METHOD OF PRODUCING FUSION COATED METAL BASE

William H. McFarland, Hobart, and Henry M. Roelofs, Chesterton, Ind., and Leslie M. Bernick, Calumet City, Ill., assignors to Inland Steel Company, Chicago, Ill., a corporation of Delaware

No Drawing. Filed Jan. 19, 1961, Ser. No. 83,637

16 Claims. (Cl. 29—528)

This invention relates to a new and improved metal base having a protective alloy coating and to a novel method of making the same. More particularly, the invention relates to a ferrous metal or steel base having a fusion coating comprising a nickel-chromium alloy.

At the present time there is a need for improved steel sheet material having a corrosion resistant surface and suited for the fabrication of various articles such as mufflers for combustion engines and the like. Heretofore, special alloy steels have been proposed for such purposes but obviously the cost is prohibitive in many cases. Conventional coated steel, such as galvanized or aluminized steel, while satisfactory for many purposes, does not always have the requisite ductility or formability and does not provide the degree of protection desired for service in a high corrosion environment. Moreover, an economically feasible process for making corrosion resistant steel sheet material must be capable of operation on a continuous basis and must be capable of being integrated easily into existing steel plant techniques.

We are aware of various prior art proposals for coating a ferrous metal base by cementation techniques involving heating the base in contact with powdered or subdivided metals to effect diffusion of the latter into the surface of the base. As will hereinafter appear, our invention utilizes a fusion coating technique employing a special powdered alloy composition and carefully controlled heating conditions.

Accordingly, a general object of the invention is to provide a novel and improved metal base, particularly a ferrous metal base, having a protective alloy coating.

A further object of the invention is to provide a novel and improved method of making a product of the aforementioned character.

Another object of the invention is to provide a novel and improved steel base having a fusion coating comprising a nickel-chromium alloy and to a novel and improved continuous method of making the same which is readily adapted for integration with conventional steel plant practice.

An additional object of the invention is to provide a novel and improved heating step in the fusion coating of a ferrous or non-ferrous metal base with a powdered nickel-chromium alloy composition.

Still another object of the invention is to provide a novel nickel-chromium alloy coated steel base which possesses sufficient ductility and formability to be utilized for a wide variety of fabricating purposes.

Other objects and advantages of the invention will become evident from the subsequent detailed description.

Briefly described, the process of our invention comprises applying a preformed powdered alloy of nickel, chromium, and phosphorus to a metal base, particularly steel or the like, and thereafter heating the base in a non-oxidizing atmosphere having a critical low moisture content whereby to melt or fuse the powdered alloy and thereby form an adherent uniform or continuous alloy surface on the base. Particularly, we have found that certain preferred techniques are advisable in connection with both the initial coating and the heating steps. The resultant product is characterized by excellent resistance to atmospheric or chemical corrosion and also to heat and oxidation. Furthermore, and most importantly, the product is substantially free of the brittle intermetallic alloy layer between the base and the coating which is characteristic of galvanized and aluminized products, and as a result our product has excellent ductility and formability so that it can be used to fabricate a wide variety of articles.

For convenience, the invention will be described hereinafter with particular reference to a ferrous metal base such as steel, but it shall be understood that the invention also embraces the use of non-ferrous metal bases having a melting point above about 1650° F., e.g., nickel, molybdenum, tungsten, cobalt, columbium, and titanium.

Suitable ferrous metal bases may include low, medium, or high carbon steels, but in the preferred continuous process it will usually be most convenient to employ low carbon, cold rolled steel strip containing from about 0.03% to about 0.20% carbon. However, other ferrous metal bases such as cast iron and high strength low alloy steels may also be used.

The preferred alloy used as the protective coating comprises a major proportion of nickel, a minor proportion of chromium, and a still smaller amount of phosphorus. The proportions of nickel and chromium may be varied considerably but are regulated to provide an alloy having the required resistance to corrosion, heat, and oxidation while at the same time having sufficient ductility and formability to permit fabrication and forming of the coated base without crumbling or cracking of the alloy coating. The purpose of the phosphorus is to lower the melting point of the alloy and also to provide protective self-fluxing properties during fusion, as hereinafter described. Preferably, the amount of phosphorus should be sufficient so that the melting point of the alloy is from about 1650° F. to about 2050° F. However, excessive amounts of phosphorus have a tendency to make the alloy coating brittle and, therefore, the phosphorus content of the original alloy should not exceed about 13 wt. percent. In general, the original alloy will comprise from about 5 wt. percent to about 20 wt. percent chromium, 7 wt. percent to about 13 wt. percent phosphorus, and the balance nickel. The preferred alloy composition comprises about 78 wt. percent nickel, 13 wt. percent chromium, and about 9 wt. percent phosphorus.

