Nov. 5, 1968 P. A. DION 3,408,727

METHOD OF METAL CLADDING

Filed Jan. 5, 1966 2 Sheets-Sheet 1

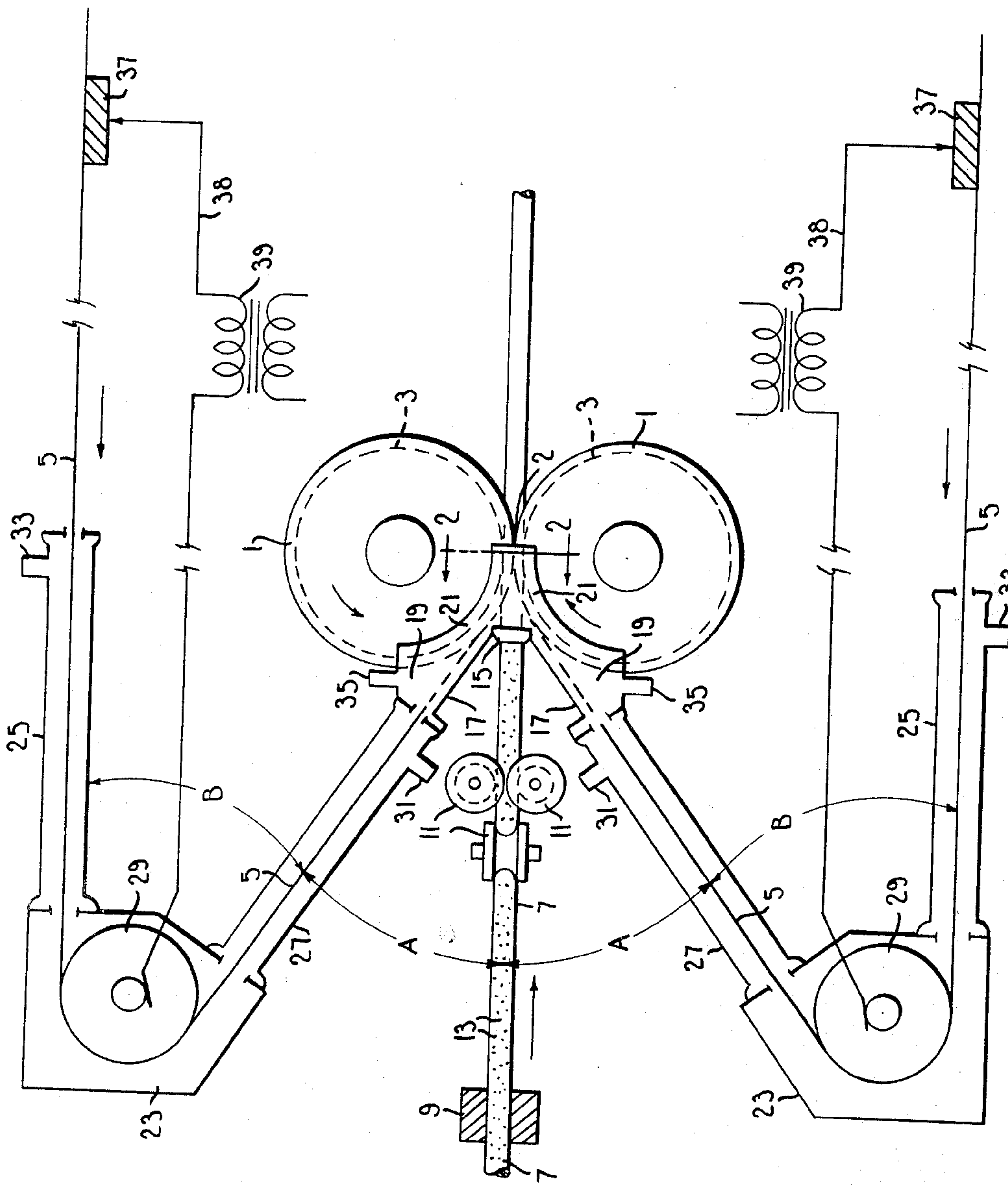

FIG. 1.

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FIG. 2.

