Jan. 3, 1967 C. E. WEBBER ETAL 3,295,174

CASTING MACHINE FOR CLAD METAL BARS

Filed March 9, 1965 4 Sheets-Sheet 1

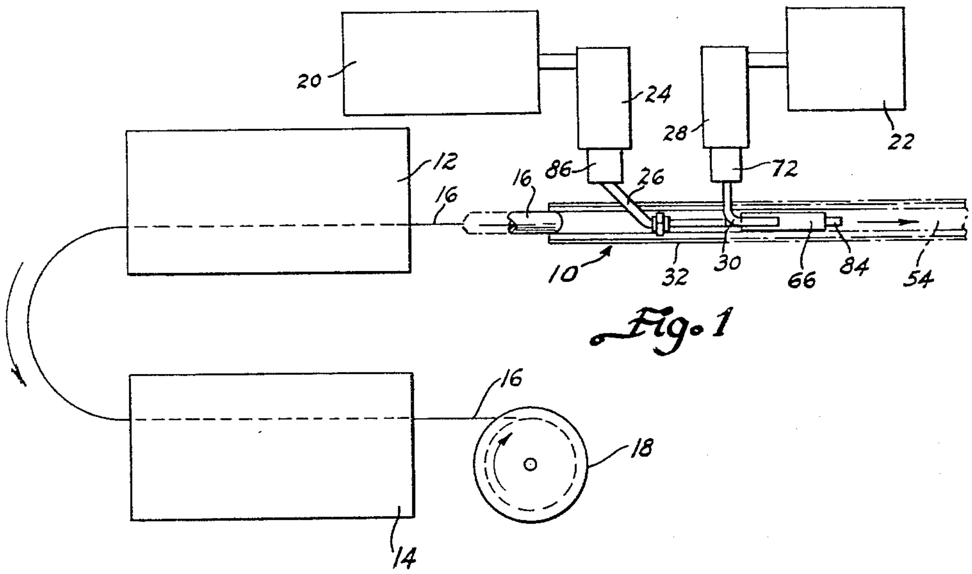

Fig. 1

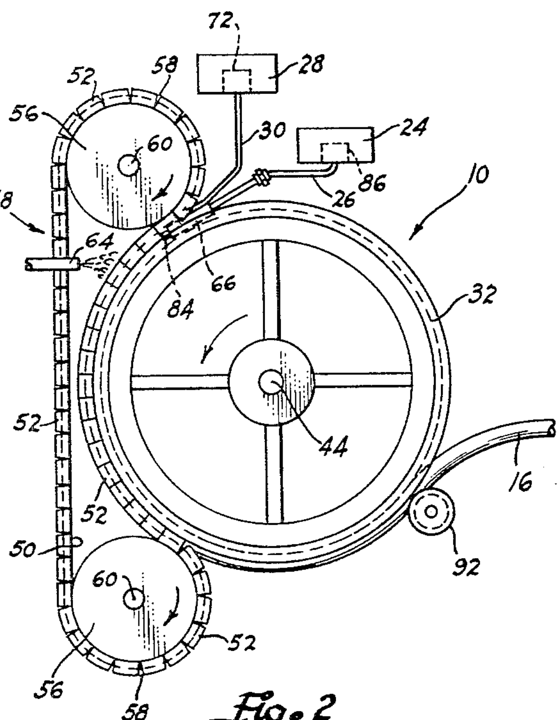

Fig. 2

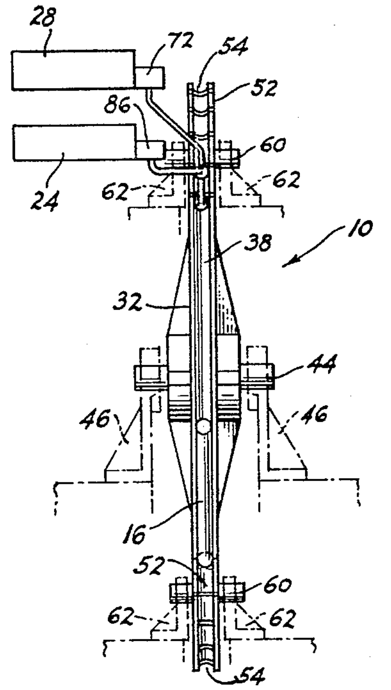

Fig. 3

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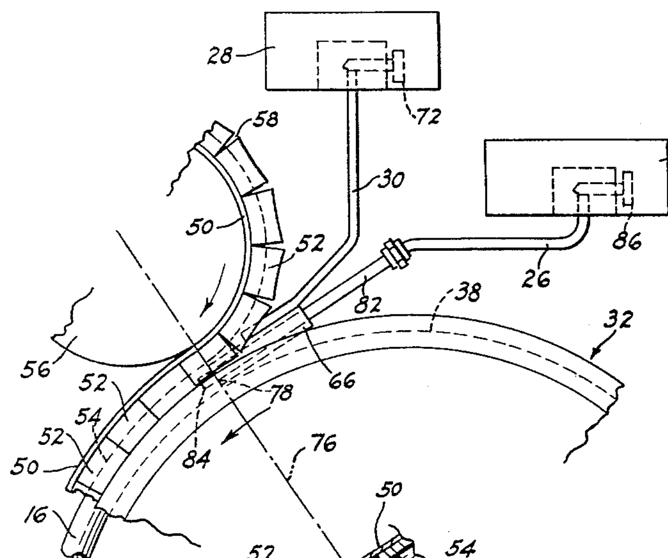