The preferred alloy composition, as described above, is applied to the ferrous metal base in subdivided or powdered form and the applied alloy particles are then melted or fused to provide a continuous and substantially uniform fusion coating on the surface of the base. Although the invention in its broadest aspect contemplates any suitable techniques for applying the powdered alloy to the surface of the base, we have found that the preferred method involves forming a suspension of the powdered alloy in a liquid suspending medium and applying the suspension to the base in any convenient manner, e.g., by spraying, dipping, electrostatic coating, roller coating, curtain coating, or electrophoresis.

The particle size of the nickel-chromium-phosphorus alloy should be small enough so that the powdered alloy can be effectively suspended in the liquid suspending medium, but regardless of the manner of applying the powdered alloy to the surface of the base, the particle size should be as fine as possible so that the applied particular coating will melt or fuse rapidly in the subsequent heating step. Dependent upon the choice of liquid suspending medium, we have found that powders ranging in size from about 100 mesh (149 microns) to about 420 mesh (40 microns) can be used, and as a result after a powder passing through a 325 mesh screen (44 microns) gives entirely satisfactory results (based on Tyler
Standard Screens). Even smaller particle sizes down to 1-5 microns can also be employed if desired. In general, water is the most convenient liquid suspending medium but other liquid mediums such as glycerine, light oils, etc. can be used. In the case of an aqueous medium, it is usually advantageous to employ an added dispersing or suspending agent, such as starch or various known surface-active agents, in order to form a relatively stable suspension or dispersion of the powdered alloy in the aqueous liquid. We have found that corn starch is highly satisfactory and economical for this purpose.

It is important that the surface of the ferrous metal base be prior to the application of a liquid suspension of powdered alloy in order to insure uniform application of the suspension. Accordingly, in most instances it will be necessary to subject the base to a cleaning operation for the removal of rust, grease, oil, dirt, scale or the like prior to the application of the suspension. Any effective cleaning techniques may be used including pickling, alkaline electrolytic cleaning, ultrasonic cleaning, flame cleaning, etc.

We have found that in order to obtain a final product having acceptable resistance to corrosion, heat, and oxidation, a coating of powdered alloy applied to the surface of the ferrous metal base must be sufficient to provide a fused coating weight of at least about 1 gram of alloy per square foot of coated surface. The upper limit of coating weight is dictated largely by ductility or formability requirements and also by economic considerations, but in general it is not feasible to provide more than about 4 grams of alloy per square foot of coated surface. In general, such coatings will have a thickness of from about .00015 to about .00070 inch.

Following the application of the powdered alloy to the surface of the ferrous metal base, the base is then subjected to a heating step for the purpose of melting or fusing the particulate alloy whereby to provide a substantially uniform or continuous alloy surface on the base. In the case where the powdered alloy is applied to the surface of the base as a liquid suspension, it will be understood that the heating step first effects drying of the coating suspension and thereafter melting or fusing of the alloy particles. As heretofore mentioned, the composition of the alloy is preferably regulated so that the melting point of the alloy is from about 1650°F to about 2050°F. Accordingly, the temperature in the heating step may range from about 1650°F to about 2050°F, but in any case the temperature must be at least as high as the melting point of the alloy and less than the melting point of the base. The heating time may be from about 20 seconds to about 2 minutes.

It will be appreciated that the particular time-temperature relationship in any given case is dependent upon the particle size of the powdered alloy and also upon the alloy composition. Increasing the chromium content of the alloy, decreasing the phosphorus content of the alloy, or increasing the particle size of the alloy each tend to increase the required temperature and time for obtaining a satisfactory fusion coating. Both the appearance and the ductility or formability of the final fused coating are also affected by the time-temperature relationship.

In the case of a continuous operation involving the use of steel strip, the strip may be passed through successive cleaning, coating, and heating zones, or if more convenient the strip may be preliminarily cleaned in a separate step. Thus, the invention lends itself readily to integration in an existing continuous annealing or normalizing line so that the step for melting or fusing the powdered alloy coating is combined with the usual annealing or normalizing step for improving the physical properties of the steel base.