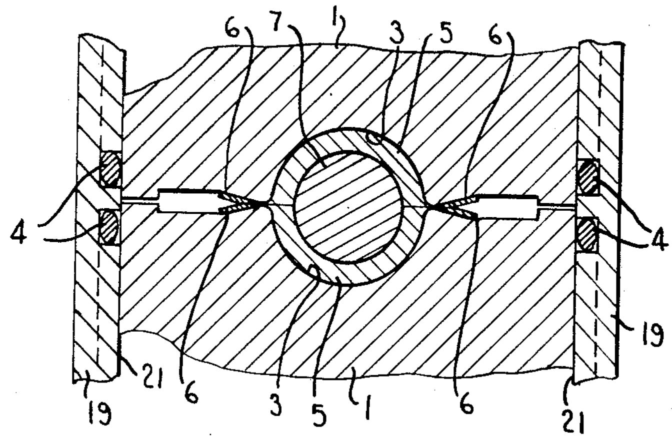
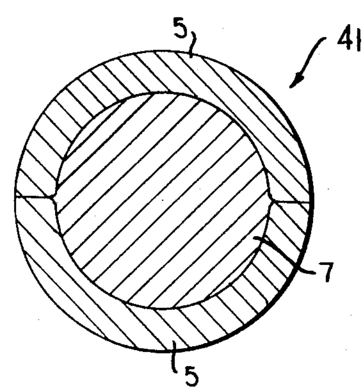


FIG. 3.



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METHOD OF METAL CLADDING

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4 Claims. (Cl. 29—474.1)

ABSTRACT OF THE DISCLOSURE

An aluminum round wire core moves along a path toward draw rolls in sequence through a drawing and back-tensioning die, a group of guide rolls, a peripheral skiving die, and a protective atmosphere which is maintained between the skiving die and the rolls. Clean copper strips are electrically resistance-heated and move through oxide-reducing atmospheres along angular approach paths on opposite sides of the core path and converge on the core within said protective atmosphere. The draw rolls form and squeeze the copper strips around the core with a reduction in the area of the composite cross-section of the core and strips thereby bonding them in the solid-phase as they are drawn togther.

This invention relates to metal cladding, and more particularly to the cladding of lengths of metal which are difficult to bond metallurgically in the solid phase because of oxides difficult to remove.

Among the several objects of the invention may be noted the provision of means for the effective removal of substantially all bond-deterent oxide or other films from the metals to be bonded, including those difficult to remove; the provision of effective means for preventing reformation of oxides before rolling to effect a solid-phase metallurgical bond; the provision of such means which is particularly effective for cladding metal strips on round or like core-forming wire, rod, tubing or the like under the comparatively low reductions imposed by such shapes when pressurized by rolling and the provision of; space-saving apparatus for carrying out the improvements. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the products, constructions and methods hereinafter described, the scope of the invention being indicated in the following claims.

In the accompanying drawings, in which one of various possible embodiments of the invention is illustrated,

FIG. 1 is a diagrammatic side elevation of apparatus for carrying out the invention;

FIG. 2 is a diagrammatic cross section taken along line 2—2 of FIG. 1; and

FIG. 3 is a cross section of a finished product.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

In U.S. Patents 2,691,815 and 2,753,623 are disclosed so-called cold and warm processes for solid-phase bonding of metal strips under substantial physical reductions effected by rolling under pressure. The principles set forth in said patents have also been employed in cladding strip material on cylindrical core material in the form of wires, rods and tubes. In this connection see, for example, U.S. patent application Ser. No. 63,678, filed Oct. 19, 1960 by Kenneth B. Clark for Forming And Solid-Phase Bonding, issued as U.S. Patent 3,220,106; and also the U.S. patent application of said Kenneth B. Clark, Serial No. 93,513, filed Mar. 6, 1961 for Manufacture of Clad Rods, Tubing and Clad Tubing, issued as U.S. Patent 3,220,107. The methods set forth in said patents and applications are generally effective but in cases of certain core materials some difficulties have been encountered which have been costly to avoid. By means of the present invention such difficulties are avoided at low cost.

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When it is desired to clad a copper strip or strips on a cylindrical aluminum core by solid-phase roll bonding, it is not feasible, as in the case of bonding strip to strip, to employ a sufficiently high reduction to break up the stable oxide film that ordinarily forms on aluminum so as to obtain bonding contact between virgin copper and virgin aluminum. Therefore it is desirable to remove the aluminum oxide before bonding. Aluminum oxide is not readily chemically reducible to aluminum in a reducing atmosphere. Thus this method of removal is practically foreclosed. If, as may be, the oxide is removed mechanically as by abraiding, skiving, shaving or the like, it reforms rapidly. For example, if after such treatment application of pressure for reduction is delayed for even as short a time as a second, the oxide reforms in amounts substantial enough to become a substantial, if not a complete, bond deterrent. Thus it has been found necessary to reduce this time to a half of a second or less, and this has made difficult the construction of adequate bonding apparatus.

In the following description the bonding of copper strip to clad aluminum core is used as an example involving the above-mentioned difficulties, but it is to be understood that the invention is applicable to other metals that present the same problems. The term metals as used herein comprehends alloys. The term protective atmosphere comprehends both oxide-reducing and inert atmospheres such as hydrogen and helium.