Fig. 4

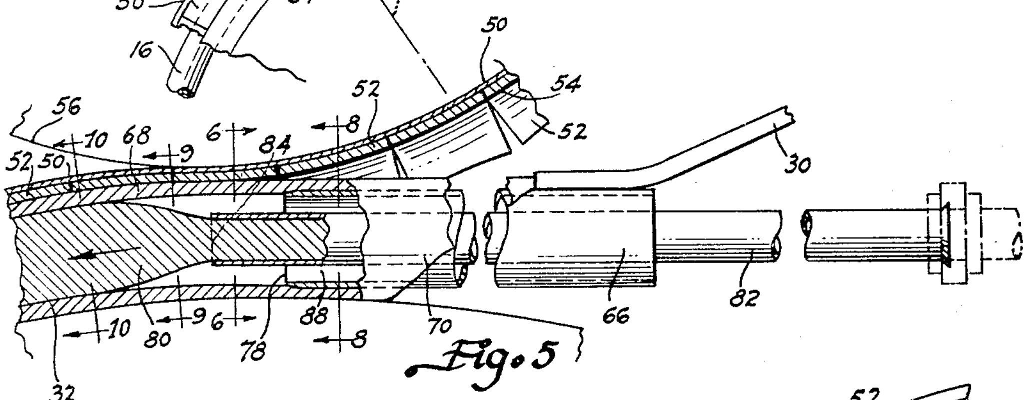

Fig. 5

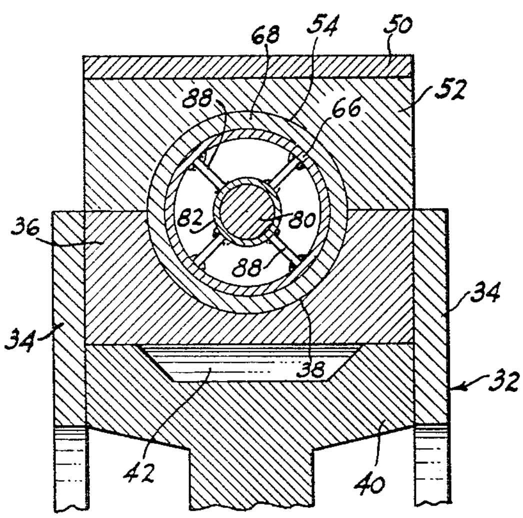

Fig. 6

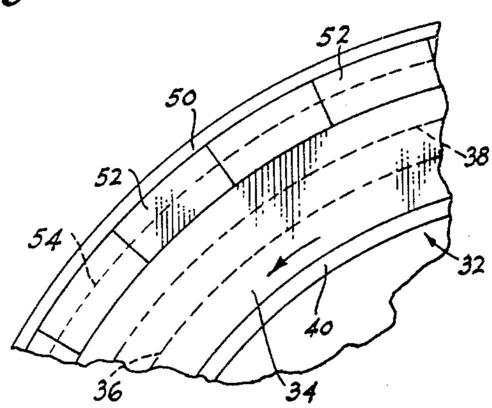

Fig. 7

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CASTING MACHINE FOR CLAD METAL BARS

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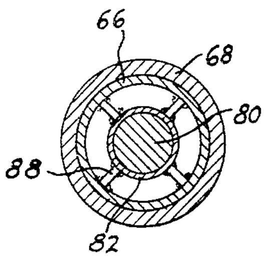

Fig. 8

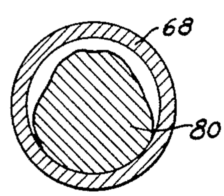

Fig. 9

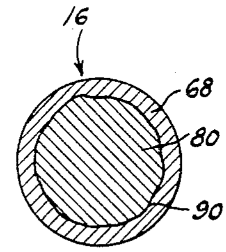

Fig. 10

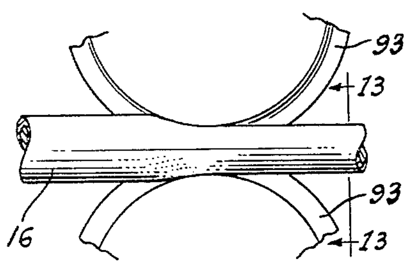

Fig. 11

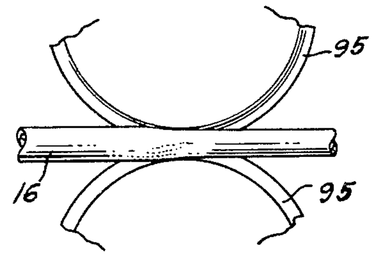

Fig. 12

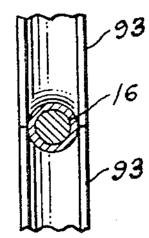

Fig. 13

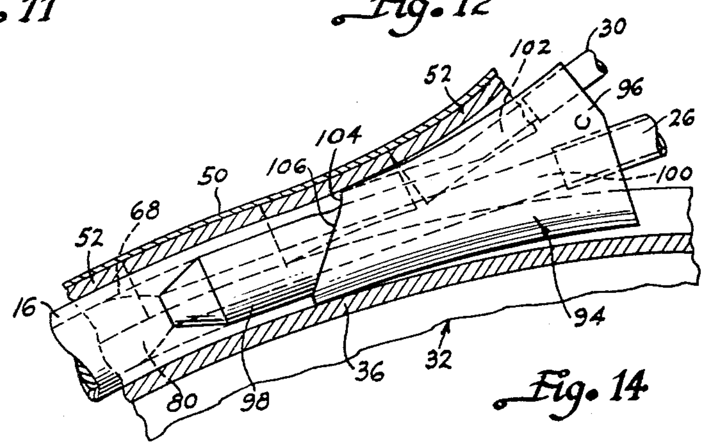

Fig. 14

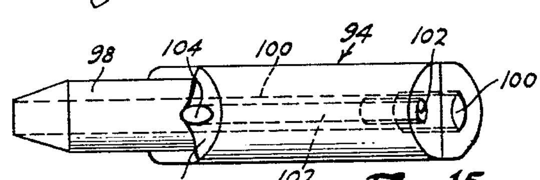

Fig. 15

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CASTING MACHINE FOR CLAD METAL BARS

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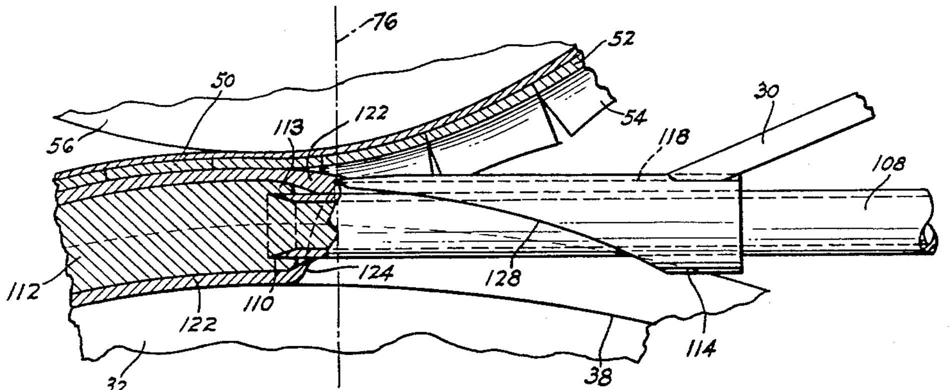

