

Description

THE PRESENT INVENTION relates to a method and apparatus for coating metal wire or fibrous materials with metal. More particularly, the present invention relates to a method and apparatus capable of producing continuous lengths of fine composite wire comprised either of metal wire coated with an extrudible, corrosion-resistant metal or a fibrous core material coated with an extrudible, corrosion-resistant metal such as lead.

GB-A-117998 discloses an apparatus for extruding a relatively soft metal sheath on to a hard metal wire. The disclosed apparatus consists of a compression chamber for receiving metal for extrusion, the compression chamber having an extrusion outlet which is connected to an extrusion die assembly. The die assembly is adapted to receive therethrough an elongated core material which is to be coated. A piston is provided in the compression chamber for compression driving metal through the extrusion outlet to the die assembly. The piston is of cylindrical form and the compression chamber is also of cylindrical form. In such an arrangement there is a grave risk that metal to be extruded will leak past the piston.

According to one aspect of this invention there is provided an apparatus for coating elongated core material with metal, comprising a compression chamber, for receiving metal for extrusion and having an extrusion outlet; an extrusion die assembly disposed for communication with the extrusion outlet of the compression chamber, and for receiving therethrough an elongated core material to be coated; and a piston disposed within the compression chamber, for compression driving metal through the extrusion outlet to the die assembly; wherein said piston has spaced annular lands defining a circumferential seal area in the form of a space between said piston and the inner wall of the compression chamber for receiving metal to form a seal against the wall and substantially prevent leakage of metal past the piston during compression; said piston including an internal passage between the circumferential seal area defined by the lands and the end of the piston that engages the metal in the chamber to admit metal to the seal area.

Preferably the passage includes a transverse opening through the piston between the lands and an axial opening through the piston and which extends from the said end of the piston to the transverse opening.

Conveniently said extrusion die assembly includes first and second die members, each having an aperture for receiving therethrough an elongated core material; and a die separator disposed between the first and second die members establishing alignment of the apertures and separation of

the apertures to be substantially equal to the radius of the thickness of the metal coating to be applied to the core material.

Advantageously said extrusion die assembly includes an entrance die and an exit die, the dies having oppositely facing tapered end portions with apertures for spaced-apart, coaxial alignment for passage of elongated core material; a die separator comprising a tubular member having the dies held therein to establish a space between the end portions and having an aperture through the side wall to admit extruded metal into the space between the dies; and a die holder holding the dies and die separator therein including an elongated barrel with an aperture through the side wall in alignment with both the aperture in the die separator and the extrusion outlet of the compression chamber, and having a member for retaining the dies and die separator within the barrel.

Preferably the die holder is detachably mounted to the compression chamber.

Conveniently the extrusion die assembly includes an entry die having an aperture in the range of 0.254mm (.010 inch) to 0.533mm (.021 inch) diameter; and an exit die having an aperture in the range of 0.381mm to 0.711mm (.015 to .028 inch) diameter.

Preferably the apparatus further includes a constant tension motor-control mechanism for causing an elongated core material to move through the extrusion die assembly.

Preferably the apparatus further includes a reel of an elongated core material selected from the group consisting of glass fiber, synthetic fiber, and carbon fiber.

Alternatively the apparatus further includes a reel of an elongated core material selected from the group consisting of aluminium, copper, gold, silver, nickel and tantalum.

The apparatus may further include a feeder mechanism for supplying metal selected from the group consisting of lead, zinc, and nickel to the compression chamber.

The invention also provides a method for coating elongated core material with metal, using an apparatus as described above, comprising the steps of feeding an elongated core material into the extrusion die; moving the piston within the compression chamber to create an extrusion force to drive a metal from the chamber into the extrusion die and applying a substantially uniform coating substantially of the metal in the extrusion die to the core material as it is fed through the die; the method also comprises the steps of directing a portion of the metal in the chamber against the inside wall of the compression chamber to seal the piston along an inside wall of the compression chamber and substantially prevent leakage of metal

past the piston during compression of the metal.

Preferably the metal is lead.

The present invention is directed to a method and apparatus for coating a high tensile strength fibrous material, optical fiber or a highly conductive metal wire with an extrudible, corrosion-resistant metal such as lead, zinc or nickel, a method of making such a metal-coated wire, and a metal-coated wire of high tensile strength and electrical conductivity made according to that method and with that apparatus. The apparatus comprises die means for receiving a high tensile strength core, a compression chamber in communication with the die means, and means for forcing the metal out of the compression chamber and through the die means. A cylinder is also provided comprising a compression chamber with a piston reciprocally mounted therein, the radial clearance between the piston and the walls of the compression chamber being virtually zero. In order to achieve this zero radial clearance, spaced, annular lands are provided on the piston between the body of the piston and the walls of the compression chamber; the piston, the annular lands and the inside walls of the compression chamber defining a space. Also provided is a means communicating with the compression chamber and the space defined by the piston, the annular lands and the walls of the compression chamber operable to allow the extrudible, corrosion-resistant metal to be extruded into said space during the compression stroke of the piston, thereby relieving the high extrusion pressure exerted on said metal and preventing the escape of said metal past the piston along the walls of the compression chamber.

The apparatus is provided with a die holder assembly comprising a first die member with an aperture in it for passage of a fibrous or metallic core material that is tapered in the direction of movement of the core material and a second die member with an aperture in it for passage of the core material that is tapered in the direction opposite the direction of movement of the core material. The first and second die members are retained by a cylindrical die separator with a portion at both ends which is larger in diameter than the central portion. The die holder assembly is provided with means communicating with a source under pressure and means operable to equalise the pressure exerted by the extrudible, corrosion-resistant metal which is forced into the die separator around the core material to achieve a coating on the core material of uniform thickness.

In a preferred method of the present invention, an extrudible, corrosion-resistant metal such as lead, zinc or nickel is extruded through a die means and a core material such as a fine aluminium, copper, silver, gold, nickel or tantalum or high

tensile strength fibrous material is drawn through the die means as the metal is extruded. Using this method, continuous lengths of a metal wire or a fiber such as an aramid, or fiberglass, carbon or optical fiber can be coated with a uniform layer of the extrudible, corrosion-resistant metal.

