

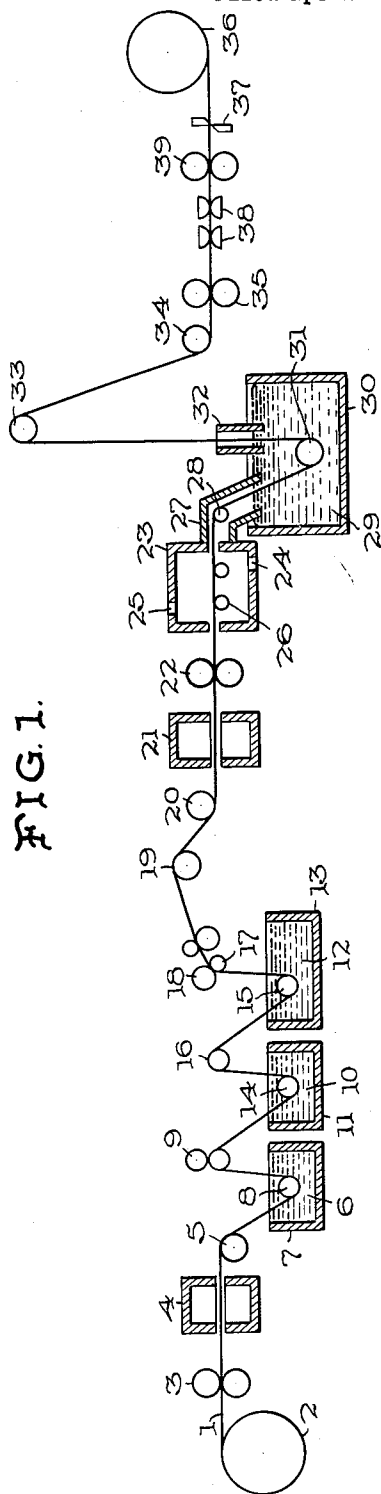
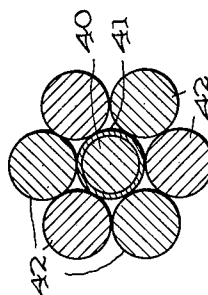
Oct. 9, 1962

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3,057,050

ALUMINIZING OF FERROUS METAL AND PRODUCT

Filed April 30, 1953



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3,057,050

ALUMINIZING OF FERROUS METAL AND PRODUCT

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Filed Apr. 30, 1953, Ser. No. 352,254
6 Claims. (Cl. 29—196.2)

This invention relates to the coating of ferrous metal with aluminum base alloys. More particularly, the invention relates to a hot dip method of coating wire, strip, sheet, or the like, of ferrous materials, e.g. plain carbon or alloy steel, with aluminum base alloys whereby high strength and other desirable physical properties can be imparted to the coated stock with no disruption of the coating layer. The invention also relates to composite stock produced by this method.

Coatings of aluminum on ferrous metal are highly desirable, since the composite resulting in effect embody the superior properties resident in each metal. To the strength and other desirable characteristics of the ferrous core, the aluminum coating adds the more salient properties of resistance to corrosion and oxidation at both atmospheric and elevated temperatures, enhanced electrical conductivity, improvement in the facility of brazing and soldering of aluminum to ferrous metal, and a more attractive appearance.

The desirability of obtaining aluminum coated ferrous products having very high strength, as well as the properties of the coating above enumerated, has been recognized for some time. Such material would be eminently suited for numerous applications where high strength in the ferrous core, as well as corrosion resistance, is a necessary prerequisite. For example, it has long been desired to produce aluminum coated steel wire for use in place of galvanized steel wire in ACSR (aluminum cable—steel reinforced) for various reasons. The conventional hot dip galvanizing processes for steel wire have not been found entirely satisfactory with respect to holidays or bare spots in the coating. Electroplating methods of applying a zinc coating have improved the uniformity of the coating over hot dip galvanizing, but such methods are very costly. Additionally, the use of a zinc coating is very undesirable from the standpoint of corrosion of the cable caused by galvanic action resulting from dissimilar metal contact. According to A.S.T.M. designation: B 245—497, the coated steel wire for ACSR must possess a minimum ultimate tensile strength of 190,000 p.s.i. and a minimum ultimate elongation (in 10 inches) of 4 percent. There are many other applications, such as springs, etc., where aluminum coated ferrous metal possessing high strength could be used.