The heating step of the invention wherein the applied coating of powdered alloy is melted in a furnace containing a protective atmosphere which is non-oxidizing with respect to both the base and the alloy and which has a critical low moisture content. A wide variety of non-oxidizing atmospheres, which may be either neutral or reducing, are well known in connection with the various normalizing, annealing, and heat treating operations which are frequently carried out in the steelmaking art. Generally speaking, such atmospheres contain moderate to high concentrations of inert gases containing none or a certain predetermined amount of hydrogen which determines the reducing character of the atmosphere. For example, a so-called HNX gas containing from about 0% to about 10% hydrogen and the balance nitrogen is particularly suitable.

However, we have found that for successful results it is essential to maintain a critical low moisture content in the furnace atmosphere and also preferably a low concentration of CO and CO₂. Water vapor is particularly detrimental since it seriously interferes with the ability of the alloy particles to melt and flow into a continuous coating. We have found that a dew point of not greater than about -5°F, and preferably not greater than about -10°F (corresponding to 0.118 and 0.093 volume percent H₂O, respectively) is essential in order to obtain proper fusion and flowing of the coating during the heating step. In addition, it is desired that the dew point of the furnace atmosphere may be from about -5°F to about -30°F, or even lower. This critical moisture content appears to be independent of the hydrogen content of the atmosphere. Furnace atmospheres containing from 0% to 75% hydrogen, the balance being nitrogen, have been used successfully. In addition, it is also desirable that the total content of CO and/or CO₂ be not greater than about 0.1% of the furnace atmosphere in order to avoid discoloration of the final coating.

In the case of a continuous operation using a gas fired furnace, the required furnace atmosphere is best maintained by providing a continuous supply of specially prepared non-oxidizing substantially dry gas, such as HNX gas, and withdrawing the same continuously so as to remove moisture-containing combustion gases and thereby avoid accumulation of moisture in the furnace atmosphere. However, as a practical matter, the most troublesome source of contaminating moisture is usually the refractory brick of the furnace walls. In order to minimize this problem, it will be found desirable to operate the furnace for an appreciable period before the process of building the invention is carried out, so that most of the moisture is driven out of the brick and an equilibrium state is reached. Thereafter, in the event of an interruption in the process, the furnace should be maintained at operating temperature until the process can be resumed. In addition, at the strip inlet end of the furnace, various well known expedients may be adopted to prevent intake of moisture-containing air into the furnace.

As heretofore briefly mentioned, the phosphorus content of the alloy used in the present invention not only serves the purpose of lowering the melting point of the alloy but also performs an important protective function during the fusion or heating step. In the original pre-formed alloy the phosphorus is present in alloy form, but during the heating step of the invention, which is carried out at a temperature ranging from about 1650°F to about 2050°F, a substantial portion of the phosphorus leaves the alloy system as phosphorus gas. Some residual phosphorus remains in the final coating dependent upon the time and temperature of the fusion step, and the final fused coating will be somewhat richer in nickel and chromium than the original alloy powder because of the volatilization. The phosphorus vaporized phosphorus provides an important scavenging or self-fluxing action by chemically combining with any oxygen or water vapor which may be present and thereby locally protecting the chromium in the alloy from oxidation, the chromium being vaporized oxidized or capable in the atmosphere of the heating step. In addition to the protective self-fluxing role of phosphorus, the presence of chromium
solely in alloy form with nickel also minimizes the susceptibility of the chromium to oxidation. Thus, it will be seen that the corrosion resistance of the alloy is protected from oxidation during the heating step of the process by (1) the use of a non-oxidizing low moisture content atmosphere in the heating furnace, (2) the scavenging or self-fluxing effect of the vaporized phosphorus, and (3) the presence of the chromium solely in prealloyed form with nickel rather than as free chromium.

The final product of the process comprising a ferrous metal or steel base having a fusing coating of nickel-chromium alloy possesses a number of valuable properties:

(1) Dependent upon the time-temperature relationship in approach discussed above, a product can readily be obtained which has an attractive metallic luster similar to the well known appearance of nickel-chromium alloys such as Inconel and the like. Thus, from an appearance standpoint, the product compares favorably with the more expensive nickel-chromium alloys.