In order that the invention may be more readily understood and so that further features thereof may be appreciated, the invention will now be described by way of example with reference to the accompanying drawings in which:

FIGURE 1 is a front view of an apparatus in accordance with the present invention showing the mechanism for feeding the metal into the compression cylinder, the die holder assembly and the portion of the piston which forces the lead into the space between dies, in longitudinal cross-section;

FIGURE 2 is a schematic representation of the apparatus of Figure 1 showing the control system plan;

FIGURE 3 is a cross-sectional view of the die assembly of the apparatus shown in Figure 1;

FIGURE 4 is an exploded, perspective view of the die assembly of the apparatus shown in Figure 1;

FIGURE 5 is an enlarged longitudinal cross-section of the piston which forces the metal out of the compression chamber and into the space between dies;

FIGURE 6 is a cross-sectional view of an alternative embodiment of the die assembly shown in Figure 3, and

FIGURE 7 is an exploded, perspective view of the die assembly of Figure 6.

When used herein, the term "extrudible, corrosion-resistant metal" refers to those metals which are capable of being extruded on to a core material using the method and apparatus of the present invention at temperatures below the melting points of those metals. Although other metals may be known to those skilled in the art who have the benefit of this disclosure, the presently preferred extrudible, corrosion-resistant metals are lead, zinc and nickel, with lead being the most preferred.

The term "core material", as used throughout the Specification and Claims, refers to fibrous and metallic materials. The fibrous materials may be glass, synthetic, optical or carbon fibers. The glass fibers may be any one of a variety of commercially available fiberglass fibers, and the synthetic fibers may be an aramid or other commercially available synthetic fiber. The optical fibers may be any of a number of proprietary glass fiber formulations used for conduction of light pulses in telecommunications. The metallic materials which are used as core materials are those highly conductive metals

such as aluminium, copper, silver, gold, nickel or tantalum.

In Figure 1, a preferred embodiment of the apparatus of the present invention is shown. Pure extrudible, corrosion-resistant metal such as the lead balls 10 is loaded into the vibratory feeder 12 for feeding through the chute or conduit 14 into the chamber 16 formed by a bore 17 through plunger 22 and the upper surface 19 of slide 21. The lead balls 10 in conduit 14 are heated to a predetermined temperature by preheating coil 18, controlled by thermocouple 20. Plunger 22, connected to the reciprocating feed cylinder 24 by means of the piston rod 26, is initially in its retracted position, allowing a plurality of heated lead balls 10 to drop into the chamber 16. When activated, feed cylinder 24 reciprocates the plunger 22 to move the lead balls 10 retained within chamber 16 along the upper surface 19 of slide 21 over the aperture 28 in the top of compression chamber 30. Feed cylinder 24 is air powered by air input line 32 and output line 34. The cylinder could also be hydraulically powered or connected to an electrical solenoid.

When the plunger 22 reaches the position shown in dotted lines 36, the end of the plunger 38 contacts limit switch 40, stopping plunger 22 and reversing the direction of its travel, returning it to its initial position. In the moment while the plunger 22 is in the position shown by dotted lines 36, the chamber 16 is positioned over the aperture 28 in the top of the compression chamber 30, allowing the lead balls in the chamber 16 to drop through aperture 28 into compression chamber 30. When the plunger 22 returns to its original position, the corner 42 of plunger 22 contacts limit switch 44, stopping the travel of the plunger 22 and reversing it for another stroke.

In the compression chamber 30, the lead or other extrudible, corrosion-resistant metal may be heated by heat imparted to the walls of the compression chamber 46 by the heating coil 48 under control of thermocouple 49. Once the metal is heated to a predetermined temperature, the hydraulic cylinder 50 is actuated, causing piston 52 to descend from its initial position down into the compression chamber 30 through aperture 28, forcing the metal out of the chamber through aperture 54 and into the space 56 between the entry die 58 and the exit die 60, held in place by die holder 62, and shown in more detail in Figure 3. Die holder 62 is threaded into threaded aperture 121 in the walls 46 of the compression chamber 30.

The hydraulic cylinder 50 is actuated by fluid pressure developed through input line 64 and output line 66. The lines 64 and 66 are provided with a proportional control valve 68 and a pressure gauge 70. Hydraulic fluid is pumped from the reservoir 72 by pump 74, through oil cooling radiator

76 to the proportional control valve 68. When the piston 52 reaches the position shown in dotted lines 78, best shown in Figure 2, collar 80 contacts limit switch 84, stopping the piston 52, reversing the direction of its travel and returning it to its original position. When piston 52 reaches its original position, collar 80 contacts limit switch 84, stopping the travel of the piston 52 and reversing it for another stroke.

Compression of the metal by the piston 52 inside the compression chamber 30 generates heat. Thermocouple 49 senses the temperature in the compression chamber 30 and regulates the heating of the walls 46 of the compression chamber 30 by the heating coil 48.

Core material 86, which may be "E glass" or "C glass" type fiberglass or other suitable fiber such as an optical, carbon or synthetic fiber, or a fine wire comprised of a highly conductive metal such as copper or aluminum, may be maintained at a predetermined tension as it is pulled off the reel 88 by a constant tension motor-control assembly such as that shown schematically in Figures 1 and 2 at 90. As core material 86 is pulled off the reel 88, the shield 92 around the reel 88 helps prevent core material 86 from tangling and shields it from any loose objects that may be near the reel 88. Core material 86 is pulled off the reel 88 through a centering ring 94, and drag tension is supplied by spring tensioner 96 to prevent fiber tangling. Roller 98 guides core material 86 toward the entry die 58 and exit die 60, where it is coated with metal to form a fine, composite wire 100. As the wire 100 exits from the die holder 62, it traverses roller 102, turning it downward to traverse floating weight 104, which turns it back up to roller 106, thereby helping to maintain constant tension during starting and stopping of the motors 90 and 108. The term "wire" is used, with reference numeral 100, to designate the composite wire which results from the coating of core material 86, whether it is a fibrous material or a highly conductive metal wire, with an extrudible, corrosion-resistant metal such as lead, zinc or nickel. Roller 110 then guides the wire 100 towards the traversing means 112. As the wire 100 traverses roller 110, proportional velocity encoder 114 measures its speed and cooperates with traversing means 112 and motors 90 and 108 to wind the wire 100 onto the take-up spool 116. The traversing means 112 moves back and forth along the traverses bar 118 to insure even winding of the wire 100 on the take-up spool 116.