Various methods have been proposed heretofore for coating ferrous metal by hot dipping. These methods, however, are applicable to the coating of ferrous metal where very high strength in the finished product is not required. Such methods as heretofore known have not been found suitable in facilitating production of a satisfactory product having very high strength.

As an illustration of the unsuitability of prior known coating methods, attempts have been made to coat high carbon hard-drawn wire with aluminum and aluminum alloys and thereafter cold draw said wire to the desired size and possessing high tensile properties on the order of 190,000 p.s.i. or over. The temperature of the coating bath and the time of immersion of the ferrous stock inevitably resulted in a great loss in tensile strength of the core stock. By subjecting such coated wire to extremely large reductions in cross-sectional area, most of

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the loss in strength occasioned by the coating operation, in some instances, could be regained but innumerable difficulties arose. These large reductions in cross sectional area generally resulted in disruption of the coating as by flaking or peeling. Additionally, the coating was found to be too thin to give the necessary corrosion resistance. Moreover, cracking of the coating occurred. This cracking was apparently caused by fracture and protrusion at the surface of the brittle iron-aluminum compounds formed between the core and the coating. Also, spalling of the coating frequently occurred on bending because of low compressive strength. Furthermore, it was found that even where some wires regained most of the loss in tensile strength occasioned by hot dipping that the elongation was for practical purposes nil and the ductility of the coated stock was undesirably low and could not be rendered satisfactory without adversely affecting the tensile strength. Accordingly, none of the methods of coating heretofore known have taught a satisfactory method of producing aluminum coated ferrous stock which possesses the desirable combination of properties of corrosion resistance, heat resistance, pleasing appearance, high strength and adequate ductility.

It is therefore the primary purpose and object of this invention to provide a novel method for coating ferrous metal with aluminum base alloys which overcomes the disadvantages attendant in prior known methods.

Another object of the invention is to provide a novel method for coating steel with aluminum base alloys wherein tenaciously adherent and substantially uniform smooth, bright coatings may be obtained and wherein high strength, adequate ductility, and other desirable physical properties may be developed in the resultant composite stock without adversely affecting the coating.

Another object of the invention is to provide a novel method for coating steel with aluminum base alloys in such manner that the resulting composite is readily susceptible to severe working for purposes of developing high physical properties.

Another object of the invention is to provide a novel method of producing aluminum coated steel possessing high strength and wherein the coating is tenaciously adherent, substantially uniform and smooth.

A further object of the invention is to provide a novel method of producing high strength aluminum alloy coated steel wherein the procedure of coating renders the ferrous core susceptible to high reductions in cross-sectional area without adversely affecting the coating.

Another object of the invention is to provide composite stock comprising a ferrous core and an aluminum base alloy coating and wherein the stock possesses high strength and corrosion resistance as well as other desirable properties.

Another object of the invention is to provide aluminum alloy coated steel stock wherein the coating is tenaciously adherent and substantially uniform and wherein the stock possesses high strength and adequate ductility.

A further object of the invention is to provide an improved steel reinforced aluminum cable having high strength and high resistance to corrosion.