Fig. 17

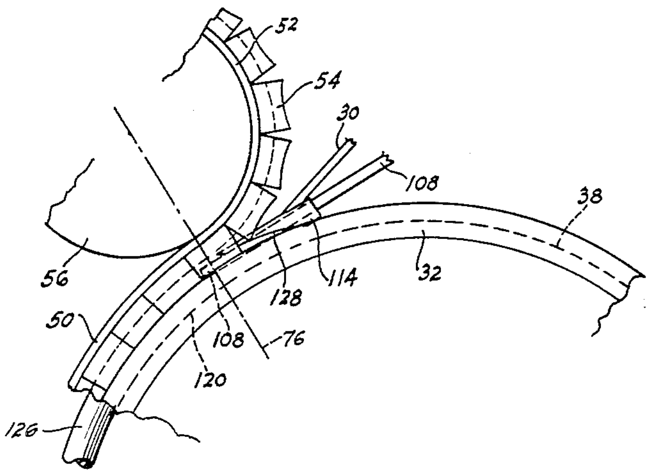

Fig. 16

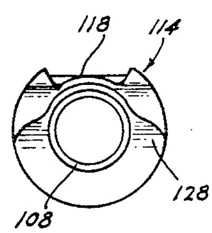

Fig. 19

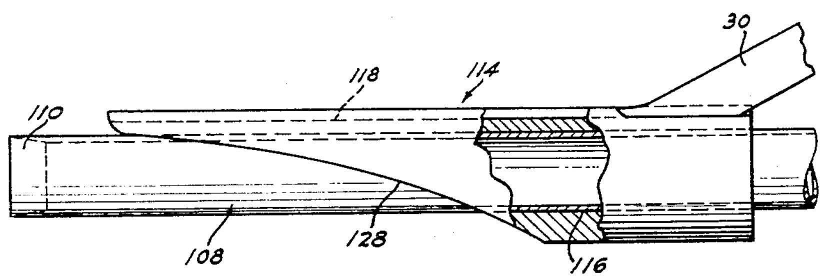

Fig. 18

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United States Patent Office

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CASTING MACHINE FOR CLAD METAL BARS

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Filed Mar. 9, 1965, Ser. No. 438,261
9 Claims. (Cl. 22—57.4)

This application is a continuation-in-part of Serial No. 353,694, filed March 23, 1964.

This invention pertains to a machine for casting metallic bar stock comprising a core of one kind of metal, clad with a sheath, extending entirely around the perimeter of the core, of another metallic composition different from that of the core and integrally united therewith. The invention also comprises a process of producing a clad metallic product of such type and, more particularly, for producing a non-ferrous type of clad metallic product in lengths of desired size and, if desired, in continuous lengths.

Many difficulties have been presented heretofore in regard to making raw material in bars of desired lengths, and especially continuous lengths, suitable for being drawn into bars of smaller diameter or wire of various sizes, particularly when it is desired to have the rod or wire product clad with a metallic composition different from that of the core material. Various means have been resorted to to produce products of this type, including the plating of suitable cladding upon a core of desired metallic composition. Cores of desired size also have been dipped in metallic coating material in molten condition. Such procedures require an extra process, however, and such procedures not infrequently present problems relative to firmly uniting of the cladding composition and core material.

Attempts to solve the problems confronting this type of production of clad metallic rod or wire products, and especially those in continuous lengths, have included mechanisms and processes for forming core material of suitable cross-sectional shapes and sizes, followed by the application of a cladding coating to said core by feeding molten cladding material to said preformed core, followed by prompt chilling of the cladding layer. This procedure, however, by using known prior techniques, frequently has not resulted in suitable firm union being made between the core and the cladding layer applied thereto.

It is the principal object of the present invention to provide several embodiments of a machine and a process for forming, simultaneously, from molten metal, a rod or bar-type metallic core clad with metallic material of suitable composition which, in one embodiment, is applied, in molten condition, to said core and, in another embodiment, a tubular cladding is filled with molten core material, these operations occurring before the co-engaging surfaces of either the enclosing cladding material and core have become frozen, thereby to effect firm union without undue intermixing of the core and cladding materials at the interface therebetween.

Another object of one embodiment of the invention is to provide a machine and process by which the cladding material is first formed into a tube-like configuration, continuously for the desired length, said tube-like cladding configuration of suitable metallic composition being subjected to limited chilling from the exterior and very slight oxidation of the inner surface to commence to induce shape stability while molten core-forming material of desired composition is fed to the interior of said tube-like cladding member at a rate adequate to fill the interior of the latter and cause firm uniting therewith while the very slight oxide film on the interior of the cladding member prevents any appreciable intermixing at the interface therebetween.

A further object of the invention ancillary to the immediately foregoing object is to induce shape stability in the tube-like cladding element by the application of cooling or chilling means to the exterior of the cladding element while the same is being filled with molten core-forming metal, the chilling being controlled so as not to cause freezing of the inner surface of the cladding sheath and while permitting only an extremely thin oxide layer to form on the inner surface before the molten core-forming metal is introduced thereinto so as to physically unite therewith, without appreciable intermixing at the interface between the core and cladding sheath, said oxide film being substantially disintegrated in the final product.

A still further object of the invention is to provide a process by which continuous lengths of composite clad core metallic product of the aforementioned type may be formed through the expedient of continuously forming an only partially stabilized tube-like sheath or cladding element and filling it with molten core-forming metal, said process being achieved by several embodiments of machines or mechanisms each having means for forming such tube-like cladding element of continuous lengths of the type described and means for introducing molten core-forming metal to the interior of said cladding element, said embodiments of machines also including means adapted simultaneously to form the exterior of the clad, composite product so as to be of substantially uniform size in diameter throughout the length thereof, thereby also chilling at least the outer portions of said composite product sufficiently while maintaining such size thereof so that when the product is discharged from the machine, the shape and composition of the product is fixed and will remain so until further reduced by subsequent procedures, such as drawing the same, or the like.

Ancillary to the foregoing object, it is a further object of the invention to provide one embodiment of mechanism in the casting machine comprising a pair of concentric tubular shaping and flow-directing members of different diameters, the larger diameter member being arranged to have molten cladding material flowed therearound and stabilized sufficiently to move longitudinally from the discharge end of said tubular member to form and permit very limited oxidation of the interior of hollow, tube-like cladding means into which molten core-forming metal is flowed from the smaller diameter tubular means of said mechanism.