Referring now to Figures 3 and 4, entry die 58 and exit die 60 are retained within die separator 120 by spacing washers 122a and 122b. Die separator 120 is retained within the cavity 65 in the die holder 62, and compression is provided by the tightening of the retaining plug 124 in the threads

123 in the die holder 62. Entry die 58 is provided with flange 59 and exit die 60 is provided with flange 61, the flanges 59 and 61 abutting the ends 119 of the die separator 120, thereby maintaining the spacing between the dies in the interior 56 of the die separator 120. Die holder 62 is provided with an aperture 126 which, when the die separator 120, entry die 58, exit die 60, and spacing washers 122 are assembled into the die holder 62, will be aligned with the aperture 128 in the die separator 120. Aperture 126 is sized to fit snugly against aperture 54 on the bottom of the compression cylinder 30 when die holder 62 is screwed on threads 119 into the threaded aperture 121 in the wall 46 of the compression cylinder 30.

Die holder 62 is also provided with aperture 130 for passage of core material 86 (not shown). Entry die 58 is provided with an aperture 132 at the apex of the taper 134. Metal is forced out of compression chamber 30 by piston 52, through apertures 54, 126 and 128, and into the space 56 between the entry die 58 and exit die 60.

The exit die 60 is provided with an exit aperture 136 at the apex of the conical taper 138. The taper 134 of entry die 58 is tapered in the direction of the movement of the core material 86. The taper 138 of exit die 60 is preferably tapered in the direction opposite the direction of movement of core materials 86, but can be tapered in the same direction as the movement of core material 86, or not tapered at all. Tapering the exit die 60 in the direction opposite the direction of movement of core material 86 is preferred because, even though other configurations may allow the use of decreased extrusion pressures, the tooling life and concentricity of the core material 86 in composite wire 100 suffers. Further, retaining plug 124 must be torqued more tightly into threads 123 against the washers 122 and flanges 59 and 61 of entry die 58 and exit die 60, respectively, because of the increased pressure exerted against the exit die 60 by the metal in space 56, if the exit die 60 utilized is not tapered in the direction opposite the direction of movement of core material 86. Retaining plug 124 is also provided with aperture 140 for passage of wire 100.

Referring to Figures 6 and 7, there is shown a presently preferred embodiment of a die assembly in which the various components are, to the extent possible, given reference numerals and descriptive names corresponding to those of the components shown in Figures 3 and 4. In particular, the entry die 58' and exit die 60' are retained within die separator 120' by back-up washers 122a' and 122b', and compression is provided by the tightening of the retaining plug 124' into the cavity 65' in the die holder 62' on the threads 123'. Because the retaining plug 124' is provided with threads 125' on

which it is threaded into cavity 65' in die holder 62', it may have a slight cant to the face 63', which could result in the skewing of the exit die 60' within the die separator 120'. To prevent any such skewing, a thrust washer assembly having a convex face washer 67' and a concave face washer 69' is interposed between the retaining plug 124' and the back-up washer 122b'. The interaction of the concave and convex surfaces of washers 67' and 69' effectively prevents any skewing which may result from the tightening of retaining plug 124' against back-up washer 122a'.

The die holder 62' is provided with aperture 126' which is sized to fit snugly against the aperture 54 on the bottom of compression cylinder 30' (see Figures 1 and 2). Die separator 120' is provided with flanges 127a' and 127b' at each end, and a central portion 129' of smaller diameter, the diameter of flanges 127a' and 127b' being approximately the same as the inside diameter of the cavity 65' in the die holder 62' which receives dies separator 120'. The combination of flanges 127a' and 127b' and the smaller diameter of central portion 129' of die separator 120' leaves a space 131' between the central portion 129' of die separator 120' and the inside wall of cavity 65' in die holder 62'. Space 131' is in fluid communication with the interior 56' of die separator 120' by means of apertures 125a' and 135b'.

Because of the pressure exerted by the pressurised material in space 56' against the entry die 58' and exit die 60', there is no need for flanges on the dies 58' and 60' such as the flanges 59 and 60 shown in Figures 3 and 4. In order to retain the dies within the space 56' in die separator 120' during transit, and to insure the axial alignment of the dies, the diameter of the dies is approximately 0.0127mm larger than the diameter of the inside walls of the interior 56' of die separator 120 and the dies are pressed fit into die separator 120' using heat, oil and a hydraulic press.

Die holder 62' is also provided with aperture 130' for passage of core material 86 (not shown). Entry die 58' is provided with an aperture 132' at the apex of the taper 134'. Exit die 60' is provided with an exit aperture 136' at the apex of the conical taper 138'. Retaining plug 124' is also provided with aperture 140' for passage of wire 100.

The embodiment shown in Figures 6 and 7 is characterised by the fact that the pressure exerted on core material 86 as it passes through space 56 is equal in all directions. When producing small diameter composite wire with an apparatus such as is shown in Figures 3 and 4, the core material does not stay centred within the space 56 relative to the aperture 136 in exit die 60 as a result of the differential pressure exerted on core material 86 from above as the lead is forced through apertures

26 and 128. This differential pressure forces core material 86 downwardly such that it no longer enters the aperture 136 in the exit die 60 in the centre of that aperture 136, causing the core material 86 to be off-centre in the composite wire 100. This differential downward pressure may also be sufficient to cause the deformation of the tooling in the die carrier 62.

The high extrusion pressure is the result of the economy afforded by high production speeds. To maximise production efficiency and reduce the need to reload the compression chamber, a larger diameter compression chamber 30 (approximately 15.875mm) and piston 52 are used. A small diameter chamber and piston would require frequent stopping of the apparatus for reloading. However, when producing a 0.381mm diameter composite wire with a 0.254mm glass core, the large diameter chamber and piston causes the reduction ratio to exceed 3100 to 1. The use of a compression chamber of very long length and small diameter would result in less frequent reloading and a decrease in reduction ratio, but is not preferred because of the problems of alignment of the piston and compression chamber and the lack of stiffness in a long piston.