It has been found according to the invention that ferrous metal, e.g. steel wire, strip, etc., can be coated with aluminum base alloys in such manner that the composite resulting therefrom can be subjected to severe reductions in cross-sectional area in order to develop high strength therein without disrupting the aluminum coating. Briefly, the invention comprises first suitably cleaning the steel stock, heating the stock in a suitable non-oxidizing atmosphere for a time and at a temperature sufficient to put the steel in the austenitic phase and thereafter directly quenching the heated metal in a suitable

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aluminum base alloy bath maintained at a predetermined temperature and holding the metal at such temperature for a time sufficient to develop a relatively fine pearlitic structure in the stock. In addition to the constituent pearlite being present, there may also be present a ferrite or cementite phase, but no martensite. By austenitic phase is meant that area of the iron-carbon constitution diagram wherein solid solutions exist in which gamma iron is the solvent. The term pearlite may be defined (Metals Handbook, 1939 Ed., pp. 8 and 369) as a lamellar aggregate of ferrite (solid solution in which alpha iron is the solvent) and cementite (iron-carbon compound) which are isothermal transformation products of the austenite.

The formation of this relatively fine pearlitic structure in the steel renders the steel susceptible to severe working without developing brittleness and thereby allowing the production of very high tensile strength. Where desired, such worked stock may be subjected to a suitable heat treatment to enhance the elongation and ductility properties of the stock without adversely affecting the strength thereof. Accordingly, it will be readily seen that by means of the present invention ferrous metal can now be simultaneously heat treated and aluminum coated such that it is readily susceptible to subsequent working and heat treating operations productive of a composite possessing high tensile strength as well as desirable ductility and elongation in combination with the properties of corrosion resistance, pleasing appearance, etc., commonly recognized as resident in aluminum coatings.

The invention will now be described in greater detail with reference to the accompanying drawing wherein FIGURE 1 schematically illustrates one embodiment of the invention in operation.

As can be seen from FIGURE 1, number 1 denotes steel stock which may be in the form of wire, strip, sheet, or the like, which is fed continuously off of a coil of stock mounted on a suitable pay-off reel 2. For purposes of this embodiment, the stock will be hereinafter referred to as wire. The wire 1 is fed through a pair of suitable feed rolls 3. From the rolls 3, the wire is caused, where necessary, to pass through a suitable bluing or oxidizing furnace 4 for the purpose of oxidizing and removing any grease, oil or other volatile material present on the surface thereof. Such a bluing furnace can make use of diluted propane, butane, or natural gas as fuel and should be capable of heating the wire to at least a temperature of from about 800° to 900° F.

Upon leaving the bluing furnace, the wire 1 is cleaned. This may be accomplished by passing wire 1 over a suitable idler roll 5 and then downwardly into pickling solution 6 contained in a suitable tank 7. For purposes of maintaining progressive portions of the wire submerged for a predetermined time, an adjustable submersion roller unit 8 may be provided. The pickling solution may comprise dilute hydrochloric acid or muriatic acid on the order of a 50% solution by volume. However, other suitable pickling solutions or cleaning methods may be used. The temperature of the pickling solution is preferably maintained from about 110° to 150° F. As wire 1 emerges from the pickling solution, it passes between a pair of suitable squeegee rolls 9 in order to remove the greater portion of acid which is carried up with the wire.

From squeegee rolls 9, wire 1 may be thoroughly washer free of acid by successive passage through first a cold water rinse 10 contained in a suitable container or tank 11 and then a hot water rinse 12 contained in a suitable container or tank 13. As in the case of the pickling solution, adjustable submersion rolls 14 and 15 can be provided in tanks 11 and 13, respectively. To facilitate movement of the wire between rinse tanks 11 and 13 there is provided a suitable idler roller 16 over which the wire passes.

As the cleaned wire leaves the hot water rinse it is preferably subjected to the action of a plurality of water

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spray and brush units 17. Each brush unit is power driven and may be made to rotate with a peripheral speed several times that of the speed of movement of the wire to effect a proper scrubbing action. Each brush unit is preferably backed up by a driven roller 18. The expended water used during the brushing flows down and into hot water rinse 12 and acts as make up solution.

