as carbon may be present as an impurity or as a desirable component to increase, for instance, the hardness of the spray-welding alloy. The upper limit of C content, however, is dictated by the fact that excessive amounts will impart too high a degree of brittleness to the alloy, thereby interfering with the property of ductility as set forth in (6) above. Another frequently occurring component of these spray-welding boron-silicon-nickel base alloys is iron, which should not be normally present in amounts exceeding 10%, and preferably not in amounts exceeding 5% by weight of the total alloy.

A typical spray-weld alloy of the boron-silicon-nickel type, as an example, consists of 0.7–1% carbon, 3.5–4.5% silicon, 2.75–3.75% boron, 3–5% iron, and optionally an adidtional 16–18% chromium and nickel making up the balance.

Such heretofore known alloys however have met the property requirements (1) to (8) above only to a very limited extent. If the alloys are designed to meet some of the requirements, they tend not to meet other requirements. For instance, an alloy of the type given in the above example has satisfactory properties with respect to melting point, wetting and slagging, but has the objection that the plastic or viscous fluidity range is not sufficiently wide, the fluidity is too great, the surface tension is too high and the alloy is subject to cracking during cooling or temperature changes. The result is that it is very difficult to apply coatings of such materials and avoid cracking of the surface, drawing away from the edges and lifting at edges. It is also difficult to apply any but the very thinnest of coatings. In fact, the practical limit for coatings of such materials is about 1/32"; although coatings have been produced with extreme difficulty up to .060" or .080", such thicknesses are not in general commercial use. This thickness limitation is due, among other reasons, to the heat-resistive nature of the alloy or the relative high fluidity, or some combination of these properties which is not altogether understood, yet for many purposes heavier coatings would be desirable.

The relative narrowness of the viscous fluidity range of the prior boron-silicon-nickel base spray-welding alloys is a serious deficiency. Though that range is for

these alloys about 75°–100° F. it is, under conditions of torch-heating, difficult and sometimes impossible to uniformly operate within that range and requires skill and experienced operators.

One object of this invention is to provide an alloy of the boron-silicon-nickel base type for use in the spray-welding process which overcomes these objections of the heretofore known alloys.

It is a further object of the invention to provide such an alloy substantially meeting all of the requirements of (1)–(8) above, to a greater and more satisfactory extent than hitherto possible.

It is a further object of this invention to provide a self-fluxing alloy which has superior properties, for use in the spray-welding process as enumerated above.

It is a further object to provide an alloy for the spray-welding process which has the property of greater toughness and improved ductility at temperatures just below its melting point.

It is a further object of this invention to provide a boron-silicon-nickel base type alloy for use in the spray-welding process which has the property of a viscous fluid range which is wider than that of hitherto known alloys of this type.

It is a further object of this invention to provide an alloy for use in the spray-welding process which has relatively low surface tension in the molten state.

It is a further object of this invention to provide an alloy for use in the spray-welding process which has the property of relatively high resistance to cracking due to temperature variations.

It is still a further object of this invention to provide an alloy of greater resistance to corrosion attack.

These and other objects of this invention will become more evident in the light of the following description.

An alloy for use in the spray-welding process in accordance with this invention comprises a nickel base alloy of the boron-silicon type, containing additionally from 3% to 8% copper, and preferably from 5% to 6% copper, and from 3% to 10% molybdenum, and preferably from 4½ to 5½% molybdenum. All percentages herein mentioned are by weight of total alloy.

Spray-welding alloys in accordance with the invention may thus comprise Si: 1–6% and preferably 4–5%; B: 1–6% and preferably 3.5–4.5%; Cr: 0–20%; Cu: 3–8% and preferably 5–6%; Mo: 3–10% and preferably 4.5–5.5%; balance Ni plus impurities. What has been said above in connection with the prior art alloys of the boron-silicon-nickel type regarding impurities and/or additives and especially carbon and free iron, applies equally to the alloys in accordance with the invention.

Typical component ranges of alloys in accordance with the invention are exemplified in the following table:

TABLE

Si	1–6	4–5	4–5	4–5	3.5–4.5
B	1–6	3.5–4.5	3.5–4.5	3.5–4.5	2.75–3.75
Cu	3–8	5–6	5–6	5–6	5–6
Mo	3–10	4.5–5.5	4.5–5.5	4.5–5.5	4.5–5.5
Cr	0–20	----------	8–12	15–18	16–18
C	0–1	0–0.2	0–0.2	0–0.2	0.7–1
Fe	0–5	0–5	0–5	0–3	0–5

Balance in all cases Ni.