This high pressure is also a result of the mathematical fact that extrusion pressure is not a linear function of the reduction ratio, consequently extrusion pressure increases at a rate greater than the proportional increase in the reduction ratio. High extrusion pressures create design problems which are overcome in the present invention. For instance, it is known that when reduction ratio exceeds 250:1, the extrusion pressure will be so high it will exceed the capability of the walls of the compression chamber to retain their shape even if the walls are constructed of high strength steel. Such high extrusion pressures can actually cause the walls of the chamber to bow outwardly as the piston is urged against the metal in the chamber, allowing the metal to escape past the piston, creating the problems which result from such leakage that are discussed below. The bowing of the cylinder walls is particularly pronounced when the piston is approximately half way down the cylinder. To prevent this bowing of the walls of the compression chamber, multiple concentric cylinders (not shown) are used as the walls of the compression chamber. In a presently preferred embodiment, as many as four cylinders, the outside diameter of each being approximately 0.0254mm larger than the inside diameter of the adjacent, surrounding cylinder, are pressed one into the other to form the walls of the compression chamber.

To minimise the loss of this extremely high extrusion pressure, thereby avoiding the use of even higher pressures to achieve the desired pres-

sure in the space 56, the exit die 60 is placed directly beneath the compression chamber 30, resulting in the differential pressure across the apertures 126 and 128 and the deflection of the core material 86 downwardly in space 56. To minimise this differential pressure, while still minimising the extrusion pressure required, the presently preferred construction of Figure 6 is utilised. Exit die 60' is located directly below compression chamber 30, but metal is admitted into the space 56 in two directions which are 180 degrees apart, thereby equalising the pressure exerted against the core material 86. Material is forced out of compression chamber 30 by piston 52, through apertures 54 and 126', into the space 131', around the central portion 129' of die separator 120', through apertures 135a' and 135b', and into the space 56' between entry die 58' and exit die 60'. Additional apertures may be provided so long as they are spaced at regular intervals around the central portion of die separator 129' and so long as none of the apertures is located directly under the aperture 54 at the bottom of the compression chamber 30. Using the embodiment shown in Figures 6 and 7, the concentricity of the core material relative to the outside diameter of the composite wire 100 can be maintained to within $\pm 5\%$.

Piston 52 is shown in enlarged detail in Figure 5. The piston 52 is provided with a beveled surface 142 on the bottom of the piston 52. The piston 52 is also provided with annular lands 144 and 146, and a transverse hole 148 through the piston. Vertical hole 150 communicates with transverse hole 148. Beveled surface 142, lands 144 and 146, transverse hole 148 and vertical hole 150 co-operate to help seal piston 52 along the inside wall 152 (Figure 1) of compression chamber 30 and to help centre the piston 52 in the compression chamber 30 during the compression stroke of piston 52. Metal under high pressure is forced up through vertical hole 150 into transverse hole 148 and into the space formed by lands 144 and 146 and the inside wall 152 of the compression chamber 30 effectively sealing piston 52 against the wall 152 and centering it within the compression chamber 30.

This sealing construction is made necessary by the high extrusion pressure of the apparatus. For instance, even though the clearance between the piston 52 and the inside wall 152 of compression chamber 30 can be made as small as 0.0127mm, that much radial clearance is enough to allow excessive leakage of the extrudible, corrosion-resistant metal past piston 52 during compression, and the concomitant loss of usable extrusion pressure. Because of the small diameters of the composite wires which may be produced using the method and apparatus of the present

invention, if this sealing construction is not used, as much as ten times more metal can leak past the piston 52 than is applied to the core material. In addition to the fact that this leakage results in the use of more metal (although the leakage can be recycled) and therefore requires more frequent re-loading of compression chamber 30, thereby slowing production, this leakage is generally asymmetrical, causing the piston 52 to be pushed off centre in compression chamber 30 and into contact with the wall 152. This contact results in the immediate scoring of the walls 46, causing even greater leakage and loss of extrusion pressure. It is for this reason that the extremely long, small diameter compression chamber discussed above has proved to be of little aid in overcoming the need for frequent reloading of the chamber: the alignment and rigidity problems associated with such a construction multiply the problems of centering the piston in the chamber, thereby exacerbating the leakage of metal past the piston. In addition to the damage caused, the increased leakage and decreased extrusion pressure causes a drop in the maximum production rate, all of which are limitations which make the sealing construction of the piston 52 a central feature of the apparatus of the present invention.

The construction shown in Figure 5 allows the extrudible, corrosion-resistant metal to flow into the space formed by piston 52, lands 144 and 146, and the inside wall 152 of compression chamber 30. The metal which extrudes into this space lacks the pressure needed to extrude past annular land 144, effectively preventing leakage past piston 52.

Additionally, the metal which extrudes into the space formed by pistons 52, lands 142 and 144, and wall 152 is, depending on the extrusion pressure, pressurised to between about 3.44 and 6.89 KN/Cm². Generally, it appears that the pressure of the metal in this space will vary from approximately one-fourth to one-third of the pressure of the compression chamber 30. This pressure is exerted between piston 52 and wall 152 equally around the piston 52, forcing piston 52 to the centre of compression chamber 30 and further preventing contact between the piston 52 and wall 152. At the same time, the metal in this space provides what amounts to be a low friction bearing surface which is similar to a babbit bearing, reducing piston drag and leaving more hydraulic force for extrusion. Pistons with seals constructed in this manner have been tested for several months. After millions of cycles, no sign of wear or leakage has appeared, and the piston and cylinder wall are unscored even after heavy use, all of the extrudible, corrosion-resistant metal having been applied to the core material.

The use of a long, small diameter compression

chamber would most likely obviate the need for the sealing construction of piston 52 since the small diameter of the chamber 30 would reduce the reduction ratio to a point at which it would not develop the 27.57 to 34.46 KN/Cm² extrusion pressures required by the preferred embodiment of the present invention to maintain efficient production rates. In fact, the use of a long, small diameter compression chamber has such an effect on extrusion pressure that it would likely permit the use of a straight piston without any seals. However, the aforementioned alignment, stiffness and centering problems associated with such a construction are such serious limitations as to limit the utility of that construction.

