

1

3,306,716

ALUMINUM CLAD ELECTRIC CONDUCTOR WIRE

Orville E. Adler, Niles, Mich., assignor to National-Standard Company, a corporation of Delaware
No Drawing. Continuation of application Ser. No. 19,488, Apr. 4, 1960. This application Feb. 14, 1963, Ser. No. 258,635
6 Claims. (Cl. 29—196.2)

The present application relates to an aluminum clad steel wire, and in particular it relates to such a wire which is suitable for use as an electrical conductor wire; and is a continuation of my copending application Serial No. 19,488, filed April 4, 1960, and now abandoned.

There are many places where aluminum coated steels could be used; but the methods heretofore available for producing such steel have greatly limited the use of the articles, because the only method for rapidly coating steel with aluminum has been a hot dip method. A properly cleaned steel surface may be contacted with molten aluminum in the presence of a suitable flux to form an aluminum-iron alloy which bonds the aluminum to the steel. This alloy is quite brittle, so that the resulting aluminum coated article is useful only in applications which require little or no deflection of the material. Furthermore, the thickness of coating which may be applied to a steel base in this manner is very limited, which again places a limitation on the area of usefulness of the resulting coated material. It has practically been unavailable as an electrical conductor because the aluminum-iron alloy is a very poor conductor of electricity, and because of the thin aluminum coating.

As far back as 1907 it was suggested in Patent 867,658 that an electric conductor wire be manufactured by extruding aluminum around a steel core. In spite of the obvious advantages of such a material, due to the high electric conductivity of aluminum, nobody has successfully manufactured it in commercial quantities. The fact is that what was thought in 1907 to be a simple method to carry out has proved to be extremely difficult, due to the problem of obtaining a satisfactory bond between the aluminum and the steel core. By a proper correlation between temperature, pressure and rate of wire travel through the extruding die it is possible to obtain a satisfactory bond; but it has not been possible to do so at high enough speed to make the process commercially practical.

I have now discovered that the rate at which aluminum may be extruded onto a steel core wire may be enormously increased if the core wire is first plated with copper or nickel, and the plated surface is thoroughly clean when the aluminum is extruded onto it. The copper or nickel plate is deposited upon the steel core by electroplating.

Either copper or nickel must be thoroughly cleaned before the aluminum extrusion takes place, and such cleaning may be by any of the accepted methods, either chemical or abrasive cleaning. In the case of copper, it is important that the cleaned plated wire be passed immediately through the aluminum extruding die, or that it be carried in an inert atmosphere, because of the rapidity with which clean copper corrodes. The greater corrosion resistance of nickel makes such care unnecessary.

Any wire which is to be used in large quantities as a conductor must be capable of being drawn without failure of the bond between the aluminum and the steel; and the wire produced by the present method is entirely adequate from this standpoint, since it can be drawn by conventional methods to produce any needed size reduction.

The aluminum sheath is amply ductile for the intended purpose, as evidenced by the fact that the wire may be

2

wrapped around its own diameter without showing any flaking, cracking or separation.

As an example of a commercially usable electric conductor wire, the steel core is a .125" carbon steel and the thickness of the copper or nickel coating is .0004". The aluminum sheath has a thickness of .013". Such a wire, if sheathed with substantially pure aluminum, the conductivity of which is 65%, has a conductivity of 30% taking pure copper as 100%. Such conductivity is determined with direct current, or with alternating current not greatly in excess of 60 cycles, and would differ at higher frequencies. The wire may be drawn to .064" by conventional wire drawing methods without any failure of the bond, and may be wrapped around its own diameter without any flaking, cracking or separation of the coating. After drawing, the .064" wire has a breaking strength of 526 lbs.

Such aluminum clad steel may be used where strength, conductivity, light weight, or corrosion resistance is a desirable characteristic. An aluminum coated steel wire of 30% conductivity weighs only 70% as much as does an equivalent conductor of copper coated steel. However, it has a somewhat lower tensile strength, because the conductivity per unit volume of aluminum is only 65% that of copper, so that for a given outside diameter of the conductor wire the steel core must be relatively smaller in order to raise the conductivity to the desired level. Likewise, the tensile strength of aluminum is less than that of copper which contributes to the overall reduction in tensile strength of the wire.