A slightly different version of the embodiment of mechanism described immediately above for forming the composite clad core product comprises a substantially solid member having one end formed so as to have molten clad material flowed therearound and continuously form a partially stabilized tube-like cladding means, while a concentric bore in said member delivers molten core-forming metal to the interior of the cladding means, as formed, to effect integral union with the inner surface of said cladding means.

Also ancillary to the foregoing objects of the invention, it is another object to provide means in the principal embodiment of molding machine and mechanism described above by which the stream of molten core-forming metal is of a smaller diameter than the interior of the immediately pre-formed cladding means which is continuously formed by the machine and into which the core-forming metal is flowed while molten, and while the heat of fusion still is substantially present especially in the inner portion of the cladding means, and the linear speed of the stream of molten core-forming metal is greater than the speed of travel of the cladding means as it is formed by said machine so as to insure the filling of the interior of the cladding means, such greater speed of the core-forming metal incidentally insuring movement of the same at a speed which will prevent any undesirable chilling or freezing of the molten metal as it flows into the interior of said cladding means and unites therewith.

Still another very important object of the invention is to provide a different embodiment of casting machine and process to produce a clad composite product of the type described and in which embodiment, conversely to the above-described objects, the core member of the product is formed immediately prior to the cladding material being flowed therearound for integral union therewith to form a tubular sheath thereon.

Ancillary to the immediately preceding object, it is a further object to flow and shape the core member in such manner that an extremely thin oxide layer is formed on the exterior thereof to aid in stabilizing the shape thereof and especially to serve as a barrier adequate to prevent any appreciable intermixing between the core and cladding members but capable of being disintegrated and dissipated in the final product after firm, integral union has been achieved between the core and cladding members.

Still further ancillary to the immediately foregoing object, it is a further object to provide, in the casting machine to form such product, shaping and flow-directing means having feeding and delivery means for rapidly and simultaneously shaping a continuous metallic core member of desired, substantially uniform diameter, and flowing molten metallic cladding material, from preferably a level above the axis of the core, completely around the immediately pre-formed core member, after the formation of only a slight oxide film on the core member, to prevent any appreciable intermixing at the interfaces, and also providing exterior shaping means in the casting machine to engage the resulting composite clad core and shape the exterior of the applied cladding sheath to control the diameter and thickness thereof, as well as chill the same to stabilize the rod product which is thus formed in continuous lengths.

Still another object of the invention is to provide, for use with either of the above-described principal embodiments of the invention, relatively simple metal molding and chilling mechanism comprising an exemplary circular wheel-like molding member having an annular groove in the periphery thereof which is, preferably, semi-circular in cross-section, and additional molding means also having grooves therein complementary to that in the circular molding member and which cooperate therewith to provide a passage therebetween which is substantially circular in cross-section and into which the composite clad core metallic member passes for final chilling of the product to render it capable of being handled for further operations including the rolling and drawing thereof to reduce the diameter to any desired smaller sizes.

A still further object of the invention ancillary to the immediately foregoing object is to compose such additional molding means from a series of flexibly connected blocks shaped to closely abut each other in end-to-end arrangement while conforming closely to the periphery of the circular movable molding member for a substantial segment thereof adequate to effect desired chilling of the product while disposed therein.

Details of the foregoing objects and of the invention, as well as other objects thereof, are set forth in the following specification and illustrated in the accompanying drawings comprising a part thereof.

In the drawings:

FIG. 1 is a diagrammatic plan view of a typical production layout embodying a casting machine employing the principles of one embodiment of the invention and illustrating, on a smaller scale, exemplary rolling mill means arranged in series to reduce the size of the product of the casting machine.

FIG. 2 is a side view showing details of one exemplary arrangement of the embodiment of casting mechanism shown in the exemplary layout of FIG. 1 in which the mechanism is seen from the top side.

FIG. 3 is an end view of the casting mechanism shown in FIG. 2 as seen from the right-hand side thereof.

FIG. 4 is a fragmentary side elevation of the upper portion of the embodiment of casting mechanism shown in FIG. 2, on a larger scale than employed in FIG. 2, to illustrate relative positions of certain elements of the mechanism.

FIG. 5 is a fragmentary side elevational view of the central portion of the mechanism shown in FIG. 4, on a still larger scale than used in FIG. 4, and partly in vertical section to illustrate certain details of the mechanism.

FIG. 6 is a fragmentary vertical sectional view of a portion of the casting mechanism as seen on the line **6—6** of FIG. 5 and on a larger scale than used in FIG. 5.

FIG. 7 is a fragmentary side elevation, on a scale similar to that of FIG. 5, illustrating certain details of the movable molding means of the casting mechanism.

FIGS. 8, 9 and 10 respectively are successive transverse sectional views illustrating various steps in the formation of the composite clad product formed by the embodiment of mechanism illustrated in the preceding figures, as seen respectively on the lines **8—8**, **9—9** and **10—10** of FIG. 5.

FIGS. 11 and 12 respectively are fragmentary exemplary side elevations illustrating representative pairs of reduction rollers of the type employed in the exemplary rolling mills of FIG. 1, FIG. 11 representing one of the early pairs of reduction rollers, while FIG. 12 represents one of the final sets of reduction rollers.

FIG. 13 is an exemplary transverse sectional view as seen on the line **13—13** of FIG. 11, showing the interface between the core and cladding sheath in a somewhat exaggerated manner.

FIG. 14 is an exemplary side elevation, partly in vertical section, of another embodiment of stationary shaping means and flow means used to form the composite clad product produced by the embodiment of machine illustrated in the preceding figures.

FIG. 15 is a top plan view of the stationary shaping means and flow means per se shown in FIG. 14.

FIG. 16 is a fragmentary side elevation similar to FIG. 4 but showing another embodiment of casting machine in which the shaping and guide means for forming the core and cladding members are arranged to effect a different sequence of the formation of said members from the embodiment of casting machine shown in FIGS. 1–10 and FIGS. 14 and 15.

FIG. 17 is a fragmentary enlarged vertical sectional view of the embodiment of the invention shown in FIG. 16 to illustrate greater detail thereof.

FIG. 18 is a side elevation, partly broken away, showing on a still larger scale than in FIG. 17, the shaping and guide means per se.

FIG. 19 is an end view of the shaping and guide means of FIG. 18 as seen from the left end thereof.

An exemplary mill layout is illustrated in FIG. 1 to show one typical embodiment of production facilities feasible to produce clad metallic rod-like products, either in continuous lengths or shorter, desired lengths, in accordance with the principles of the present invention. It is to be understood that the layout is merely illustrative, however, and is not restrictive. In said figure, a casting machine **10** is shown which is capable of producing either continuous or shorter lengths of clad product and which incorporates the present invention disposed in one suitable layout arrangement. Other layout arrangements are possible.