Hydraulic cylinder 50 is mounted on platform 154, supported above base 158 by columns 156, and held in place by bolts 160 and 162. Slide 21 is mounted to columns 156 and serves as a support for feed cylinder 24 and its piston rod 26 and plunger 22. Compression chamber 30 is supported by table 164 and is provided with a downwardly projecting hemispherical ear 166 which is received within cavity 168 of table 164. Bolt 170 projects up through a hole 172 in the base 158 and hole 174 in table 164 and is received in the threaded aperture 176 of the hemispherical ear 166. The inside radius of cavity 168 is slightly larger than the radius of hemispherical ear 166 such that when compression chamber 30 is screwed onto bolt 170, cavity 168 and hemispherical ear 166 will cooperate to center the compression chamber on table 164 so that aperture 28 is in axial alignment with bore 17 when plunger 22 is in the extended position shown by the dotted lines 36 in Figure 1 and in axial alignment with piston 52 when plunger 22 returns to its initial position.

Referring now to Figure 2, operation of the apparatus of the present invention is controlled from control panel 178 by appropriate circuitry. Control panel 178 is connected to feed cylinder 24 by input line 32 and output line 34. Proportional control valve 68 is connected to the control panel 178 by input line 68_i and output line 68_o, thereby controlling hydraulic cylinder 50. Limit switches 40, 44, 82, and 84 and motors 90 and 108 are connected to control panel 178 by the respective input and output lines 40_i and 40_o, 44_i and 44_o, 82_i and 82_o, 84_i and 84_o, and 108_i and 108_o, and 90_i and 90_o. Inputs to the control panel 178 are received from the thermocouples 20 and 49 through lines 20_i and 49_i, respectively, and preheating coil 18 and heating coil 48 are controlled on the basis of that input through respective input and output lines 18_i and 18_o and 48_i and 48_o. Input is also received from proportional velocity encoder 114 by means of line 114_i. In this manner, all operational parameters may be set and controlled before and/or

ring operation of the apparatus of the present invention.

An important characteristic of the continuous, composite wire of the present invention is its resistance to corrosion from attack by the acid of a battery or, in the case of fiber optic communications cables, the harsh environment in which the cable will be used as described below. As a general rule, the smaller the grain size of lead, for instance, the greater its resistance to corrosion. The large grain size does not itself cause corrosion, but when corrosion starts, it attacks the grain boundaries, and small grain size reduces the susceptibility of the grain boundaries to attack. The method and apparatus of the present invention result in the extrusion of lead of high corrosion resistance at least partly because of the small grain size produced.

When lead is cast and then solidified, the average grain size is approximately 6.35mm. Using the method and apparatus of the present invention, the average grain size of the lead is approximately 6.35×10^{-6} mm as determined with the scanning electron microscope.

The method of the present invention may be better understood by reference to the following examples.

Example I

For use in Example I, the apparatus of the present invention was provided with an entry die with an aperture of approximately 0.33mm (0.013 inches). The aperture in the exit die was approximately 0.51mm (0.020 inches) in diameter, and the distance between the end of the entry die and entrance of the exit die was set at approximately 7.15mm (0.006 inches).

Lead balls were loaded into vibratory feeder, vibrated into the conduit for preheating, and then allowed to feed into the compression chamber, where the lead was heated further and the temperature in the chamber allowed to stabilise at approximately 232°C. With the constant tension motor-control assembly pulling the fiber to keep it from tangling, the fiber was moved through the dies at a rate of approximately 30.48 meters per minute while the lead was extruded at a pressure of approximately 27.57 KN/cm² plus or minus 25%. When measured at the apex of the exit die aperture, the temperature of the lead was approximately 207°C.

Using this method, a commercially available aramid fiber, marketed under the trade name "KEVLAR 49", was used as a core fiber to produce a fine, continuous, composite, electrically conductive wire of a diameter of approximately 0.508mm. The thickness of the lead around the fiber core was

approximately 0.127mm.

EXAMPLE II

The same operating procedure was used to coat a commercially available chemical glass yarn known in the industry as "C glass". Production rates of from 46 to 91 meters per minute were utilised at extrusion pressures of 27.57 to 34.46 KN/cm², plus or minus 25%. When "C glass" is used as the fiber core of a lead coated wire, the composite wire produced according to this procedure has a diameter of approximately 0.635mm and the thickness of the lead coating is approximately 0.1524mm.

EXAMPLE III

The same operating procedure was used to coat a commercially available C glass of 0.254mm in diameter, resulting in a composite wire with an outside diameter of 0.381mm. An entry die with an aperture of approximately 0.3048mm in diameter was used with an exit die with an aperture of about 0.381mm, and the space between the dies was about 0.0762mm. Extrusion pressures of from about 27.57 to about 34.46 KN/cm² $\pm$ 25% were utilised.

EXAMPLE IV

The same operating procedure was used to coat a 24 AWG copper wire with a diameter of 0.508mm with lead, resulting in a composite wire with a diameter of 0.7112 mm. The diameters of the entry and exit dies utilised were about 0.5334mm and about 0.7112mm, respectively, and the space between the dies was about 0.1016. Extrusion pressures of from about 20.68 to about 27.57 KN/cm² $\pm$ 25% were utilised.

EXAMPLE V

The same operating procedure was used to coat an aluminium wire 0.2032mm in diameter with lead, resulting in a composite wire with a diameter of 0.381mm. The diameters of the entry and exit dies utilised were about 0.254mm and about 0.381mm respectively, and the space between the dies was about 0.0762mm. Extrusion pressures of from about 27.57 to about 34.46 KN/cm² $\pm$ 25% were utilised.

EXAMPLE VI

The same operating procedure was used to coat a single monofilament optical fiber available from Owens-Corning Fiberglass of 0.381mm in di-

ameter with lead, resulting in a composite wire with a diameter of 0.635mm. The diameters of the entry and exit dies utilised were about 0.4572mm and about 0.635mm, respectively, and the space between the dies was about 0.127mm. Extrusion pressures of from about 20.68 to about 27.57 KN/cm² were utilised.

Similar operating parameters may be used to coat other fibers with extrudible, corrosion-resistant metals such as lead, zinc or nickel. For instance, other grades of Kevlar may be used, as well as materials such as the carbon fibers which are commercially available under the trade name "FORTAFIL" made and sold by the Great Lakes Carbon Corporation in New York in several grades. In addition, other glass yarns such as the yarn known as "E glass" may be coated using the method of the present invention. Highly conductive metals such as silver, gold, nickel and tantalum may likewise be suitable as core materials for the composite wire of the present invention.