On the other hand, by increasing the outside diameter of the aluminum clad wire from .064" to .067" and using the same tensile strength steel core as on the .064" copper clad steel, a wire is produced which has a breaking strength and electrical resistance equal to that of the copper clad wire, and which still weighs only 83.2% as much as does the copper clad conductor.

It is obvious that the weight of the conductor is very important in electrical transmission lines and communication lines, because the self-weight of the wire determines the distance between poles, the ice and wind load which the wires will tolerate, and sag and tension requirements. Likewise, aluminum clad conductors are less expensive than copper clad, both because of the favorable conductivity-weight ratio and because of the lower cost of aluminum as compared to copper.

As an example of the method used to produce the foregoing wire, a .125" carbon steel wire is cleaned and copper or nickel plated in any conventional manner. The wire is then cleaned, and it is important that the aluminum be extruded onto the surface while it is clean. The desired surface may be readily obtained by a buffing, or abrasive cleaning method, since such a surface does not tarnish readily. Common chemical cleaning procedures may be used, although if such procedures are used on copper the wire must be kept in an inert atmosphere from the cleaning tank to the extruding die.

For an example of a preferred extruding press and die for practicing the present method, reference is made to the copending application of William F. Hope, Serial No. 165,815, filed January 2, 1962 as a continuation of abandoned application 23,219, filed April 19, 1960. The wire is passed through the extruding die, preferably by pulling, and an aluminum slug, or billet in the die is heated to a temperature of about 1000° F. and is extruded concentrically onto the copper plated wire core under a pressure of at least 50,000 lbs. per square inch on the slug.

Since a substantial part of the total extruding pressure is required merely to overcome resistance in the die, it is obvious that pressure on the plated core is substantially

3

less than 50,000 p.s.i. Furthermore, it is clear that with a press and die design requiring less force merely to overcome resistance, an adequate bond may be obtained at a lower pressure on the slug than that above stated.

The copper plating of the steel core has permitted extrusion speeds up to 28 feet per minute, at the above pressure, in the particular press and die above referred to, whereas without the copper layer an extrusion speed in excess of 10 feet per minute failed to produce a satisfactory bond between the aluminum and the core wire. With a press which will take a slug of more than 1 3/8" diameter, it is clear that faster extrusion should be possible at the same pressure on the slug.

It is possible to produce a satisfactory bond without a freshly cleaned copper surface if the extrusion pressures are substantially increased. Operating at the same temperature in the above mentioned press and die, an extrusion pressure of 70,000 p.s.i. on the aluminum slug has produced a satisfactory bond even upon a tarnished copper or nickel surface.

The excellent bond obtained between the aluminum and the copper or nickel plated wire is believed to be due, at least in part, to a recrystallization of the copper or nickel at the temperature and pressure of the extrusion operation. The copper or nickel layer also prevents alloying of the aluminum and steel core if the wire is annealed during processing. Further, since neither the copper nor nickel, nor the extruded aluminum, is in a molten state there is no alloying of the aluminum with the thin layer beneath it, or with the ferrous base; and this is very advantageous because such alloys are very brittle and provide a fragile bond between the various layers in the wire, as well as reducing the electric conductivity of the aluminum.

At the processing temperature herein disclosed, a strong bond is obtained upon a core which is not cold worked after plating. It is known that cold working decreases the recrystallization temperature of copper, and accordingly the aluminum may be extruded onto a copper plated wire at considerably lower temperatures if the copper is first cold worked.

The above method may be followed if nickel is used instead of copper, except that cleaning of the nickel surface is not important because it does not corrode as easily as copper.

A wire in accordance with the present invention may be drawn from .151" to .064" in seven passes, either with or without annealing between passes. Any standard lubricant used for drawing aluminum is satisfactory, a preferred lubricant being a mixture of 95 parts of SAE 10 motor oil and 5 parts of tallow.