Referring now more particularly to the drawings, there is shown at numeral **1** a pair of rolls of a rolling mill designed in the usual way to draw lengths of metal between them and to exert squeezing and section reducing pressure. As shown in FIG. 2, the rolls contain peripheral grooves **3** which are substantially semicircular in cross section and adapted to receive in the bite **2** between them flat strips **5** on opposite sides of an aluminum wire core **7**. The dimensons of the core and strips are such that the grooves of the rolls transversely bend the strips around the core and reduce the total cross section of the assembly under pressure such as will bring about solid-phase bonding between the copper and the aluminum, provided they are sufficiently clean, By this is meant that their contacting surface must not only have gross contaminants removed but also bond-deterrent films such as oxides and the like.

At numeral **9** is shown a drawing die providing back tension in response to the drawing action of the rolls **1**. This die may also straighten and size the wire **7**. Four idler rolls **11**, three of which are shown, guide the wire core **7** from the die **9** to the nip **2** between rolls **1**.

In FIGURE 1 the stipling indicated by the numeral **13** represents the usual highly stable adherent oxide film which rapidly forms over on virgin aluminum. In order to remove this oxide film **13** there is placed as closely as possible to the rolls **1** an annular inlet skiving or shaving die or other metal removing device **15** designed to skive or otherwise remove the oxide from the core. The structure hereinafter described makes this close placement possible. The die **15** is mounted upon and in the angular recess provided by an angled or forked framework **17**. The framework **17** forms two gas manifolds **19** having sealing flanges **21** engaging marginal portions of the rolls **1** in advance of the bite **2**. Packing **4** is employed between the flanges **21** and the rolls **1**. Numerals **23** indicate gas manifolds each of which has an inlet portion **25** and back-angled portion **27**. Each portion **27** connects with one of the gas manifolds **19**. In each manifold **23** is mounted an idling guide roll **29**. Each roll **29** receives one of the strips

5 through its inlet portion 25 and guides it from manifold 25 to manifold 27 for subsequent passage to the nip 2 through connected manifold 19. Each set of manifolds 19, 27, 23 and 25 is internally connected.

Each manifold portion 27 includes an inlet 31 for the introduction of a reducing gas such as hydrogen for flow upwardly through the manifolds 27, 23 and 25, then through an outlet provided at 33. Each manifold 19 includes a gas inlet 35 into which, if desired, an inert atmosphere such as helium may be introduced. In the absence of such an inert atmosphere, manifolds 19 may receive reducing atmosphere from a manifold 27.

At numerals 37 are shown electrical brush contacts for the strips 5. Contacts 37 are in independent circuits 38 containing controlled power sources 39. The circuits connect with rolls 29. Thus the reaches of the strip 5 between the brush contacts 37 and the rolls 29 close the circuit, thus providing for heating of said reaches.

Rolls 29 and 1 could also be connected to other taps in the power supply in such a manner that heat is provided between contacts 37 and rolls 29 and 1 to maintain or increase the temperature between these rolls.

In this regard, reference may be had to U.S. Patent No. 3,095,500 in which are disclosed similar heating methods.

Typical operation is as follows:

The copper strips 5 are cleaned by pickling, wire brushing or the like to remove gross and other contaminants, including oxide. Rotation of the rolls 1 in the direction shown by the darts draws into the nip 2 the copper strips 5 and the core 7. The strips pass in heated condition through air between contacts 37 and manifolds 25 where reduced oil and other contaminants are oxidized and burned off. The strips 5 then pass through the gas manifolds 25, 23, 27 and 19, respectively, wherein the oxides are chemically reduced. The heating which may for example be at 1600° F. drives off molecular films not theretofore removed. The core 7 may be at room temperature or as much as 300° F. or so. The heating is also useful for controlling the physical characteristics of the strips 5 preparatory to bonding. Some cooling may occur in the manifolds 27 and 19 unless provision is made for additional power input as described above. The rolls 1 squeeze the copper strips 5 around the skived aluminum wire core 7 as the core is pulled through the back-tensioning drawing die 9 and the circular skiver 15. Thus oxide-free virgin copper and aluminum surfaces are squeezed together by reduction of the composite cross section with a resulting solid-phase bond between all parts 7 and 5. The resulting marginal waste 6 is in some cases squeezed off and falls away, and, if not, it may readily be removed by suitable bending or skiving. The form of the finished product is shown at 41 in FIGURE 3. It may be subsequently heated to improve the bonds by sintering action.