Production rates as high as about 152.4 meters per minute have been attained with the apparatus and method of the present invention, with extrusion pressures ranging up to about 41.36 KN/cm². The speed at which the composite wire is produced is limited by the temperature of the metal at the aperture of the exit die. This temperature will vary according to the metal being coated on to the core material and the pressure at which it is extruded. For instance, under the conditions summarised in Example 1 above, the temperature of the metal at the aperture of the exit die is approximately 307° C. This temperature is significantly lower than the melting point of lead, 327° C, thereby preventing liquid lead runaway, yet high enough to impart the required plasticity to the lead. In the case of zinc or nickel, temperatures at this point of between 385 and 404° C or 1066 and 1121° C, respectively, are called for. Generally, at higher production rates, higher extrusion pressures are required, and hence, the temperature at the aperture of the exit die will be higher. In order to attain production rates higher than about 152 meters per minute under the conditions summarised in Example 1, above, it is necessary to cool the area round the dies, i.e. by the use of hydraulic oil or synthetic cooling fluid such as is available under the brand name DOWTHERM, or a similar fluid, and input and output lines leading to a heat radiator.

The composite wire having a core of either a fibrous material or a highly conductive metal made by the above-described methods and a coating of lead may be woven on a conventional weaving apparatus into a scrim or wire cloth. In addition to its use in electrochemical cells, such a scrim or cloth has a number of other uses, for instance, as a blanket or wrapping to absorb ionizing and/or elec-

tromagnetic radiation or as sound insulation. The mass of the scrim per unit area, and hence its ability to absorb ionizing radiation, is governed by the number and diameter of composite wires per unit of length of the woven cloth, and to a lesser extent, by the choice of core material. Of course, a fabric woven from the composite wire of the present invention will not have total shielding, but will significantly attenuate the radiation. Multiple layers may also be used to increase attenuation as desired.

A large scrim or blanket woven with a lead-coated E glass core 0.508mm in diameter, the core being 0.3302mm in diameter, can, for instance, be woven 4 strands per cm and supplied in rolls. The blanket is wound off the rolls and glued or epoxied to the Sheet-rock used to finish out the interior walls of a building, thereby providing effective shielding of that room so that it can be safely used for X-ray equipment or radiation therapy equipment. The blanket may also be used as a curtain, hung, for instance, from a track so that it can be retracted for the same purpose.

When an optical fiber is used as the core material, the resulting composite wire has particular application in tele-communications cables.

Claims

1. An apparatus for coating elongated core material with metal, comprising a compression chamber(30), for receiving metal for extrusion and having an extrusion outlet(54); an extrusion die assembly disposed for communication with the extrusion outlet of the compression chamber, and for receiving therethrough an elongated core material(86) to be coated; and a piston(52) disposed within the compression chamber, for compression driving metal through the extrusion outlet to the die assembly; characterised in that said piston has spaced annular lands(144,146) defining a circumferential seal area in the form of a space between said piston and the inner wall of the compression chamber(152) for receiving metal to form a seal against the wall and substantially prevent leakage of metal past the piston during compression; said piston including an internal passage(148,150) between the circumferential seal area defined by the lands and the end of the piston that engages the metal in the chamber to admit metal to the seal area.
2. An apparatus according to Claim 1 wherein the passage includes a transverse opening(148) through the piston between the lands and an axial opening(150) through the piston end which extends from the said end of the piston

ameter with lead, resulting in a composite wire with a diameter of 0.635mm. The diameters of the entry and exit dies utilised were about 0.4572mm and about 0.635mm, respectively, and the space between the dies was about 0.127mm. Extrusion pressures of from about 20.68 to about 27.57 KN/cm² were utilised.

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2. An apparatus according to Claim 1 wherein the passage includes a transverse opening(148) through the piston between the lands and an axial opening(150) through the piston end which extends from the said end of the piston



to the transverse opening.

3. An apparatus according to Claim 1 or Claim 2 wherein said extrusion die assembly includes first and second die members(58,60), each having an aperture(132,136) for receiving therethrough an elongated core material; and a die separator(120) disposed between the first and second die members establishing alignment of the apertures and separation of the apertures to be substantially equal to the radius of the thickness of the metal coating to be applied to the core material. 5
4. An apparatus according to Claim 1 or Claim 2 wherein said extrusion die assembly includes an entrance die(58) and an exit die(60), the dies having oppositely facing tapered end portions(134,138) with apertures for spaced-apart, coaxial alignment for passage of elongated core material; a die separator(120) comprising a tubular member having the dies held therein to establish a space between the end portions and having an aperture(128) through the side wall to admit extruded metal into the space between the dies; and a die holder(62) holding the dies and die separator therein including an elongated barrel with an aperture through the side wall(126) in alignment with both the aperture in the die separator and the extrusion outlet of the compression chamber, and having a member(124) for retaining the dies and die separator within the barrel. 10 15 20 25 30
5. An apparatus according to any one of the preceding Claims wherein the die holder is detachably mounted to the compression chamber. 35
6. An apparatus according to any one of the preceding Claims wherein the extrusion die assembly includes an entry die having an aperture in the range of 0.254mm (.010 inch) to 0.533mm (.021 inch) diameter; and an exit die having an aperture in the range of 0.381mm to 0.711mm (.015 to .028 inch) diameter. 40 45
7. An apparatus according to any one of the preceding Claims further including a constant tension motor-control mechanism(108) for causing an elongated core material to move through the extrusion die assembly. 50
8. An apparatus according to any one of the preceding Claims further including a reel of an elongated core material selected from the group consisting of glass fiber, synthetic fiber, and carbon fiber. 55

9. An apparatus according to any one of Claims 1 to 7 further including a reel of an elongated core material selected from the group consisting of aluminium, copper, gold, silver, nickel and tantalum. 5
10. An apparatus according to any one of the preceding Claims further including a feeder mechanism for supplying metal selected from the group consisting of lead, zinc, and nickel to the compression chamber. 10
11. A method for coating elongated core material-(86) with metal, using an apparatus according to any one of Claims 1 to 10, said method comprising the steps of feeding an elongated core material(86) into the extrusion die; moving the piston(52) within the compression chamber(30) to create an extrusion force to drive a metal from the chamber into the extrusion die(60), and applying a substantially uniform coating substantially of the metal in the extrusion die to the core material as it is fed through the die, characterised in that the method also comprises the steps of directing a portion of the metal in the chamber against the inside wall of the compression chamber(152) to seal the piston(52) along an inside wall of the compression chamber and substantially prevent leakage of metal past the piston during compression of the metal. 15 20 25 30
12. A method according to Claim 11 wherein the metal is lead. 35