The composite wire after being drawn to any desired size smaller than .151" has the characteristic elongated grain structure of drawn metal, in the ferrous metal core and also in the aluminum sheath. This differs from the substantially equi-axial grain structure of an undrawn material.

It has been proposed in the prior art to form a composite metal slug by dipping a ferrous billet first into a pot of heated copper, the billet being in a jacket with a removable bottom which permits the billet to be withdrawn with a layer of copper in the jacket, and permitting the layer to solidify on the billet; and thereafter repeating the operation so as to cast an aluminum sheath around the billet and copper.

There are several reasons that the foregoing process cannot produce a satisfactory continuous spool length of composite wire. In the first place, the minimum practical temperature for a molten aluminum bath for depositing aluminum on a core is approximately 1300°, and at this temperature the aluminum and copper form a copper-aluminum alloy, even though the copper melts at a much higher temperature than that of the aluminum bath. Such a copper aluminum alloy has a much lower

4

electrical conductivity than does pure aluminum. A similar effect occurs with nickel.

The reduction in conductivity of aluminum when alloyed with small amounts of copper is shown in the following table:

Percent Cu added	Percent conductivity (Cu 100%)
0	65
1	57.5
2	51.8
3	47
4	43
5.6	38

In the second place, unless a very thick layer of copper is used, the copper does not act as a barrier between the aluminum and the ferrous metal core; and the interface between the aluminum and the ferrous core consists of a brittle layer containing aluminum, iron, and perhaps copper. The same is true if nickel is used instead of copper. Such material cannot be drawn by any known methods, because the bond between the aluminum and the ferrous core fails upon drawing.

In the third place, it is quite obvious that casting a sheath around a billet produces an article which must be reduced by rolling, and could not possibly be drawn. Even if the ferrous metal core were of small enough diameter to permit drawing, it is apparent that the maximum length to which the composite metal slug might be drawn (even if capable of being drawn), would be only a few feet.

Thus, in no case does the foregoing process produce a composite article having a discrete layer of copper or nickel on a ferrous core, and an aluminum sheath which is substantially uncontaminated by copper or nickel and thus has substantially unimpaired electric conductivity.

In addition it is a well known fact that aluminum containing copper has considerably lower corrosion resistance than aluminum free from copper; and since corrosion resistance is very important for an electrical conductor wire, this provides a further reason that a process which brings copper into contact with molten aluminum is not a practical way to produce an electrical conductor wire.

The foregoing detailed description is given for clearness of understanding only and no unnecessary limitations are to be understood therefrom, as some modifications will be obvious to those skilled in the art.

I claim:

1. A composite wire comprising: a ferrous metal core of unbroken spool length and of predetermined tensile strength; a thin, discrete, effectively continuous coating in direct and uninterrupted contact with said core, said coating being of a metal selected from the group consisting of copper and nickel; and a smooth relatively thick, substantially concentric discrete sheath of high electrical conductivity aluminum firmly bonded in direct and uninterrupted contact with said entire coating, said entire sheath being of substantially uniform composition throughout, and being effectively free of contaminants from said core and effectively free of contaminants from said coating, said sheath having an electrical conductivity in the composite wire which is substantially equal to that of the sheath material before bonding, and said composite wire being capable of being drawn in a conventional manner without damaging the bond between the core and the coating and without damaging the bond between the coating and the sheath.

2. A composite wire comprising: a ferrous metal core of unbroken spool length and of predetermined tensile strength; a thin, discrete, effectively continuous copper coating in direct and uninterrupted contact with said core; and a smooth relatively thick, substantially concentric discrete sheath of high electrical conductivity aluminum firmly bonded in direct and uninterrupted contact with said entire coating, said entire sheath being of substantially uniform composition throughout, and being effective-

5

tively free of contaminants from said core and effectively free of contaminants from said coating, said sheath having an electrical conductivity in the composite wire which is substantially equal to that of the sheath material before bonding, and said composite wire being capable of being drawn in a conventional manner without damaging the bond between the core and the coating and without damaging the bond between the coating and the sheath.