From the spray brush units the cleaned wire may pass over and under suitable idler rolls 19 and 20, if necessary, to bring the wire in line with a suitable hot air dryer 21. This dryer may be provided with automatic temperature control means and be suitably heated as by indirect heating from radiant tubes internally heated with propane, butane or natural gas. Other means of heating such as by electrical resistance elements can also be satisfactorily used.

Upon leaving the dryer 21, wire 1 may be passed between suitable feed rolls 22, at least one of which is power driven by suitable means. Thereafter, wire 1 passes into a suitable pre-heating furnace 23. The primary function and purpose of this furnace is to heat the wire to such a temperature that it is in the austenitic or gamma range. The secondary function of the preheating furnace is to reduce the time necessary for immersion in the aluminum coating. Within this furnace there is maintained a suitable non-oxidizing atmosphere. Examples of atmospheres suitable for this purpose are carbon monoxide gas, producer gas, or forming gas comprising approximately 10% hydrogen and 90% nitrogen.

Any one of several conventional furnace constructions may be used for the preheating furnace. A suitable gas inlet 24 and outlet 25 are provided for introduction and exhaust of the non-oxidizing furnace atmosphere. The preheating furnace may be heated by various means such as electrical heating elements, fuel fired radiant tubes, or combinations thereof. Also, the wire may be heated by direct electrical resistance. Where desired, suitable rollers or guides 26 may be provided for supporting the wire during its travel through the furnace.

In order to heat carbon steel such that it is in the austenitic range, the lowest temperature that can be used is theoretically 1333° F. and this only applies to steel of eutectoid composition (0.80% C). This temperature of 1333° F. is based on the very slow heating of the steel through the critical region and on the assumption that the rate of heating is low enough to permit the establishment of equilibrium at all times. In actual practice, however, some time is required for this transformation because such processes as nucleation, diffusion and grain growth in the solid state are involved. Accordingly, when steel is heated through the critical region at practical rates, the critical point of transformation will occur at higher temperatures than are indicated on the iron-carbon constitution diagram. For practical purposes of this invention, it has been found that the steel stock should be heated at least to about 1400° F. for steel of eutectoid composition. Where the composition of the steel used contains carbon in amounts greater or less than the eutectoid composition, the temperature of heating will have to be necessarily greater to redissolve the ferrite or cementite present in the austenite. For example, where the steel is a 0.50% carbon steel it is desirable to use a temperature of at least approximately 1450° F. for practical purposes. In the instant invention it has been found preferable to preheat steel containing from about 0.50-0.90% carbon to a temperature of at least about 1500° F. to insure that it is in the austenitic phase within a practical period. The minimum temperature may be slightly raised or lowered when the steel contains alloying additions in minor amounts of elements such as manganese, chromium, and vanadium, but it has been found in most cases that heating to a temperature of at least about 1500° F. is desirable. Higher temperatures may be used satisfactorily and such higher temperatures, in certain instances, may be necessary depending on the composition of the steel.

It will be understood that a certain amount of flexibility in the temperature used exists depending upon the period of time of travel of the progressive portions of the stock through the furnace and the composition of the stock.

As the preheated wire 1 leaves the exit end of preheating furnace 23 it is passed through a suitable air-tight nozzle or enclosed chute 27 downwardly directly into an aluminum coating bath 29 contained in a suitable furnace 30. It has been found essential to have the exit end of chute 27 submerged below the level of molten bath 29 in order to exclude the presence of air. This chute can be made of any suitable material which is inert or substantially inert to molten aluminum as, for example, graphite. By means of this chute the preheated wire will be in contact with the non-oxidizing atmosphere of the preheating furnace immediately prior to immersion in the coating bath. In this way any tendency toward oxidation of the steel, particularly where the rate of immersion is relatively slow is eliminated. While chute 27 could extend downwardly at a constant angle, or in other words be a straight passageway, it is desirable in the interests of saving operating space to utilize an angular chute as schematically illustrated. In such case, provision is generally made for one or more suitable idler rollers 28 for maintaining the heated wire free of contact with the inner surfaces of the chute.