Revendications

1. Appareil pour revêtir de métal un matériau d'âme allongé, comportant une chambre de compression (30), destinée à recevoir du métal pour extrusion et ayant une sortie d'extrusion (54) ; un ensemble formant matrice d'extrusion disposé de façon à communiquer avec la sortie d'extrusion de la chambre de compression, et destiné à être traversé par un matériau d'âme allongé (86) devant être revêtu ; et un piston (52) disposé à l'intérieur de la chambre de compression afin de pousser par compression du métal à travers la sortie d'extrusion jusqu'à l'ensemble formant matrice ; caractérisé en ce que le piston possède des rainures annulaires espacées (144, 146) définissant une zone de joint circonférentielle sous la forme d'un espace ménagé entre le piston et la paroi interne de la chambre de compression (152) et destiné à recevoir du métal afin de former un joint contre la paroi et d'empêcher sensiblement une fuite de métal par-delà le piston lors



de la compression ; le piston comprenant un passage interne (148, 150) entre la zone de joint circonférentielle définie par les rainures et l'extrémité du piston qui vient en contact avec le métal dans la chambre de façon à laisser du métal passer jusqu'à la zone de joint.

2. Appareil selon la revendication 1, dans lequel le passage comprend entre les rainures une ouverture transversale (148) traversant le piston entre les rainures et une ouverture axiale (150) qui traverse l'extrémité du piston et s'étend de l'extrémité du piston jusqu'à l'ouverture transversale.

3. Appareil selon la revendication 1 ou la revendication 2, dans lequel l'ensemble formant matrice d'extrusion comprend des premier et deuxième éléments de matrice (58, 60), ayant chacun une ouverture (132, 136) destinée à être traversée par un matériau d'âme allongé ; et un séparateur (120) de matrices, disposé entre les premier et deuxième éléments de matrice, qui détermine l'alignement des ouvertures et la distance entre les ouvertures, laquelle doit être sensiblement égale au rayon de l'épaisseur du revêtement métallique qui doit être appliqué sur le matériau d'âme.

4. Appareil selon la revendication 1 ou la revendication 2, dans lequel l'ensemble formant matrice d'extrusion comprend une matrice d'entrée (58) et une matrice de sortie (60), les matrices ayant des parties d'extrémité coniques (134, 138) se faisant face avec des ouvertures destinées à être espacées et alignées coaxialement pour le passage du matériau d'âme allongé ; un séparateur (120) de matrices comportant un élément tubulaire dans lequel les matrices sont maintenues de façon à déterminer un espace entre les parties d'extrémité, ayant une ouverture (128) ménagée à travers la paroi latérale afin de faire passer du métal extrudé dans l'espace entre les matrices ; et un support (62) de matrices à l'intérieur duquel sont maintenus les matrices et le séparateur de matrices et comprenant un cylindre allongé muni d'une ouverture traversant la paroi latérale (126) et alignée à la fois avec l'ouverture ménagée dans le séparateur de matrices et la sortie d'extrusion de la chambre de compression, et comportant un élément (124) destiné à retenir les matrices et le séparateur de matrices à l'intérieur du cylindre.

5. Appareil selon l'une quelconque des revendications précédentes, dans lequel le support de matrices est monté de façon amovible sur la

chambre de compression.

6. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'ensemble formant matrice d'extrusion comprend une matrice d'entrée ayant une ouverture de diamètre compris dans la fourchette allant de 0,254 mm (0,01 pouce) à 0,533 mm (0,021 pouce) ; et une matrice de sortie ayant une ouverture de diamètre compris dans la fourchette allant de 0,381 mm à 0,711 mm (0,015 à 0,028 pouce).

7. Appareil selon l'une quelconque des revendications précédentes, comportant en outre un mécanisme (108) de commande de moteur pour maintenir une tension constante, destiné à amener un matériau d'âme allongé à se déplacer d'un bout à l'autre de l'ensemble formant matrice d'extrusion.

8. Appareil selon l'une quelconque des revendications précédentes, comportant en outre une bobine d'un matériau d'âme allongé choisi dans le groupe composé des fibres de verre, des fibres synthétiques et des fibres de carbone.

9. Appareil selon l'une quelconque des revendications 1 à 7, comportant en outre une bobine d'un matériau d'âme allongé choisi dans le groupe composé de l'aluminium, du cuivre, de l'or, de l'argent, du nickel et du tantale.

10. Appareil selon l'une quelconque des revendications précédente, comportant en outre un mécanisme d'alimentation destiné à amener jusqu'à la chambre de compression du métal choisi dans le groupe composé du plomb, du zinc et du nickel.

11. Procédé pour revêtir de métal un matériau d'âme allongé (86), en utilisant un appareil selon l'une quelconque des revendications 1 à 10, le procédé comportant les étapes qui consistent à amener dans la matrice d'extrusion un matériau d'âme allongé (86) ; à déplacer le piston (52) à l'intérieur de la chambre de compression (30) afin de créer une force d'extrusion de façon à pousser un métal depuis la chambre jusque dans la matrice d'extrusion (60), et à appliquer sur le matériau d'âme, lorsqu'il traverse d'un bout à l'autre la matrice, un revêtement sensiblement uniforme sensiblement du métal présent dans la matrice d'extrusion, caractérisé en ce que le procédé comporte également les étapes consistant à diriger contre la paroi intérieure de la chambre de compression (52) une partie du métal pré-



sent dans la chambre afin de réaliser l'étanchéité le long d'une paroi intérieure de la chambre de compression entre le piston (52) et cette paroi, et d'empêcher sensiblement une fuite de métal par-delà le piston lors de la compression du métal.