The clad product produced by the machine 10 is led directly to a first rolling mill 12 which is illustrated on a substantially smaller scale than that employed in showing the casting machine 10, for purposes of conserving space. The drawing mill 12 may comprise a series of sets of reduction rollers, for example, each arranged successively to reduce the continuous clad product to smaller diameter. Such product then may be suitably guided into the entrance or left-hand end of a second rolling mill 14 which, like rolling mill 12, preferably includes another series of sets of reducing rollers or other reducing means successively arranged to reduce the continuously formed clad product to smaller diameters until the product 16, for example, may be coiled or spooled at 18 so that the same may be handled conveniently. Flying shears or other means, not shown, may be employed to sever the product when the spool 18 is filled and a new spool quickly is moved into place to receive the continuing discharge of product 16.

The several rolling mills 12 and 14 shown in FIG. 1 merely are illustrated to provide at least an approximate concept of a typical type of production layout within which the casting machine 10, embodying the principles of the present invention, may be used. While not restricted thereto, the machine 10 especially is adapted to form a composite product comprising a core which is integrally connected to an encircling cladding layer or sheath, the core and cladding layer preferably being of non-ferrous nature. By way of further specific example, the machine 10 especially is adapted for the production of clad aluminum wire and particularly such wire of the type employed in the weaving of insect screening or cloth.

Further, without restriction thereto, one type of aluminum clad wire suitable for weaving into insect cloth is that wherein the core is formed from an aluminum alloy having substantial tensile strength and being of a relatively hard nature compared with the cladding material which preferably is of a different composition of softer aluminum capable of protecting the core from oxidation more suitably than such core material alone. Nothwithstanding this specific illustration, however, it is to be understood that the casting machine 10 which embodies the principles of the present invention is adapted for the formation of other types of clad, preferably non-ferrous products in either continuous or shorter lengths.

In FIG. 1, a furnace or cupola 20 is provided in which appropriate raw material, such as pigs of desired metallic composition are fed for reduction to molten condition. The furnace 20 is of commercial type and thus is only diagrammatically illustrated, as is a second furnace or cupola 22 in which suitable raw material of appropriate metallic composition, different from that melted in furnace 20, also is reduced to molten condition. By way of specific example, the furnace 20 is intended to melt core material, while furnace 22 is intended to melt cladding material. In accordance with the preferred operation of the entire mill system, molten material is withdrawn from the furnaces 20 and 22, for a desired period or continuously, while raw material is continuously added thereto to be melted, thus insuring continuous production for substantial periods of time, if desired.

Molten core material is withdrawn from furnace 20 into a suitable transfer pot 24, which feeds molten core-forming material into delivery tube 26. Similarly, furnace 22 in which the cladding material is melted, discharges a continuous stream of cladding material into transfer pot 28 for discharge into delivery tube 30. The transfer pots 24 and 28 primarily are used for purposes of controlling the flow of molten material respectively to the delivery tubes 26 and 30 and in order to accomplish this, the transfer pots preferably are mounted on suitable pivotal supports to permit limited tilting of the same and thereby control the flow of molten material very readily to the delivery tubes 26 and 30. Other equivalent types of feeding and delivery mechanism may be used, however.

The molding mechanism which receives the molten metal from delivery tubes 26 and 30 now will be described. There are 2 principal cooperating portions of such molding mechanism. One of these comprises, in accordance with the preferred construction of the invention, a circular movable molding member 32 resembling a wheel, for example. The details of preferred construction of said molding member 32 are best shown in FIG. 6 wherein it will be seen that exemplary side members 34, of circular configuration, may be employed to support therebetween a circular rim 36 formed preferably from material having a high coefficient of thermal conductivity, such as copper or the like. The periphery of the circular rim member 36 is provided with a preferably semi-cylindrical groove 38 but it is to be understood that the shape of the groove 38 may be conformed to whatever shape is desired for the exterior of the product to be molded by the member 32.

Also mounted directly in contact with the inner periphery of the circular ring 36 is a complementary circular member 40 having an annular channel 42 therein for purposes of circulating cooling fluid of either gaseous or liquid nature which is supplied to said channel by any suitable means of conventional nature in order that a cooling effect may be imparted continuously to the circular rim 36 of the mold member 32 in order that appropriate chilling may be imparted to the semi-cylindrical groove 38 for purposes to be described.

The mold member 32 is supported for rotation about a suitable transverse axle shaft 44 which is journaled in appropriate bearing members 46 shown in FIG. 3. Any suitable drive means, not shown, may be connected to the shaft 44 to rotate the mold member 32 at a desired speed suitable to accomplish the purposes of the mold member 32 as described in greater detail hereinafter.

Cooperating with mold member 32 is additional molding means 48 which, in accordance with the preferred construction of the invention, is of a flexible nature in order that it may conform to and move so as to cooperate with a desired segmental portion of the movable mold member 32 while preferably traveling at the same peripheral speed. The additional molding means 48 may be constructed in one of several different ways, the present illustration comprising a flexible band 50 of suitable spring steel or the like, for example, but it is to be understood that other means such as appropriate chain construction or the like, may be substituted and used in lieu of such flexible band.

Connected to the flexible means 50 of the additional molding means is a series of mold blocks 52 which preferably are formed from material similar to that from which the circular rim is formed, whereby said blocks likewise will be capable of efficient transfer of heat at suitable rates. Each of said blocks is provided with a preferably semi-cylindrical groove 54 which is complementary to the groove 38 of the circular rim 36. The blocks 52 also are in end-abutting relationship as is clearly shown in FIG. 7, when the same are disposed around the perimeter of movable mold member 32 as shown in FIG. 2. In order that the end-abutting series of blocks 52 may conform closely to the perimeter of circular rim 36 of mold member 32, the faces of each of the blocks 52 which coact with rim 36 are slightly concave so as to conform very closely to the convex contour of the perimeter of mold member 32 and especially the circular rim 36. Further, the ends of the blocks 52 are not exactly perpendicular to the longitudinal axis of said blocks, whereby when they are stretched in a straight line and also when they pass around the peripheries of the supporting rolls 56 therefor, V-shaped spaces 58 occur between said ends but these spaces are closed when the blocks contact the periphery of mold member 32.