When an alloy in accordance with this invention is used in the spray-welding process, it is found to have the desirable properties enumerated above, to a much greater extent than any heretofore known alloy. When fusing a metal sprayed coating of this alloy in place, it is found to remain semi-plastic or "slushy" over a much wider temperature range than previous alloys. The properties of plastic range and low fluidity may, each or both, contribute to this characteristic of remaining in a somewhat plastic or semi-fluid condition, and it is not known to what extent each of the two properties referred to as "plastic range" and "low fluidity" contribute to this characteristic. This "slushy" condition of the new alloy, however, is very pronounced and makes it possible to build up and fuse coatings of much greater thickness than with any previously known alloys.

The new alloy in accordance with this invention has, to a much greater degree than previous alloys, the property of low-surface tension during the fusing operation of the spray-welding process. This property manifests itself by the tendency of the coating to lie flat on its upper surface and to avoid rounding over the edges of the surface and also to avoid lifting up and away from the edges of the surface. In carrying out the spray-welding process, it is very important to avoid these tendencies of rounding away from the edges and of lifting at the edges since the objective of the coating process is to provide an even coat over the surface. In many cases, the coatings are finished such as by grinding, and in such cases, it is important that the coating material be applied evenly over the surface and that it reach to and remain as nearly square as possible, with the edges, so that the entire surface will clean up by the grinding operation. As an example, suppose that the head of a small valve is to be coated, the head representing a disc approximately ½" in diameter, and that it is to be coated to a thickness of 1/16". Any previously known alloy would tend to draw away from the edge, which in this case is the periphery of the disc, with the metal drawing toward the center of the disc in its attempt to form a more nearly spherical surface. The result of this would be that excessive grinding would be required at the center, and that it would be impossible to clean up to the edges with a coating anywhere near to a thickness of 1/16". If the average amount of metal ground off the surface, for instance, were 1/64", then it would be expected that the surface would not be ground at all to within about 1/16" of the edge. This condition is avoided almost entirely by the new alloy in accordance with this invention. In the case of the example just cited, it would be possible to apply a coating of approximately 5/64", which would lie so nearly flat during and after fusing that it would be possible to grind off approximately 1/64" to give a finished coating thickness of 1/16" and the coating would clean up all over, to within a few thousandths of an inch of the edge.

The alloy in accordance with this invention has a relatively high resistance to heat-cracking, which manifests itself in its avoidance of cracking in places upon cooling. Where materials with relatively poor heat-cracking resistance are used, small hairline cracks frequently develop in the surface of the coating and sometimes these cracks extend through the coating and even form major fractures. These cracks can, to some extent, be prevented by limiting the use of the method to thin coatings and by taking special precautions during cooling, such as by insulating the parts with asbestos or by keeping them in a furnace while the furnace is slowly cooling off over a period of hours. The new alloy, in accordance with this invention, is much less critical to the formation of cracks than any previously known alloys. This characteristic of the coating helps prevent distortion of the base material and the new alloy is superior in this respect.

The following example illustrates the use of an alloy in accordance with this invention:

Example I

One alloy in accordance with this invention has the following analysis:

Element:	Percent
Carbon	0.1
Silicon	4.5
Boron	3.75
Molybdenum	5
Iron	2
Copper	5.5
Chromium	15.5
Nickel	Balance

In one method of applying the alloy exemplified by the above specified analysis, it is subdivided so that it will all pass through a 120 mesh standard screen and applied by means of conventional-powder-metal spray gun. As a specific example of this application, a steel shaft having a 2" diameter section 4" long, and with a keyway ⅛" x ¼" x 1" long at one end of the section to be sprayed, is prepared for the spray-welding operation by grit-blasting with a conventional blast machine, in which the grit is blown forcibly against the surface of the shaft by means of compressed air, using S. A. E. G–16 crushed steel grit and a blast air pressure of 100 p. s. i. for a few minutes, sufficiently to roughen and thoroughly clean the surface to be coated. A steel key, ¼" square, is fitted into the keyway of the shaft before blasting.

A coating of ⅛" thickness of the alloy is metal-sprayed in conventional manner over the entire shaft section to be coated while the shaft is rotated in a lathe. The key is then removed by grinding away the edges of the sprayed coating adjacent the key and tapping the key out of the keyway.

While rotating the shaft in a lathe, the shaft is preheated, using a conventional oxy-acetylene heating torch over the entire coated section, to a temperature of approximately 1000° F. The torch is then concentrated at one end of the coated section while the shaft is still rotating, so as to raise the temperature of a small band of the coating. As the coating fuses, the torch is gradually moved along the coated section of the shaft so as to successively fuse each small band of the coating until the entire coating has been fused. The heating is then stopped and the shaft allowed to cool in air and without any attempt at controlled cooling or heat-insulation.

The coated end of the shaft is then ground to a diameter of approximately 2 3/16". The coating will shrink about 20% during fusing from the original sprayed thickness of ⅛". This will still leave sufficient finish allowance for grinding the coating to a finished thickness of approximately 3/32" on a side of the shaft.