3. A composite wire comprising: a ferrous metal core of unbroken spool length and of predetermined tensile strength; a thin, discrete, effectively continuous nickel coating in direct and uninterrupted contact with said core; and a smooth relatively thick, substantially concentric discrete sheath of high electrical conductivity aluminum firmly bonded in direct and uninterrupted contact with said entire coating, said entire sheath being of substantially uniform composition throughout, and being effectively free of contaminants from said core and effectively free of contaminants from said coating, said sheath having an electrical conductivity in the composite wire which is substantially equal to that of the sheath material before bonding, and said composite wire being capable of being drawn in a conventional manner without damaging the bond between the core and the coating and without damaging the bond between the coating and the sheath.

4. A composite wire comprising: a ferrous metal core of unbroken spool length and of predetermined tensile strength; a thin, discrete, effectively continuous electro-deposited coating in direct and uninterrupted contact with said core, said coating being of a metal selected from the group consisting of copper and nickel; and a smooth relatively thick, substantially concentric discrete sheath of high electrical conductivity aluminum firmly bonded in direct and uninterrupted contact with said entire coating, said entire sheath being of substantially uniform composition throughout, and being effectively free of contaminants from said core and effectively free of contaminants from said coating, whereby said sheath has an electrical conductivity in the composite wire which is substantially equal to that of the sheath material before bonding, and said composite wire being capable of being drawn in a conventional manner without damaging the bond between the core and the coating and without damaging the bond between the coating and the sheath.

5. A composite wire comprising: a ferrous metal core of unbroken spool length and of predetermined tensile strength; a thin, discrete, effectively continuous coating in direct and uninterrupted contact with said core, said coating being of a metal selected from the group consisting of copper and nickel; and a smooth relatively thick, substantially concentric discrete sheath of high electrical conductivity aluminum firmly bonded in direct and uninterrupted contact with said entire coating, said entire sheath having the physical characteristics of aluminum

6

which has been extruded at a pressure of at least about 50,000 p.s.i. and a temperature of about 1000° F., and said sheath being of substantially uniform composition throughout, and being effectively free of contaminants from said core and effectively free of contaminants from said coating, said sheath having an electrical conductivity in the composite wire which is substantially equal to that of the sheath material before bonding, and said composite wire being capable of being drawn in a conventional manner without damaging the bond between the core and the coating and without damaging the bond between the coating and the sheath.

6. A composite drawn wire comprising: a ferrous metal core of unbroken spool length and of predetermined tensile strength; a thin, discrete, effectively continuous coating in direct uninterrupted contact with said core, said coating being a metal selected from the group consisting of copper and nickel; and a smooth, relatively thick, substantially concentric discrete sheath of high electrical conductivity aluminum firmly bonded in direct and uninterrupted contact with said entire coating, said entire sheath being of substantially uniform composition throughout, and being effectively free of contaminants from said coating, said sheath having an electrical conductivity in the composite wire which is substantially equal to that of the sheath material before bonding, and at least the ferrous metal core and the aluminum sheath having elongated grain structures characteristic of said metals when they have been drawn through a die to reduce their diameter and elongate them.

References Cited by the Examiner

UNITED STATES PATENTS

929,778	8/1909	Monnott	29—197
1,078,906	11/1913	Eldred	29—473.5
2,371,348	3/1945	Murray	29—473.5
2,612,581	9/1952	Robinson	29—196.2
2,735,170	2/1956	Moffatt	29—197
2,752,667	7/1956	Schaeffer	29—197
2,753,623	7/1956	Boessenkool	29—194
2,876,137	3/1959	Drummond	29—196.2
2,883,739	4/1959	Russel	29—196.2
2,916,337	12/1959	Fike	29—196.2
3,011,933	12/1961	Barnes	29—183
3,059,326	10/1962	Jominy	29—196.2

OTHER REFERENCES

Making, Shaping and Treating of Steel, published 1957, 7th edition, pages 692—701.

HYLAND BIZOT, *Primary Examiner.*

D. L. RECK, *Assistant Examiner.*