It will be seen that flexible, additional molding means 48 is so position by their supporting rolls 56, which revolve about the axes of suitable shafts 60 extending between bearing members 62, that approximately one quarter of the periphery of movable mold member 32 is engaged by the additional molding means 48. Any suitable drive means, not shown, are connected to shafts 60 to advance the molding means 48 preferably at the same speed as the periphery of molding member 32. Further, if desired, suitable chilling means such as an exemplary air blast 64, and/or other equivalent cooling means, may be applied against the additional molding means 48, especially in the vicinity of where the same first comes in contact with the periphery of movable mold member 32, as well as after leaving contact with movable mold member 32.

The direction of movement of the mold members 32 and 48 is indicated by suitable arrows in FIG. 2, as well as in certain of the subsequent figures. It thus will be seen that said mold members, and especially the complementarily grooved portions thereof, converge and come into contact at a point substantially on a line between the centers of shaft 44 and upper shaft 60, while the same separate at a point substantially on the line of centers between the shaft 44 and the lower shaft 60, as viewed in FIG. 2.

There is also illustrated in FIGS. 1–6, and 8–10, one embodiment of shaping and flow means for the molten core-forming and cladding material in which, essentially, the cladding material is formed into a tubular sheath and, immediately thereafter, molten core material is flowed into the same to unite firmly therewith. This embodiment comprises a tubular stationary shaping means 66, which may be formed from suitable steel or other appropriate material, said shaping means being of a smaller diameter than that of the complementary and cooperating grooves 38 and 54 of the molding means, the difference in diameters preferably being substantially that of the thickness desired to be imparted to the cladding means 68 which flows between and is formed by the spaced opposing surfaces comprising the exterior of shaping means 66 and complementary grooves 38 and 54 as readily can be visualized best from FIGS. 5 and 6.

The molten cladding metal flows from transfer pot 28, through delivery tube 30, to the upper exterior surface of stationary shaping means 66, as best shown in FIG. 5, so as to flow around said shaping means, down opposite sides thereof and forwardly from the delivery end of tube 30, somewhat following the exemplary line 70 denoting the flowing edge of such cladding material until the streams thereof flowing down opposite sides of tube 66 meet at the bottom, within the molding groove 38 of movable mold member 32.

Flow of the molten cladding material down the delivery tube 30 is controllable through the use of suitable means such as a graphite valve 72 and such flow is so proportioned to the movement of the cooperating molding member 32 and additional molding means 48 that the space between the cooperating grooves 38 and 54 and the exterior of shaping tube 66 will be filled with cladding material 68 of substantially uniform wall thickness as best can be seen in FIG. 6.

As best can be seen along the line of centers 76 shown in FIG. 4, for the upper roll 56 and movable mold member 32, the terminal end 78 of shaping tube 66 is substantially coincident with said line of centers, whereby as soon as the flowing tubular sheath of cladding means 68 is formed as a result of passing from the terminal end 78 of shaping tube 66, the exterior surface thereof is reasonably stabilized by virtue of being immediately subjected to the chilling effect of the circular rim 36 of mold member 32 and the blocks 52 of additional molding means 48. Also, an oxide film of very slight thickness is permitted to form on the interior of said sheath, while the heat of fusion is very largely still present in said sheath.

Especially when the cladding material is of high thermal conductivity, such as an aluminum alloy, for example, such chilling effect imparted to the exterior of the cladding sheath 68 migrates interiorly quite quickly, whereby the shape of even the interior of the cladding sheath 68 is reasonably stabilized though definitely not frozen until the sheath has traveled a short distance beyond the end 78 of the shaping tube 66. Accordingly, though the inner surface of the cladding sheath 68 is not fluid as it emerges from the end 78 of the shaping tube 66, it is not frozen, it has a very thin oxide film thereon, it still retains much of the original heat of fusion, and is highly capable of being united integrally with core-forming material 80 which is delivered to the interior of the cladding sheath 68 at a rate to continuously completely fill it. The oxide film, though thin on the interior of the sheath, is adequate to prevent any appreciable intermixing of the sheath and core at the interfaces thereof and is substantially disintegrated in the final composite product after it has served the forgoing purpose, so that it in no way interferes with the core and cladding sheath firmly, integrally uniting.

The core-forming material is delivered from flow means comprising a tube 82, formed from suitable metal or other appropriate material, which preferably is coaxial with and interior of the stationary shaping tube 66, as readily is seen particularly from FIGS. 5 and 6. Preferably, flow means 82 is of smaller diameter than the outer diameter of shaping tube 66, whereby as said molten core-forming material 80 emerges from the terminal end 84 of flow means 82, it spreads out or expands in order to completely fill the interior of the hollow tubular cladding sheath 68, as illustrated in exemplary manner in FIG. 5.

Said molten core-forming material 80 integrally unites with the inner surface of the hollow cladding sheath 68 which, as described above, has not frozen by the time such union takes place, though the inner surface of such tubular cladding sheath 68 has been stabilized sufficiently and a thin oxide film has formed so that no undue amount of intermixing of the cladding material takes place with the core material at the interfaces thereof. This results from suitable control of the temperature of the respective material, the rate of flow thereof, and the rate of movement of the cooperating molding members 32 and 48.

The flow of the core-forming material 80 is controlled principally by additional valve means such as, for example, a graphite valve 86. The flow of such material is regulated preferably so that the linear speed of the molten core-forming material through the flow means 82 is greater than the peripheral speed of the movable mold member 32. This not only is necessary in order to effect filling of the interior of the hollow cladding sheath 68 with said core-forming material, but, in view of the fact that the inner diameter of flow means 82 is substantially less than that of stationary shaping means 66, there is some danger of the core-forming material freezing within the tubular flow means 82 because the rate of flow is such as to prevent freezing from occurring. Further, to position the flow means 82 substantially concentrically with the tubular shaping means 66, any suitable means therebetween such as spider ribs or strips 88, or the like, may be employed. The united means 66 and 88 is supported by suitable mechanism such as by the means 66 and 88 respectively being connected to flow means 82 and delivery tube 30.

To graphically illustrate the progress of the formation of the united composite rod-like product comprising core 80 encircled by and united with cladding sheath 68, attention is directed to FIGS. 8, 9 and 10 which respectively show such progressive formation relative to the section lines 8—8, 9—9, and 10—10 of FIG. 5. Particularly with reference to FIG. 10, it will be seen that the interface 90 between the core and sheath of the composite rod-like product 16, though somewhat irregular, generally is circular in cross-section.