The aluminum coating bath furnace 30 may be any one of a number of conventional types as, for example, a low frequency induction heated furnace or a submerged electrode salt bath furnace. For purposes of maintaining the steel wire submerged in the coating bath for a predetermined time, the furnace is provided with a suitable adjustable submerged roll 31. This roll, together with the necessary bearings and shafts may be made from any suitable material inert or substantially inert to molten aluminum as, for example, graphite or hard carbon.

The composition of the aluminum coating bath used has been found to be very critical to the successful practice of the invention. Stated another way, the temperature at which the aluminum coating bath is sufficiently fluid to satisfactorily coat the steel passing therethrough and at the same time to perform the function of a suitable quenching and holding medium to produce the desired pearlitic structure in the steel has been found to be critical. It has been found that aluminum alloys which are not satisfactorily fluid at a temperature of about 1200° F. will not suffice for the intended purpose. By "fluid," as used herein, is meant that state where the steel immersed therein can be readily given a smooth coating which is relatively thin. This desired state of fluidity will generally be found at a temperature of from about 50° F. or over above the melting point of the particular aluminum alloy used. Immersing preheated steel wire in an aluminum alloy bath maintained at a temperature less than about 50° F. above its melting point will generally result in an undesirably rough and thick coating layer not suitable for severe working of the coated stock. Accordingly, it will thus be seen that for practical purposes, success of the instant invention is predicated upon the use of an aluminum base alloy having a melting point of approximately 1150° F. or lower. Commercially pure aluminum, having a melting point on the order of 1218° F. has not been found productive of satisfactory results.

Although the purposes of the invention can be achieved using a molten aluminum alloy bath temperature of not over about 1200° F. it is highly desirable to utilize a lower bath temperature to insure successful operation in view of temperature variations which will inevitably be present in attempting to maintain a constant bath temperature. Additionally, the lower temperatures are desirable from the standpoint of minimizing the formation and growth of the brittle iron-aluminum compound at the steel-aluminum alloy interface. It has been found preferable to utilize aluminum base alloys having melting points such that the molten bath can be maintained at a temperature

not over about 1170° F. It is to be understood, however, that bath temperatures lower than this can desirably be utilized, the primary consideration being to satisfactorily coat and heat treat the steel simultaneously. Examples of suitable aluminum base alloys are the aluminum-silicon binary alloys as, for example, the eutectic alloy comprising 11.6% silicon, balance aluminum and having a melting point of approximately 1071° F. Not only are such alloys desirable from the standpoint of low melting temperature, but the silicon present tends to result in a relatively thin layer of the brittle intermetallic iron-aluminum compound which is found between the steel core and the aluminum coating. Where desired, other alloying elements may be added in relatively small amounts without significantly changing the melting point of the binary alloy. Titanium or boron may be added in amounts up to about 0.03% individually for purposes of grain refinement and general surface appearance. When used in combination, the amount of titanium and boron should not exceed about 0.03% total. Beryllium may be added in amounts of from about 0.009 to 0.02% in order to minimize oxidation or gross formation of the coating bath surface and staining of the coating.

It is to be noted that during the course of operation, either batch or continuous, the molten aluminum alloy bath gradually increases in iron content due to pickup by dissolution of iron from the stock immersed therein. At such time as the iron content becomes undesirably high, for example, approaches saturation, various procedures may be adopted for reducing the iron content. Among such procedures may be mentioned discontinuance of operation of the bath while permitting the heavy iron component to settle out of the molten aluminum alloy, or addition of fresh amounts of pure aluminum alloy to effectively reduce the concentration of iron in the total molten bath.

As the coated steel wire emerges from coating bath 29 it is directed preferably vertically upward through a suitable exit tube 32. This vertical movement of the wire gives uniform drainage of excess bath metal resulting in a coating of uniform thickness and appearance. During its passage vertically upward the coating on the wire solidifies with a bright finish. The tube 32 can be made of a suitable refractory material inert or substantially inert to the action of molten aluminum so as to facilitate its submersion in the molten coating bath. The use of this tube is desirable in minimizing the drift of oxide to the emerging wire from the remainder of the coating bath surface surrounding the tube as well as for providing a steel atmosphere at the point of exit of the wire from the bath. Subsequent to the complete solidification of the coating, the coated wire may be passed over a suitable idler roll 33 and directed downwardly by means of another idler roll 34. The coated wire may then be passed through suitable feed rolls 35, at least one of which is driven and from there to a suitable rewind machine or up-coiler 36 having an adjustable speed motor. Where desired, provision can be made for a suitable shear mechanism 37 ahead of the up-coiler 36 in order to facilitate production of coated wire of varying lengths. Such a mechanism is particularly useful when the process is a truly continuous one.

In the event that a truly continuous process is used, there may be provided a suitable welding machine (not shown) close to the pay-off reel 2 and two conventional looping pit mechanisms (not shown), one of which would be located intermediate the welding machine and feed rolls 3 while the other would be located intermediate idler roll 34 and feed rolls 35. The purpose and operation of such looping pit mechanisms is well known in the art and no further discussion is deemed necessary.

It will thus be seen that by practice of the instant invention steel stock can be simultaneously aluminum coated and heat treated to provide composite stock which is susceptible to severe working in order to develop high strength therein. By reference to the schematic

illustration it will be seen that in the case of wire, one or more suitable drawing dies 38 may be provided ahead of shear mechanism 37. To facilitate movement of the wire through the drawing dies suitable pulling means 39 may be provided. In cases where the reduction in cross-sectional area is extremely large it may be advantageous to provide suitable cooling means for the dies, e.g. water cooled passages, in order to eliminate any tendency for the aluminum coating to become excessively heated and soft or mushy which may result in clogging of the dies and spalling and tearing of the coating. Any one of the conventional die lubricants can be used as, for example, vaseline, beeswax, carbowax, etc. As an alternative to drawing the wire prior to coiling, the coated wire may be first coiled and at some subsequent time subjected to the necessary working operations to develop the desired high strength in the composite stock. By means of the instant invention, reductions of from 50% to 85% and higher have been given to the coated steel without fracture, tearing, or spalling of the coating and at the same time developing extremely high strength in the composite stock.

Subsequent to working the composite stock, it may be desirable to subject the stock to a suitable stress relieving treatment in order to enhance certain physical properties, particularly elongation and ductility. For example, it has been found that in certain instances a subsequent batch heating to a temperature of from about 400° F. to 600° F. for a period of from 3 to 5 hours will improve these physical properties without adversely affecting the tensile strength. Alternatively, a stress relieving and brightening treatment may be conducted on a continuous basis wherein the temperature will generally be considerably higher and the time of treatment less than in the case of batch treatment. For example, the worked stock could be continuously passed through a lead bath maintained at a temperature of about 900° to 1000° F.

As a laboratory example of the practice of the invention, 11 gauge steel wire comprising 0.68% carbon, 0.85% manganese, 0.018% phosphorous, 0.016% sulfur, 0.21% silicon, balance iron, was simultaneously coated and heat treated and thereafter drawn. The aluminum alloy coating bath was the aluminum-silicon binary eutectic alloy containing about 11.6% silicon. The wire was preheated in a forming gas atmosphere to a temperature of about 1600° F. and immersed in the molten coating bath maintained at a temperature of approximately 1130° F. The rate of travel of the wire was on the order of 6.2 feet per minute and the average time of immersion in the bath was about 23 seconds. The resultant composite stock comprised a very smooth, uniform, continuous, and tenacious coating and a steel core possessing a relatively fine pearlitic structure. After subjecting the composite wire to a 50% reduction by means of suitable dies, the wire exhibited a tensile strength of about 216,000 p.s.i., an elongation (in 10 inches) of 1.8%, and good ductility. Moreover, the aluminum coating was not torn, spalled, or fractured. In order to enhance the elongation of this wire, it was subjected to a stress relieving treatment at 600° F. for 3 hours with the result that the elongation increased to 4.3%. This stress relief did not adversely affect the tensile strength of the drawn wire. In fact, it was found that this stress relief actually increased the tensile strength a minor amount.