Aluminum or copper oxide reformation does not occur in manifolds 19 because of the existence of reducing or inert gas therein. It will be understood that if inert gas is not introduced into the manifold 19, the hydrogen will flow into them from the manifold 27. It will also be seen that since the skiver 15 is close to the nip 2, the time interval of core travel therebetween is short.

The annular skiver 15 removes all aluminum oxide and other contaminants, leaving a virgin aluminum surface against which the cleaned surfaces of the strips are brought at the nip space.

A feature of the invention is that the electrical heating of the strips 5 may be terminated at substantial distance from the nip 2. Thus there is provided a dwell time during which the strips may cool somewhat or be maintained at a constant temperature before entering the nip. This permits the strip being taken to temperatures for facilitating copper oxide removal by heating without having the strip unduly hot upon entering the nip. It may be remarked that heretofore when electrical heating was used as in U.S. Patent 3,220,107 mentioned above, the connection with the strip instead of being made at some distance ahead of the nip was made at the nip by closing the circuit through rolls such as 1. This did not admit of any dwell time.

It will be noted that it is the outside of each copper strip 5 which requires cleaning and it is the other side of the strip that contatcts its roll 29. Thus the bonding surface of strip 5 are on the outside of idler rolls 29 and remain clean and uncontaminated all the way through the pass line to the nip 2.

Another advantage of the invention exists by reason of the large angles A indicated on FIGURE 1. This provides considerable space close to the nip 2 in which the skiving ring 15 may be located on and between the manifolds 19. Since the skiving ring 15 forms an inlet to both manifolds 19, the skived core is not subject to substantial oxide reformation before it reaches the nip 2. Moreover, even if a protective atmosphere is not used in the manifolds 19, the fact that the large angles A permit the skiver 15 to be brought close to nip 2 results in a very short distance that the virgin aluminum core needs to travel between skiving and bonding. Thus if the rolls 1 are, for example, 7 inches in diameter, a minimum practical distance is about 3 inches. At a normal product speed of 50 feet a minute, the elapsed time between skiving and bonding is on the order of .30 second, that is about ⅓ of a second, which is short enough to prevent the substantial reformation of aluminum oxide on the virgin aluminum even in air which might leak into the manifolds 9.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above products, constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. The method of cladding a round metallic core, comprising moving it through a round skiving die to peripherally cut therefrom oxidized metal and expose a virgin metal surface therearound, then moving the core over a distance to the nip space between grooved draw rolls, maintaining a protective atmosphere around the core material during its movement between the skiving die and the nip space, moving clean strips of metal cladding material convergently over paths angled with respect to the path of the core and from opposite sides thereof to provide for a location of the skiving die to minimize the distance between the skiving die and the nip space, heating said strips, maintaining an oxide reducing atomsphere around the strips as they move along said paths, said strips entering the nip space at points between it and said skiving die, and squeezing the core and cladding material between the rolls with a reduction in their composite cross section to effect solid-phase bonding.

2. The method cladding a round aluminum wire core, comprising moving it through a circular skiving die to peripherally cut therefrom oxidized metal and expose a virgin aluminum surface entirely therearound, then moving the core through a short distance to the nip space between grooved draw rolls, maintaining a protective atmosphere around the skived core during its movement through said short distance between the skiving die and the nip space, moving clean strips of copper cladding material over paths including portions which are angled with respect to the path of the core to provide for location of said skiving die to provide for said short distance, heating said strips as they move, and maintaining an oxide reducing atmosphere around said strips unit they reach sadi protective atmosphere, said strips entering the nip space at points between it and said skiving die, and

squeezing the aluminum core and copper cladding material with a reduction in their composite cross section to effect solid-phase bonding between the clean surfaces of the strips and the virgin surface of the core.

3. The method according to claim **1**, including the step of passing resistance-heating current through a length of each strip to heat it in its movement through said oxide-reducing atmosphere and toward the nip space.

4. The method according to claim **3**, including cooling the strips through a length of each in its movement through said oxide-reducing atmosphere after heating thereof and before reaching said nip space.

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U.S. DEPARTMENT OF COMMERCE

PATENT OFFICE

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,408,727 November 5, 1968

Paul A. Dion

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 41, "of;" should read -- of --. Column 2, line 46, "clean, By" should read -- clean. By --; line 57, "forms over on" should read -- forms on --; line 69, "and back-angled" should read -- and a back-angled --. Column 4, lines 8 and 9, "surface" should read -- surfaces --; line 54, "atomsphere" should read -- atmosphere --; line 73, "unit" should read -- until --; line 74, "sadi" should read -- said --.

Signed and sealed this 24th day of February 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

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Commissioner of Patents