The coating thus applied will be found to be completely finish-ground on the diameter, have a relatively small radius on the corner at the edge of the keyway, be firmly adherent at the edges of the keyway, as well as elsewhere, and be free from cracks in its entire surface.

Other spray-weld alloys, differing in specific composition from the above sample alloy but corresponding in their analysis to the ranges herein claimed, may be substituted in the above example to obtain corresponding results.

Another specific example of my spray-weld alloys is:

Example 2

Element:	Percent
C	0.8
Si	4.0
B	3.5
Mo	5
Fe	2.5
Cu	5.3
Cr	16.0
Ni	Balance

Another specific example of my spray-weld alloys is:

Example 3

Element:	Percent
C	0.2
Si	3.0
B	3.0
Mo	4.5
Fe	2,0
Cu	4.5
Cr	---
Ni	Balance

Another specific example of my spray-weld alloys is:

Example 4

Element	Percent
C	0.2
Si	3.25
B	3.00
Mo	4.75
Fe	2.25
Cu	5.0
Cr	10.5
Ni	Balance

Although I have described a specific case in which a spray-weld alloy made in accordance with my invention is applied by means of a powder metal gun, it will of course be understood that the alloys made in accordance with my invention may also be sprayed from a wire or rod using a conventional so-called wire-type metal spray gun. The alloys may be present in wire form, either as such or by way of finely subdivided material bonded together with a plastic agent which will disintegrate during the spraying operation. Many of the spray-weld alloys in accordance with the invention cannot be properly drawn into wire form and may then, however, be cast into rods of suitable length in lieu of compounding the same into a plastic bonded wire. Thus the specific alloy used in accordance with the above examples may be sprayed from a wire-type gun in the form of a rod or such plastic wire, the spray metal coating being thereafter treated the same as specified in the examples, obtaining similar results.

The foregoing specific description is for purposes of illustration and not of limitation and it is therefore my intention that the invention be limited only by the appended claims or their equivalents wherein I have endeavored to claim broadly all inherent novelty.

I claim:

1. A spray-weldable alloy of the boron-silicon-nickel type containing at least 40% nickel, 1–6% boron and silicon in amount up to about 6% having an additional component consisting of 3–8% Cu and 3–10% Mo by weight of total alloy and possessing a range of viscous fluidity of at least 100° F.

2. The alloy in accordance with claim 1 in which said component consists of 5–6% Cu and 4.5–5.5% Mo by weight of total alloy.

3. The alloy in accordance with claim 1 in which the same contains 4–5% Si, 3.5—4.5% B, and 8–20% Cr by weight of total alloy.

4. The alloy in accordance with claim 3 in which the same contains 15–17% Cr by weight of total alloy.

5. A spray-weldable alloy of the boron-silicon-nickel type essentially consisting of 0–1.5% C, 1–6% Si, 1–6% B, 0–10% Fe, 0–20% Cr, 3–8% Cu, 3–10% Mo and at least 40% nickel by weight of total alloy, said alloy having a range of viscous fluidity of at least 100° F.

6. The alloy in accordance with claim 5 in which said carbon content does not exceed substantially 1% by weight of total alloy.

7. The alloy in accordance with claim 6 in which said iron content does not exceed about 5% by weight of total alloy.

8. The alloy in accordance with claim 7 in which the content of Si is 4–5%, of B is 3.5–4.5%, of Cu is 5–6%, and of Mo is 4.5–5.5% by weight of total alloy.

9. The alloy in accordance with claim 8 in which the same contains from 8–20% of Cr by weight of total alloy.

10. The alloy in accordance with claim 9 in which the same contains from 15–17% of Cr by weight of total alloy.

11. A spray-weldable nickel base alloy of the boron-silicon type consisting of 1–6% Si, 1–6% B, 0–10% Fe, 0–20% Cr, 3–8% Cu, 3–10% Mo by weight of total alloy, the balance being nickel.

12. The alloy in accordance with claim 11 in which the same contains 0–10% C and 0–5% iron by weight of total alloy.

13. The alloy in accordance with claim 12 in which the same contains 4–5% Si, 3.5–4.5% B, 5–6% Cu, and 4.5–5.5% Mo by weight of total alloy.

14. The alloy in accordance with claim 13 in which the same contains 8–20% Cr by weight of total alloy.

15. The alloy in accordance with claim 14 in which the same contains 15–17% Cr by weight of total alloy.

16. The alloy in accordance with claim 15 in which the same contains 0.2% C and 0.3% Fe by weight of total alloy.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,875,043 February 24, 1959

Sam Tour

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 5, line 72, for "2,0" read -- 2.0 --; column 7, line 2, for "0-10%" read -- 0-1% --.

Signed and sealed this 9th day of June 1959.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents