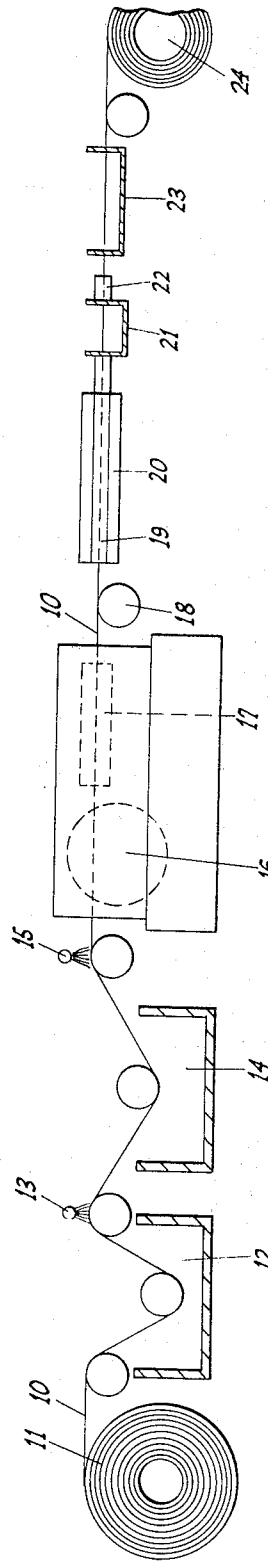
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METHOD OF PRODUCING HIGH TENSILE STRENGTH ALUMINUM COATED FERROUS STRANDS

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METHOD OF PRODUCING HIGH TENSILE STRENGTH ALUMINUM COATED FERROUS STRANDS

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ABSTRACT OF THE DISCLOSURE

Process for producing high tensile strength aluminum coated steel wire, wherein the surface of the wire is thoroughly cleaned and then brought to a bath of molten aluminum coating metal at a temperature equal to or below that of the bath so that the surface of the strand is heated to a temperature not substantially greater than the melting point of the coating metal during its immersion therein.

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation of application Serial No. 397,538, filed Sept. 18, 1964 entitled Method of Producing Metallic Coated Ferrous Strands, now abandoned, in the names of Marvin B. Pierson and Earle L. Knapp.

BACKGROUND OF THE INVENTION

The fundamental nature of this invention can perhaps best be understood by referring to a specific article which may be produced by the instant process more economically than has heretofore been possible. For example, ACSR high tension cable (Aluminum Conductors—Steel Reinforced) consists of a plurality of aluminum wires wound about a central steel reinforcing wire or wires. This steel support wire must possess a minimum tensile strength of of 165,000 to 185,000 p.s.i., depending on gauge, and must meet minimum elongation requirements. In addition, it is highly desirable that the steel reinforcing wire possess a high degree of corrosion resistance, usually obtained by a coating step. The preponderance of steel core wire in present day ACSR is produced by a hot dip galvanizing process which is undesirable from a number of standpoints, not the least of which is the shortened life in corrosive atmosphere.

While it has long been recognized that it would be desirable to produce a pure aluminum coated steel wire characterized by a very high tensile strength, it has not been accomplished under prior art practices. In the first place, it is understood that the base metal will normally be subjected to a thermal cycling during the coating process which will greatly reduce its original tensile strength to a level below the specified minimum. On the one hand, it has been suggested that a satisfactory product can be obtained by alloying the aluminum coating metal with a second metal such as silicon. It is well known that the aluminum-silicon alloys have a lower melting point than pure aluminum, and it was therefore thought possible to run the coating process at considerably lower temperatures which would permit retention of the desirable physical properties. Unfortunately, alloying the aluminum with silicon substantially reduces the corrosion resistance of the coated product.

A second solution to the above mentioned problem has been to restore the lost mechanical properties by a drawing operation subsequent to the coating step. This redrawing operation is then followed by a stress relieving post anneal to meet the minimum elongation requirements. As is well known in the art, subjecting a steel wire to a severe reduction in cross-sectional area will greatly increase its tensile strength. However, the drawing of a coated wire is not entirely satisfactory for various reasons. Other than the anneal required after redrawing, the primary problem is that the soft aluminum tends to accumulate at the die entrance and may pinch off the wire.

Still another solution advanced by the prior art involves the utilization of complex salts as a flux, which, by eliminating the necessity for furnace cleaning, permits the retention of a high degree of the original mechanical properties of the wire. The problem is that complete removal of the flux during coating is extremely difficult, and residual flux on the wire after coating impairs the corrosion resistance of the product.

In view of the foregoing comments, the specific objects of this invention may be set forth as follows:

It is a primary object of the invention to provide a process by means of which a ferrous, strand-like article having predetermined physical properties may be coated with essentially pure aluminum while maintaining an acceptable level of the original tensile strength.

A further object of this invention is the provision of a process whereby a high strength alumnium coated steel wire may be produced which is characterized by superior corrosion resistance.

Another object of the invention is to provide a method for coating a ferrous strand-like article with essentially pure aluminum which requires no pre-fluxing step.

Still another object of the instant invention is the provision of a method which may be used to produce an aluminum coated steel base wire meeting ACSR standards and which does not involve a redrawing operation.

Still another object of the invention is the provision of a process which will effect the above noted objections in an economical and commercially feasible manner.

SUMMARY OF THE INVENTION

The practice of the invention contemplates that a continuous strand of cold drawn wire having the desired physical properties is subjected to a series of cleaning operations, which will thoroughly clean the surface of the strand. The cleaned strand is then introduced into a furnace having a reducing atmosphere and operated under a fairly narrow and precisely controlled temperature range set out more fully hereinafter. Without re-exposing the strand to the outside atmosphere, it is then passed through a pot of molten coating metal. The temperature of the coating metal, and the time of immersion of the strand therein are very important aspects of the instant invention. The apparatus described in U.S. Pat. No. 3,354,864 in the name of Earle L. Knapp, may be utilized to carry out the coating step in the instant process. As soon as possible after emerging from the coating bath, the wire must be quickly cooled to solidify the coating and retain the desired physical strength in the coated product.

BRIEF DESCRIPTION OF THE DRAWING

The single figure schematically illustrates one embodiment of a wire coating line according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The starting material for the practice of the instant invention is preferably high carbon steel which has been cold drawn to a tensile strength of approximately 260,000 p.s.i. The acceptable range of carbon content for the starting material appears to be rather narrowly limited, it has

been determined that steel wire having a carbon content varying from .60% to .90% is entirely satisfactory, but it will be understood that the chemistry of the strand can be varied outside this range with the addition of appropriate alloying elements. The pre-coated strength of the base metal strand may, of course, vary within a relatively wide range, and in securing the as-coated strength range set forth earlier, the initial strength is not particularly critical.

A steel wire **10** satisfactorily meeting the above noted requirements will be led from a pay-off reel **11** through the various operations of this invention.

The first stage of the invention, broadly considered, serves to thoroughly clean the surface of the wire strand. In the first step of the exemplary cleaning operation, carbonaceous drawing compounds are removed from the surface of the wire. This is accomplished by passing the wire through a Mar-Temp salt bath **12** (consisting essentially of sodium nitrate and sodium nitrite) maintained at a high enough temperature to heat the wire to a temperature in the range of 700° F. to 1000° F. Various conventional steps, such as a lead oxidizing bath, or simply heating the strand in an oxidizing furnace, may be used so long as these temperature conditions are met.

Upon leaving the salt bath **12**, the wire passes under the warm spray rinse **13** and into the acid pickle bath **14** which will remove drawing compounds impressed in the surface of the wire during drawing. The precise strength and temperature of the acid solution are not absolutely critical to this invention. A solution containing 8% HCl and maintained at 130° F. will provide acceptable results. This acid pickle bath, in addition to removing drawing compound particles encrusted in the surface of the steel wire, will also remove the surface oxide which will result upon leaving the salt bath, and provide a bright wire surface.

Before passing into the reducing furnace, it is necessary to remove pickle residue from the wire **10**. This may be accomplished by the cold water rinse **15**, the brush scrubber **16** and a hot water rinse as at **17**. The hot water rinse **17** is largely self drying. In some cases, the brush scrubber **16** can be omitted, the residual acid being removed by a high pressure alkaline spray. Where the scrubber **16** is utilized, it is preferred that the rinse solution used at **17** be very slightly alkaline, so that a very thin film of alkaline material will be left on wire entering the dryer to minimize rusting while the surface of the wire is drying.

There are obviously many other satisfactory methods of accomplishing these pre-cleaning steps, including the use of an aqueous alkaline solution, sodium hydride, shot or sand blast and the like. These particular steps set forth above are not critical as such to this invention.

The wire **10** is next led over a suitable guide sheave **18**, and into the heat resistant tube **19** mounted within the furnace **20**. Suitable gas, such as dissociated ammonia, will be introduced into the tube **19** from an inlet not shown in the drawing, to provide a reducing atmosphere.

In the tube **19**, the wire will be heated to a temperature which approaches but does not exceed 1220° F. As is known by the skilled worker in the art, this is below the melting point of substantially pure aluminum, so that at this point, wire heat is insufficient for "proper finishing" of the coating; that is, there is not enough latitude in the coating metal temperature to afford a sufficient fluid film of molten metal around the wire. "Proper finishing" refers to the controlled application of molten coating metal on the wire so as to form a smooth, uniform, concentric coating of desired thickness as more fully described in U.S. Pat. 3,354,864. The details of the heat balance will be explained in more detail in connection with the discussion of the temperature of the bath of coating metal.

Without re-exposing the wire **10** to the atmosphere, it is passed from the tube **19** in the furnace into a bath of molten aluminum **21**. The preferred coating apparatus has been set forth in detail in the patent referred to above.

As stated at the outset of this application, superior corrosion resistance is attained by utilizing a bath of commercially pure aluminum, and hence the pure coating metal is preferred. The term "commercially pure aluminum" refers to aluminum containing only insignificant amounts of impurities. It is of course, possible to alloy the aluminum bath to provide greater latitude in meeting ACSR standards.

It will be noted from the accompanying schematic drawing, that the wire **10** passes directly and free of support from the reducing atmosphere in tube **19** into the coating bath. This is important in insuring that wire temperature is continuously increasing from the time it enters the reducing furnace until it leaves the coating bath, and results in a very simple coating line characterized by the lack of guide sheaves and the like at this stage, thereby eliminating strip deflection, drag, and attendant difficulties.

The time-temperature relationship during immersion of the steel strand in the aluminum bath is also critical to this invention. As explained before, the exit temperature of the wire from the reducing furnace will be below 1220° F., which is also below the fluid point of commercially pure aluminum. The wire must therefore be heated to final finishing temperatures (1220° to 1250°) by the molten aluminum.

The time-temperature relationship required during the actual coating step is one which will increase the surface temperature of the wire to over 1220° F. so that finishing can be accomplished. Optimum conditions occur when the wire is heated to a temperature of just over 1220° F., but under commercial conditions, this would be practically impossible. Therefore, for commercial operations, the practical wire surface temperature range is 1220° to 1250° F. High temperatures are possible but rather impractical in obtaining high as-coated tensile strength, due to lack of rapid enough cooling or quenching means.

By way of brief summary, the wire surface temperature is a function of the temperature attained prior to entering the coating bath, the temperature of the bath, and the time of immersion therein. In other words, the temperature of the wire upon entering the coating bath, plus the superheat added by the bath itself, must be sufficient to bring the surface of the wire up to finishing temperature, wherein there is enough heat in the wire at the time it leaves the coating bath so that there is a fluid film of metal on the surface of the wire for subsequent finishing. These factors can be varied as desired, so long as a wire surface temperature in the above range during coating is obtained.

The provision of some means for effectively solidifying the aluminum coating, and cooling the wire immediately after emerging from the bath **21**, is essential to retain an adequate as-coated strength. To this end, the drawing illustrates a short gas finishing chamber **22** followed immediately by a water quench **23**.

The coated wire may then be taken up by a winding reel **24** for storage or further processing.

In order to set forth a specific embodiment of this method, the following data from an actual laboratory run will be given. The starting material was .101 gauge wire having the following pertinent chemistry:

	Percent
Carbon	.80
Manganese	.68
Phosphorus	.009
Sulfur	.030
Copper	.14
Silicon	.19
Aluminum	.004

The wire had been cold drawn to an initial tensile strength of 266,000 p.s.i.

The cleaning steps were accomplished as generally set forth earlier in this specification, and included immersion

in a lead oxidizing bath at a temperature of 1000° F. for a period of about 4 seconds.

The wire attained a surface temperature of 1150° F. in the reducing furnace just prior to entering the coating bath. The bath (of pure aluminum) was maintained at 1260° F., and the immersion time was limited to 1¼ seconds. Under these conditions, the wire temperature was raised slightly over 1220° F., and good coating was obtained. It should be emphasized that, as noted below, this critical wire temperature may be reached in a shorter immersion time by using a higher bath temperature.

Analysis of the coated wire showed the following physical properties: 1% yield strength, 165,700 p.s.i.; ultimate tensile strength, 187,200 p.s.i; and elongation in 10 inches, 4.5%.

In another exemplary run using generally the same starting material, a Mar-Temp salt bath in place of the lead bath of the preceding example, the aluminum bath was maintained at 1300° F., and immersion time was limited to 0.4 second. Analysis of this wire showed the following physical properties: 1% yield strength, 167,000 p.s.i.; ultimate tensile strength, 190,000 p.s.i.; and elongation in 10 inches, 5%.

Briefly reviewing the thermal cycling to which the wire has been subjected, it is first heated to a temperature in the range of 700° F. to 1000° F. in the salt bath, then is cooled to a relatively low temperature, before being continuously heated so as to arrive at the necessary coating temperature while in the bath of molten coating metal. It is believed that the first heating step is in the nature of a pre-tempering or stress relieving treatment, and it has been determined that this pre-tempering operation very definitely and materially raises the elongation or ductility of the coated wire and helps to retain cold drawn strength during the second heating step.

Having thus described this invention in terms of an exemplary embodiment, it should be apparent to the skilled worker in the art, that numerous changes and modifications are possible. Accordingly, no limitation is intended except insofar as set forth in the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A continuous process for coating a high tensile strength ferrous strand with commercially pure aluminum to produce a coated product having a tensile strength in excess of 165,000 p.s.i. comprising the steps of:

(a) thoroughly cleaning the surface of said strand while maintaining the surface of said strand at a temperature below 1000° F.,

(b) continually heating said cleaned strand in a reducing atmosphere to a maximum temperature approaching but not exceeding the 1220° F. melting point of aluminum, said maximum temperature being attained at substantially the end of said heating step,

(c) immediately thereafter passing said strand through a bath of commercially pure molten aluminum, the speed of passage of said strand through said bath being related to the temperature of said bath whereby the surface of said strand is heated to a temperature in the range from 1220° F. to 1250° F., and

(d) quenching said coating.

2. The process claimed in claim 1, wherein said strand passes directly and free of support from said heating-reducing step to said bath of molten aluminum.

3. The process claimed in claim 1, wherein the step of thoroughly cleaning the surface of said strand is accomplished by heating said strand to a temperature in the range from 700° to 1000° F., and including the step of cooling said strand prior to heating said strand in a reducing atmosphere.

4. The process claimed in claim 1, wherein the step of thoroughly cleaning the surface of said strand is accomplished by first heating said strand to a temperature in the range from 700° F to 1000° F. to burn carbonaceous material from the surface thereof, then subjecting said strand to an acid pickle to remove particles of drawing compound encrusted in the strand surface, and thereafter rinsing said strand to remove residual pickle acid and smudge.

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