(2) The product has excellent resistance to atmospheric corrosion and also provides good resistance to chemical corrosion such as in alkaline environments. Furthermore, the protective coating of the product also provides a high degree of resistance to heat and oxidation which is approximately greater than that of mild steel. The corrosion resistance of the product can be improved further by subjecting the product to suitable chemical treatment or passivating treatment in accordance with techniques well known in the art for treating nickel, chromium, or nickel-chromium surfaces.

(3) The product has highly satisfactory ductility or formability, e.g. as determined by the Pittsburgh Lock Forming test and the 180° TT bend test. In most instances the product of the present invention is superior in this respect to conventional galvanized and aluminized products. Microscopic examination of the coated product of the present invention shows no visible evidence of the brittle intermetallic compound formation which is characteristic of hot dip aluminized and galvanized products. It is believed that the fusion bond between the base and the nickel-chromium alloy coating is the result of the absence of intermetallic compound formation, which is responsible for the highly satisfactory ductility and formability of the product.

(4) The product has satisfactory welding characteristics which, together with its excellent formability properties, makes the product suitable for a wide variety of fabrication and structural purposes. With automatic welding and spot welding equipment, fouling of the welding tips is considerably less than is encountered when welding galvanized steel and the continuity of the coating is not destroyed.

(5) The coated product of the invention can be treated to improve or alter the physical properties of the base without adversely affecting the alloy coating. For example, the product may be air annealed to impart ductility and softness to the ferrous metal base, or the product may be temp rolled to eliminate the yield point of the base. Neither of these operations has any adverse effect on the ductility or formability of the alloy coating. Such is not the case, however, with galvanized or aluminized steel wherein the ductility and formability of the zinc or aluminum coating is impaired by subsequent heat or mechanical treatment. Thus, in practicing the present invention it is highly advantageous to be able to apply the alloy coating to the steel base in the as received condition and thereafter heat treat or temper the coated product to obtain the desired physical and mechanical properties in the steel base.

In view of the atmospheric corrosion resistance, the chemical corrosion resistance, and the heat and oxidation resistance of the product of our invention, it will be recognized that the product has many different fields of potential use of which the following may be named as representative: metal building sections, roofing and siding, automobile paneling, railroad and railway car siding, window frames, laundry dryer parts, washing machine parts, farm equipment such as pans and poultry feeders, tank and tank car liners, containers for organic acids, combustion tubes for hot water heaters, space heaters, automotive mufflers and tailpipes, etc.

The following specific examples of the invention are presented by way of illustration but not by way of limitation.

Example 1

Using a 24 gage mild steel strip, the process was conducted on a continuous normalizing line wherein the strip was preheated successively through a preheating furnace, an electrostatic spraying system, and a fusion furnace. Prior to being passed through the foregoing apparatus, the strip was electrolytically cleaned. The composition of the mild steel strip was as follows: 0.17% C, 0.55% Mn, 0.1% P, 0.025% S, and 0.08% Si. The speed of the line was 100 ft. per minute.

In the preheating zone the strip was heated to a temperature of 200–230° F. In the electrostatic spraying zone an aqueous suspension of alloy powder was applied to both sides of the strip. The suspension contained 300 gms per liter of a preformed alloy powder (78 wt. percent nickel, 13 wt. percent chromium, and 9 wt. percent phosphorus) and 35 gms per liter of corn starch. The viscosity of the suspension was 16.8 seconds (No. 4 Ford Cup). The suspension was sprayed onto the strip in quantities sufficient to yield 1 to 2 grams of alloy per sq. ft. of strip surface. The particle size of the alloy powder in the suspension was such that all of the powder passed through a 325 mesh screen.

The maximum temperature in the fusion furnace was about 1950°F and the time at 1950°F, was about 30 seconds. The furnace was supplied with HNX gas comprising 4% hydrogen, the balance nitrogen. The dew point in the high temperature zone of the furnace ranged from about −6°F to about −10°F.

The corrosion resistance of the resultant fusion coated product was evaluated by an accelerated immersion test simulating atmospheric corrosion (ASTM designation B192–44T) and also by a synthetic muffler condensate test.