12. Procédé selon la revendication 11, dans lequel le métal est du plomb.

Patentansprüche

1. Vorrichtung zum Überziehen langgestreckten Kernmaterials mit Metall, mit einer Kompressionskammer (30), zum Aufnehmen von Metall zum Extrudieren und mit einem Extrudierauslaß (54); einer Extrusionsdüsenanordnung, die kommunizierend mit dem Extrudierauslaß der Kompressionskammer angeordnet ist, und zum Aufnehmen eines langgestreckten Kernmaterials (86), das überzogen werden soll, durch diese; und einem Kolben (52), der innerhalb der Kompressionskammer angeordnet ist, zum Treiben von Metall unter Druck durch den Extrudierauslaß zur Düsenanordnung; dadurch gekennzeichnet, daß der Kolben beabstandete ringförmige Vorsprünge (144,146) aufweist, die einen Umfangsdichtbereich in Form eines Raumes zwischen den Kolben und der Innenwand der Kompressionskammer (152) zum Aufnehmen von Metall definieren, um eine Dichtung gegen die Wand zu bilden und im wesentlichen dem Abgang von Metall hinter den Kolben während der Kompression vorbeugen; wobei der Kolben einen inneren Durchlaß (148,150) zwischen dem durch die Vorsprünge definierten Umfangsdichtbereich und dem Ende des Kolbens, das auf das Metall in der Kammer wirkt, umfaßt, um Metall auf die Dichtfläche zu lassen.
2. Vorrichtung nach Anspruch 1, bei der der Durchlaß eine quer verlaufende Öffnung (148) durch den Kolben zwischen den Vorsprüngen und eine axiale Öffnung (150) durch das Kolbenende, die sich von dem Ende des Kolbens zu der quer verlaufenden Öffnung erstreckt, umfaßt.
3. Vorrichtung nach Anspruch 1 oder 2, bei der die Extrusionsdüsenanordnung erste und zweite Düsenelemente (58,60) umfaßt, die jedes eine Öffnung (132,136) zum Aufnehmen eines langgestreckten Kernmaterials durch diese aufweisen; und eine Düsentrenneinrichtung (120), die zwischen den ersten und zweiten Düsenelementen angeordnet ist, welche eine Ausrichtung der Öffnungen und Trennung der Öff-

nungen bewirkt, so daß sie im wesentlichen gleich dem Radius der Dicke des Metallüberzuges sind, der auf das Kernmaterial aufgegeben wird.

4. Vorrichtung nach Anspruch 1 oder Anspruch 2, bei der die Extrusionsdüsenanordnung eine Eingangsdüse (58) und eine Ausgangsdüse (60), wobei die Düsen gegenüberliegende abgeschrägte Endabschnitte (134,138) mit Öffnungen zur beabstandeten coaxialen Ausrichtung für den Durchlaß langgestreckten Kernmaterials aufweisen; eine Düsentrenneinrichtung (120), welche ein rohrförmiges Element aufweist, das die Düsen darin gehalten hat, um einen Raum zwischen den Endabschnitten einzurichten, und mit einer Öffnung (128) durch die Seitenwand, um extrudiertes Metall in den Raum zwischen die Düsen zu lassen; und einen Düsenhalter (62), der die Düsen und die Düsentrenneinrichtung hält, welcher eine langgestreckte Walze mit einer Öffnung durch die Seitenwand (126) in Ausrichtung sowohl mit der Öffnung in der Düsentrenneinrichtung als auch dem Extrudierauslaß der Kompressionskammer umfaßt und mit einem Element (124) zum Zurückhalten der Düsen und der Düsentrenneinrichtung innerhalb der Walze, umfaßt.
5. Vorrichtung nach einem der vorangehenden Ansprüche, bei der der Düsenhalter lösbar an der Kompressionskammer angebracht ist.
6. Vorrichtung nach einem der vorangehenden Ansprüche, bei der die Extrusionsdüsenanordnung eine Eingangsdüse mit einer Öffnung eines Durchmessers in dem Bereich von 0.254 mm (.010 Zoll) bis 0.533 mm (.021 Zoll); und eine Ausgangsdüse mit einer Öffnung eines Durchmessers in dem Bereich von 0.381 mm bis 0.711 mm (.015 bis .028 Zoll) umfaßt.
7. Vorrichtung nach einem der vorangehenden Ansprüche, der weiterhin einen Konstant-Spannungs-Motor-Steuermechanismus (108) zum Bewirken, daß ein langgestrecktes Kernmaterial sich durch die Extrusionsdüsenanordnung bewegt, umfaßt.
8. Vorrichtung nach einem der vorangehenden Ansprüche, die weiterhin eine Rolle eines langgestreckten Kernmaterials umfaßt, das aus der Gruppe aus Glasfaser, synthetischer Faser und Carbonfaser ausgewählt ist.
9. Vorrichtung nach einem der Ansprüche 1 bis 7, die weiterhin eine Rolle eines langgestreckten Kernmaterials umfaßt, das aus der Gruppe



Aluminium, Kupfer, Gold, Silber, Nickel und Tantal ausgewählt ist.

10. Vorrichtung nach einem der vorangehenden Ansprüche, die weiterhin einen Zufuhrmechanismus zum Aufgeben von Metall, das aus der Gruppe aus Blei, Zink und Nickel ausgewählt ist, in die Kompressionskammer umfaßt. 5
11. Verfahren zum Überziehen langgestreckten Kernmaterials (86) mit Metall unter Verwendung einer Vorrichtung nach einem der Ansprüche 1 bis 10, wobei das Verfahren die Schritte des Zuführens eines langgestreckten Kernmaterials (86) in die Extrusionsdüse; des Bewegens des Kolbens (52) innerhalb der Kompressionskammer (30) zum Erzeugen einer Extrudierkraft zum Treiben eines Metalles in der Kammer in die Extrusionsdüse (80) und des Aufgebens eines im wesentlichen gleichförmigen Überzuges im wesentlichen aus dem Metall in der Extrusionsform auf das Kernmaterial, wenn es durch die Form geleitet wird, umfaßt, dadurch gekennzeichnet, daß das Verfahren weiterhin die Schritte des Leitens eines Teiles des Metalles in die Kammer gegen die Innenwand der Kompressionskammer (152), um den Kolben (52) entlang einer Innenwand der Kompressionskammer abzudichten und im wesentlichen dem Abgang von Metall hinter den Kolben während der Kompression des Metalles vorzubeugen, aufweist. 10 15 20 25 30
12. Verfahren nach Anspruch 11, bei dem das Metall Blei ist. 35

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