Considering the fact that a product of this type is merely the initial phase of the end product which, generally, is many times smaller in diameter than such initial phase, it is understandable that after said rod-like product 16 emerges, in chilled condition, from between guide wheel 92, for example, and movable mold member 32, and is subjected to repeated reductions to reduce the diameter thereof, any irregularities in the interface between the core and sheath of the product 16 will be minimized and the remaining traces of oxide film will substantially completely disappear especially in the reduced products of small diameter.

Solely by way of exemplary illustration, FIG. 11 represents, for example, the first pair of reduction rollers 93 of the first mill shown in FIG. 1, and FIG. 12 illustrates the last pair of reduction rollers 95 at the terminal end of the second mill shown in FIG. 1, for example. By way of further example, whereas the initial diameter of the composite product 16 emerging from the molding members 32 and 48 may be relatively large, the diameter of the product 16 emerging from the final pair of drawing rolls 95 may be of the order of 3/8", depending entirely upon the number of sets of drawing rolls or other diameter-reducing means embodied in each of the mills. However, when reduction of the exemplary type described above occurs, the product emerging from the second mill, for example, readily may be coiled, reeled or spooled at 18 with no difficulty and thereby adapt the product to ready handling for introduction to further wire drawing means or otherwise.

Referring to FIGS. 14 and 15, a variation of shaping means, per se, is shown for forming a product in accordance with the embodiment of the invention described above and in which the cladding sheath 68 is formed immediately prior to the flow means directing the molten core-forming material thereto to fill the cladding sheath 68. Said variation of shaping means comprises a unitary member 94, which is suitably supported by any appropriate stationary means substantially at the convergence of the movable mold member 32 and the flexible additional molding means 48 as best shown in FIG. 14. Member 94 may be formed from any suitable material such as an appropriate ceramic-like substance, or otherwise, readily capable of withstanding the heat of molten metal and especially molten non-ferrous metals. In side view, the member 94 somewhat resembles a horn of simple configuration, having an enlarged outer end 96, and a cylindrical inner terminal end 98 having an outer diameter less than the vertical dimension of the intermediate portion of member 94, and preferably substantially equal to the outer diameter of stationary shaping tube 66 of the embodiment shown in the preceding figures.

Combination shaping and flow member 94 is provided with a plurality of longitudinally extending, internal bores respectively receiving molten cladding material and molten core-forming material. Bore 100 extends longitudinally through the entire length of member 94. The discharge end of delivery tube 26 for the core-forming material is connected to the outer end of bore 100 and the opposite end thereof discharges molten core-forming material into the interior of the cladding sheath 68 which is formed by molten cladding material being delivered through bore 102 to which the delivery end of delivery tube 30 is connected. The terminal end 104 of bore 102 opens through a shoulder surface 106 intermediately of the ends of member 94 and defining one end of the cylindrical terminal end portion 98 of member 94.

As best seen from FIG. 14, the shoulder surface 106, in side elevation, slopes forwardly and downwardly so as to direct molten cladding material around all surfaces of the exterior of the terminal end 98 of member 94 and insure the formation of a completely tubular cladding sheath member 68. As in regard to the embodiment illustrated in the preceding figures, as the cladding sheath 68 is formed by emerging from the end of terminal portion 98 of member 94 and chilling thereof commences from the exterior thereof through contact with the grooves 38 and 54 of the molding members, stability of shape is induced in said tubular cladding sheath 68, without freezing of the inner surface thereof until after molten core-forming material 80 has been discharged from the terminal end of bore 100 thereinto for integral union with the inner surface of the tubular cladding sheath 68 without substantial intermixing at the interface, all in accordance with the details described above relative to the structure of the preceding figures. Also as in regard to the preceding description, the rate of flow of the respective materials, temperatures thereof, and speed of the molding members are all controlled with respect to the variation of shaping means shown in FIGS. 14 and 15 so as to produce a composite clad product 16 similar to that produced by said above-described mechanism.

In addition to the above-described embodiment of forming a composite rod product by first forming the cladding sheath and immediately thereafter filling the same with molten core material, the present invention also provides a further embodiment wherein, conversely to the above-described embodiment, the core member of the composite product is first formed and immediately thereafter, cladding material is flowed circumferentially around the core member to unite therewith and constitute a cladding sheath while the core member and flowing cladding material are moving simultaneously, in an axial direction incident to the exterior of the cladding sheath of the composite product being finally shaped by molding members of the type illustrated in the drawings and described hereinbefore relative to the above-described embodiment of the invention. This additional embodiment of the invention, which comprises both a process and apparatus for achieving the same, is illustrated in FIGS. 16–19 of the drawings, to which attention now is directed.

The molding or casting members illustrated particularly in FIGS. 1–7, comprising circular wheel-like mold member 32 and the flexible, endless outer molding means comprising mold blocks 52, which are fastened to flexible band 50, are employed for purposes of feeding the composite product and shaping the exterior thereof which is made in accordance with the aforementioned additional embodiment of the invention. Accordingly, these same molding or casting members are illustrated in FIGS. 16 and 17 in regard to said additional embodiment, the same being referred to by the same reference characters as in FIGS. 1–7.

It also will be understood that the same furnaces or cupolas 20 and 22, shown in FIG. 1, which respectively furnish the core material and cladding material are utilized in regard to furnishing these same materials relative to the embodiment shown in FIGS. 16–19. Further, the flow of the material to the various delivery and shaping means of said latter embodiment, such as the graphite valves 72 and 86, are employed to control the delivery rate of said materials.

Referring to FIGS. 16 and 17 in particular, with respect to this latter embodiment of the invention, a shaping and delivery tube 108 receives molten core-forming material from furnace 20, as controlled by valve 86, shown in FIG. 1. The valve 86 is adjusted to deliver the desired quantity of continuously flowing molten core material in relation to the peripheral speed of the wheel-like rotary mold member 32, which has an annular casting or molding groove 38 therein which is semi-circular in cross-section and cooperates with the semi-circular grooves 54 formed in the molding blocks 52 carried by flexible band 50.

The tube 108 may be formed from any appropriate material such as steel, appropriate titanium alloys, and the like. These materials are suitably heat-resistant to accommodate molten non-ferrous metals in particular, especially aluminum alloys, with which the entire machine is especially adapted to operate, but is not to be considered as restricted to operating only with this type of alloy. The delivery end 110 of tube 108 preferably is flared, or at least on its inner surface, as illustrated in FIG. 17 in cross-section, and the molten core-forming material flowing therefrom forms core 112 comprising part of the composite product. It will be seen that this core is materially larger in diameter than the interior of tube 108. Further, it will also be seen from FIG. 17 that, in emerging from the delivery end 110 of tube 108, the molten core material tends to back flow to a limited extent and form a sort of annular meniscus 113. When the tube 108 is circular in cross-section, the core 112 formed thereby likewise will be circular in cross-section.