Another laboratory example involved the coating and drawing of 13 gauge steel wire comprising 0.59% carbon, 0.89% manganese, 0.020% phosphorous, 0.020% sulfur, 0.21% silicon, balance iron. The aluminum coating bath composition was similar to that used in the above example. The wire was preheated in a forming gas atmosphere to a temperature of about 1550° F. and immersed in the molten coating bath maintained at a temperature of about 1150° F. The rate of travel of the wire was on the order of 11 feet per minute and the average immersion time

was about 30 seconds. After subjecting the coated wire to a 74% reduction, it exhibited a tensile strength of about 210,000 p.s.i., an elongation on the order of 1.7%, and good ductility. The coating was free of fracture, tears or spalling. It is to be noted that the maximum rate of travel of the stock and the minimum immersion time of same in the bath of these laboratory examples was limited by the preheater capacity and that on a commercial basis, the rate of travel could be increased and time of immersion decreased to that commensurate with the minimum time required to isothermally transform the austenite to relatively fine pearlite, the technology of which is well known to one skilled in the art of heat treating various types of steel.

It is also to be noted that while the above examples pertain to the use of plain carbon steels, it is to be understood that these examples are to be taken as illustrations and not by way of limitation. Materials other than plain carbon steels are imminently suited for practice of the invention as, for example, structural alloy steels, tool steels and other high strength-low alloy steels. Generically, the instant invention has application to any steels capable of being coated with aluminum and aluminum alloys and being capable of developing the necessary metallurgical structure (relatively fine pearlite) such that it may undergo severe working to develop very high strength.

As one specific application of the invention, it is now possible to produce ACSR (aluminum cable—steel reinforced) wherein the steel core strand or strands are provided with an aluminum alloy coating rather than the conventional zinc coating thereby eliminating undesirable corrosion. Reference is made to FIGURE 2 of the drawings which illustrates the cross-section of one form of steel reinforced aluminum cable wherein 40 denotes a single steel core wire or strand, 41 denotes the aluminum alloy coating on the core wire, and 42 denotes a plurality of aluminum conductor strands which are helically wound about and in contact with the composite core. By means of the instant invention, aluminum alloy coated steel core wire can be produced which satisfies the minimum ultimate tensile strength requirement of 190,000 p.s.i. and the minimum ultimate elongation requirement (in 10 inches) of 4 percent. It is to be understood that the ACSR shown in FIGURE 2 is merely by way of illustration and not limitation. Such aluminum cables may have more than one coated steel strand forming the core and may have various numbers of aluminum conductor strands surrounding the core.

Although the particular embodiment of the invention described herein relates to the treatment of wire, the invention is equally applicable to the treatment of material in other forms as, for example, strip, sheet, rod, or any other configuration where high strength aluminum coated products are desired. It is also to be noted that the invention may be practiced on a continuous, semi-continuous, or batch basis. Where the invention is practiced on a batch basis, suitable apparatus for permitting submersion of the objects into the molten bath and withdrawal therefrom after a predetermined time would necessarily have to be provided.

Accordingly, it will thus be seen by the instant invention that ferrous metal can now be coated with aluminum base alloys in such a manner as to provide composite stock having a tenacious, substantially uniform aluminum coating on a core possessing a relatively fine pearlitic or patented structure such that it is susceptible to severe working to develop high strength in the composite. By practice of the instant invention, it is now possible to produce aluminum coated ferrous metal wherein the more salient properties of resistance to corrosion and oxidation at both atmospheric and elevated temperatures, enhanced electrical conductivity, improvement in the facility of brazing and soldering of aluminum to ferrous metal, and attractive appearance of the coating is added extremely high strength and other desirable properties of the core metal.