The alternate immersion test consisted of alternately immersing the test specimens in a synthetically prepared solution at 150°F for 48 hours. The solution comprised 10 liters of distilled water to which was added 6.3 ml of 48% HBr, 10 ml of concentrated HCl, 1 gram of NaNO₃, 5.5 grams of KNO₃, 1 drop of concentrated H₂PO₄, and 10 drops of concentrated H₂SO₄. The pH of the solution is adjusted to 2–3.5. Evaluation is visual. The test samples of the alloy coated product were unaffected even after 96 hours of testing, whereas after 24 hours control samples of galvanized steel had developed a heavy film of white rust with some pitting-type corrosion.

The synthetic muffler condensate test consisted of immersing the test specimens in a synthetically prepared solution at 150°F for 48 hours. The solution comprised 10 liters of distilled water to which was added 6.3 ml of 48% HBr, 10 ml of concentrated HCl, 1 gram of NaNO₃, 5.5 grams of KNO₃, 1 drop of concentrated H₂PO₄, and 10 drops of concentrated H₂SO₄. The pH of the solution is adjusted to 2–3.5. Evaluation is visual. The test samples of the alloy coated product were unaffected even after 72 hours immersion in the test solution. After 48 hours in the same solution, galvanized steel control samples were severely pitted with some evidence of red rust.
men in a predetermined pattern and is described fully in Proceedings of The Galvanizers Committee, Vol. 31–33, p. 20 (1954–1955), “Design and Operation of Lock Forming Machines” by E. C. Bill. The 180° IT bend test comprises bending a test specimen through 180° around a radius equal to the thickness of the specimen at room temperature using a smooth jawed vise or the like. This test is substantially as described in the ASTM speci-
fications for zinc-coated sheets (A93) and in the ASTM specification for aluminum-alloy sheet and plate (B209–
5T).

Example 2

Tests were made on a laboratory scale to demonstrate the criticality of the dew point of the atmosphere during the fusion step. The steel base, alloy powder, suspension formulation, and coating weight were the same as in Example 1, but in each case the coated base was heated at 1950° F. for 30 seconds. The results at different dew points and hydrogen contents were as follows:

<table>
<thead>
<tr>
<th>Dew Point, °F.</th>
<th>Percent Hydrogen in H₂–H₂O Atmosphere</th>
<th>Appearance of Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0</td>
<td>Bright</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
<td>Green powder, some melting,</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>Green powder, some melting,</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
<td>Green powder</td>
</tr>
<tr>
<td>60</td>
<td>40</td>
<td>Green powder, very light melting,</td>
</tr>
<tr>
<td>70</td>
<td>50</td>
<td>Some green, mostly black powder</td>
</tr>
<tr>
<td>80</td>
<td>60</td>
<td>Green powder</td>
</tr>
<tr>
<td>90</td>
<td>70</td>
<td>Green powder, very light melting,</td>
</tr>
</tbody>
</table>

As will be seen from the foregoing, at high dew points proper fusion is not obtained as evidenced by the presence of black or green powder. However, at dew points of -10° F. or lower, a bright fused coating is obtained over a wide range of hydrogen content of the furnace atmosphere.

Example 3

The coated product of Example 1 as produced on a continuous normalizing line was subjected to box annealing at 1100° F. with the following improvement in the tensile properties of the steel:

- Normalized at 1,500° F., Box Annealed at 1,100° F.

<table>
<thead>
<tr>
<th>Property</th>
<th>As Normalized (1,500° F.)</th>
<th>Normalized at 1,500° F., Box Annealed at 1,100° F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>51</td>
<td>42</td>
</tr>
<tr>
<td>Ultimate Tensile Strength</td>
<td>30,000</td>
<td>29,000</td>
</tr>
<tr>
<td>Percent Elongation In 2&quot;</td>
<td>50.000</td>
<td>20.000</td>
</tr>
</tbody>
</table>

The foregoing improvement in the mechanical properties of the coated base was obtained without any deleterious effect on the formability of the coating as measured by the Pittsburgh Lock Forming test and the 180° IT bend test.

We claim:

1. A process for providing a nickel-chromium alloy coating on a metal base which comprises applying to said base a powdered alloy of nickel, chromium, and phosphorus in an amount to provide at least about 1 gram of said alloy per square foot of coated surface, said alloy consisting essentially of from about 5 wt. percent to about 20 wt. percent chromium, from about 20 wt. percent to about 13 wt. percent phosphorus, and the balance nickel, thereafter heating the base in a protective non-oxidizing atmosphere at a temperature and for a time sufficient to melt the powdered alloy and, controlling the moisture content of said atmosphere to maintain a dew point not greater than about -5° F. whereby to provide a continuous fusion coating of said alloy on the surface of said base.