It will be understood that various changes, omissions and additions may be made to this invention without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A high strength, ductile and corrosion resistant composite product comprising a steel member containing from about 0.50 to 0.90% carbon and having a tenacious, substantially uniform aluminum alloy coating thereon, said coating being in alloy bond relationship with said steel member, said composite product possessing a tensile strength of at least about 190,000 pounds per square inch.

2. A high strength, ductile and corrosion resistant composite product comprising a steel member containing from about 0.50 to 0.90% carbon and having a tenacious, substantially uniform aluminum alloy coating thereon, said coating being in alloy bond relationship with said steel member, said composite product possessing a tensile strength of at least about 190,000 pounds per square inch and an elongation in 10 inches of at least about 4 percent.

3. A method of coating steel with an aluminum base alloy and simultaneously therewith rendering such steel susceptible to severe reductions in order to develop high strength therein without disrupting the coating, comprising the steps of providing steel capable of being transformed by heat into the austenitic phase and having developed therein a relatively fine pearlitic structure upon quenching, cleaning the steel, heating said steel in a non-oxidizing atmosphere to the austenitic phase, said atmosphere comprising about 10% hydrogen and 90% nitrogen and the temperature to which said steel is heated being about 1500° F., developing a relatively fine pearlitic structure in said steel and simultaneously coating same with aluminum base alloy by passing said steel at substantially the austenitic phase heating temperature directly into a molten coating bath of said aluminum base alloy, said coating bath being an aluminum-silicon alloy containing about 11.6% silicon and being maintained at a temperature of about 1130° F., and then withdrawing the coated steel from said molten bath in substantially a vertical path during solidification of the metal coating.

4. A ductile and corrosion resistant composite product comprising a steel member containing from about 0.50 to 0.90% carbon and possessing a relatively fine pearlitic structure, said steel member having a tenacious, substantially uniform aluminum alloy coating thereon, said steel member being in alloy bond relationship with said coating, said composite product being capable of developing a tensile strength of at least about 190,000 pounds per square inch without disruption of said coating when subjected to a reduction in cross-sectional area of at least about 50%.

5. A method of coating steel with an aluminum base alloy and simultaneously therewith rendering such steel susceptible to severe working in order to develop high strength therein without disrupting the coating, comprising the steps of providing steel capable of being transformed by heat into the austenitic phase and having de-

veloped therein a relatively fine pearlitic structure upon quenching, cleaning the steel, heating said steel in a non-oxidizing atmosphere to the austenitic phase, developing a relatively fine pearlitic structure in said steel and simultaneously coating same with aluminum base alloy by passing said steel at substantially the austenitic phase heating temperature directly from said non-oxidizing atmosphere into a molten coating bath of an aluminum-silicon alloy containing about 11.6% silicon and wherein the temperature of said bath is about 1130° F., and then withdrawing the isothermally transformed, coated steel from said molten coating bath.

6. A method of coating steel with an aluminum base alloy and simultaneously therewith rendering such steel susceptible to severe working in order to develop high strength therein without disrupting the coating, comprising the steps of providing steel capable of being transformed by heat into the austenitic phase and having developed therein a relatively fine pearlitic structure upon quenching, cleaning the steel, heating said steel in a non-oxidizing atmosphere to the austenitic phase, developing a relatively fine pearlitic structure in said steel and simultaneously coating same with aluminum base alloy by passing said steel at substantially the austenitic phase heating temperature directly from said non-oxidizing atmosphere into a molten coating bath of said aluminum base alloy maintained at a temperature not over about 1170° F. and wherein the melting point of said coating metal is not less than about 50° F. below said bath temperature, and then withdrawing the isothermally transformed, coated steel from said molten coating bath.

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