2. The process of claim 1 further characterized in that said alloy has a melting point of from about 1650° F. to about 2050° F., and the temperature in said heating step is within the range of from about 1650° F. to about 2050° F. and is at least as high as the melting point of said alloy and less than the melting point of said base.

3. The process of claim 1 further characterized in that said powdered alloy contains about 78 wt. percent nickel, about 13 wt. percent chromium and about 9 wt. percent phosphorus.

4. A process for making a nickel-chromium alloy coated ferrous metal base having sufficient ductility and formability for fabricating purposes which comprises applying to a ferrous metal base in sheet or strip form a powdered alloy of nickel, chromium, and phosphorus in an amount to provide from about 1 to about 4 grams of said alloy per square foot of coated surface, said alloy consisting essentially of from about 5 wt. percent to about 20 wt. percent chromium, from about 7 wt. percent to about 13 wt. percent phosphorus, and the balance nickel, thereafter heating the base in a protective non-oxidizing atmosphere at a temperature and for a time sufficient to melt the powdered alloy, and controlling the moisture content of said atmosphere to maintain a dew point not greater than about -5° F. whereby to provide a continuous fusion coating of said alloy on the surface of said base.

5. The process of claim 4 further characterized in that said powdered alloy contains about 78 wt. percent nickel, about 13 wt. percent chromium, and about 9 wt. percent phosphorus.

6. The process of claim 4 further characterized in that said alloy has a melting point of from about 1650° F. to about 2050° F., the temperature in said heating step is within the range of from about 1650° F. to about 2050° F., but is at least as high as the melting point of said alloy, and the time of said heating step is within the range of from about 20 seconds to about 2 minutes.

7. The process of claim 4 further characterized in that said atmosphere has a dew point not greater than about -10° F.

8. The process of claim 4 further characterized in that said atmosphere has a total content of CO and CO₂ not greater than about 0.1%.

9. A process for making a nickel-chromium alloy coated ferrous metal base having sufficient ductility and formability for fabricating purposes which comprises applying to a ferrous metal base in sheet or strip form a liquid suspension of a powdered alloy of nickel, chromium, and phosphorus in an amount to provide from about 1 to about 4 grams of said alloy per square foot of coated surface, said alloy consisting essentially of from about 5 wt. percent to about 20 wt. percent chromium, from about 7 wt. percent to about 13 wt. percent phosphorus, and the balance nickel, thereafter heating the base in a protective non-oxidizing atmosphere at a temperature and for a time sufficient to dry said suspension and thereby to melt the powdered alloy, and controlling the moisture content of said atmosphere to maintain a dew point not greater than about -5° F. whereby to provide a continuous fusion coating of said alloy on the surface of said base.

10. The process of claim 9 further characterized in that said base is cleaned to remove dust, grease, oil, dirt, scale, or the like prior to application of said suspension.

11. The process of claim 9 further characterized in that said powdered alloy has a particle size of from about 100 mesh to about 420 mesh.

12. The process of claim 9 further characterized in that said powdered alloy is suspended in an aqueous starch-containing medium.

13. The process of claim 9 further characterized in that said powdered alloy contains about 78 wt. percent nickel,
about 13 wt. percent chromium, and about 9 wt. percent phosphorus.

14. A process for making a nickel-chromium alloy coated steel base having sufficient ductility and formability for fabricating purposes which comprises applying to a steel base in cold hard sheet or strip form a powdered alloy of nickel, chromium, and phosphorus in an amount to provide from about 1 to about 4 grams of said alloy per square foot of coated surface, said alloy consisting essentially of from about 5 wt. percent to about 20 wt. percent chromium, from about 7 wt. percent to about 13 wt. percent phosphorus, and the balance nickel, heating the steel base in a protective non-oxidizing atmosphere at a temperature and for a time sufficient to melt the powdered alloy, controlling the moisture content of said atmosphere to maintain a dew point not greater than about 

\[ -5^\circ F \]

whereby to provide a continuous fusion coating of said alloy on the surface of said base, and subsequently treating the coated base to alter the physical or mechanical properties of the steel base without impairment of the ductility and formability of said coating.

15. The process of claim 14 further characterized in that the coated base is annealed to impart softness to the steel base.

16. The process of claim 14 further characterized in that the coated base is temper rolled to eliminate the yield point of the steel base.

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