In this latter embodiment of the invention, the cladding material is applied to the core 112 by means of a delivery and shaping member 114, details of which are best shown in FIGS. 18 and 19. Said member preferably is formed from an appropriate, heat-resistant, non-metallic material. Certain forms of ceramic substances are suitable, these being capable of being molded into the appropriate shape, one exemplary form thereof being illustrated in aforementioned FIGS. 18 and 19. Member 114 has a tubular bore 116 extending longitudinally thereof, through which the tube 108 extends in close conformity to the inner surface of the bore, thereby also serving as a support for the member 116. The tube 108 is supported by any suitable means, not shown in detail.

By reference particularly to FIG. 19, it will be seen that the upper portion of shaping member 114 has a delivery channel or gutter 118, which extends longitudinally along the member 114 and at the receiving end thereof, communicates with the discharge end of delivery tube 30 which receives cladding material from the furnace 32, the flow of which is controlled by valve 72, as seen in FIG. 1. From FIG. 19, it will be seen also that the width of the delivery channel 118 is at least equal to the outer diameter of tube 108.

The molten cladding material flows along the delivery channel 118 and at the discharge end thereof, at the left-hand end thereof, as viewed in FIGS. 17 and 18, it will be seen that the tube 108 extends therebeyond a limited distance, such as about 1" in actual practice where the tube 108 is about ½" in diameter, for example. Further, the discharge end of the member 114 is approximately even with the line of centers 76 extending between supporting roll 56 and movable mold member 32. Accordingly, the discharge end of the core-forming tube 108 extends beyond said line of centers and into the closed circular configuration 120, defined by the dotted lines in FIG. 16, which is formed by the cooperating semi-circular grooves in the movable mold member 32 and the mold blocks 52 when the perimeters thereof are in close contact with each other and the spaces between the blocks 52 are closed, as clearly shown in FIG. 6 directly to the left of the discharge end of the tube 108. Such arrangement facilitates the accurate formation of a core which is circular in configuration and an even thickness of cladding material formed thereon, as now will be described.

The molten cladding material, which is of a different composition from that which forms the core 112, flows along the channel 118 in member 114 to the outer, delivery end thereof and then flows around the projecting delivery end of tube 108, as best seen in FIG. 17, also flowing onto the exterior surface of the core 112 which is slightly pre-formed, in point of time, ahead of the cladding sheath 122 shown in cross-section in FIG. 17. An exemplary flow line 124, representing the forming end of the cladding sheath 122, is illustrated in FIG. 17 also.

It is to be understood that the speed of the casting or molding members 32 and 52, in relation to the rate of flow of the metal for forming both core 112 and the cladding sheath 122, the flow of these respective materials likewise being regulated with respect to each other, will determine the diameter of the core 112 and the thickness of the cladding sheath 122. The semi-circular surfaces 38 and 54 of the molding wheel 32 and molding blocks 52 determine the exterior surface of the composite product 126 shown in FIG. 16, as well as chilling the same to fix the final shape thereof as in regard to the embodiment described above with respect to FIGS. 1–7.

Also as occurs in regard to the first-described embodiment of the invention, when the core 112 is discharged from the delivery end 110 of tube 108, a very thin oxide surface is immediately formed on the exterior thereof. A limited amount of air is available at said delivery end 110 of the tube, due primarily to the fact that the flow of the cladding material, as it discharges from the channel 118, is not completely smooth as to volume, width, or transverse extent. Spaces occur in the body of this material through which air can gain access to the outer surface of the core 112 and, as in regard to the previously described embodiment, though very thin, such oxide film serves a beneficial purpose of partially stabilizing the shape of the core 112, but, primarily, prevents any appreciable intermixing of the cladding material with the core as the former flows around the latter, thus quite substantially fixing the relative shapes of the two members of the composite product but in no way interfering with a firm union occurring between the two so that the core and cladding sheath are integral with each other. Further, said oxide film is substantially disintegrated and dissipated incident to the formation of the final product and particularly after the composite rod is subject to a number of passages through reducing rolls and the like.

The embodiment of the invention illustrated in FIGS. 16–19 offers several salient advantages over the embodiments shown in FIGS. 1–7. One of the advantages is that the composite forming and shaping member comprising tube 108 and member 114 are more simple and consequently less expensive than the corresponding forming and shaping member 66, 82 of the preceding embodiments. As best can be visualized from FIG. 16, also, the arcuate undersurface 128 of the shaping member 114 permits the operator to view the flow of the material, thereby enabling him to adjust the flow particularly of the core material since it is primarily the formation of the core 112 that controls the thickness of the cladding sheath 122 on the composite product 126.

It is to be understood in the foregoing description and the appended claims that while the process and several embodiments of apparatus comprising the present invention are particularly adapted to produce a rod-like clad product of continuous length, the term "continuous" is to be construed as embracing either bars of relatively limited length as well as bars of many hundreds of feet in length, depending upon the use to which the product is to be put or further processing to which it is to be subjected. Also, while the illustrations and descriptions herein have pertained mainly to composite rod products which are substantially circular in cross-section, it is to be understood that the invention is equally applicable to forming composite rod products having other cross-sectional geometric shapes than circular.

While the invention has been described and illustrated in its several preferred embodiments, it should be understood that the invention is not to be limited to the precise details herein illustrated and described since the same may be carried out in other ways falling within the scope of the invention as claimed.

We claim:

1. A machine for casting continuous lengths of metallic composite rods and the like of uniform cross-section and comprising a core member completely encased in a sheath united integrally therewith, said machine comprising in combination, molding means comprising a plurality of

members movable at similar speeds and having mating surfaces movable into engagement with each other to define a longitudinal cavity of uniform cross-section from the point of engagement of said members and of sufficient length to form and stabilize the exterior surface of said composite rods, shaping means having a passage therethrough of smaller cross-sectional area than said longitudinal cavity and terminating substantially adjacent the point of engagement of said mating surfaces of said molding members and substantially coaxial with said cavity of uniform cross-section formed thereby, means to deliver molten metal of one composition to said shaping means for passage therethrough to form a core member of continuous length and uniform cross-sectional shape, and additional means to deliver molten cladding metal of a different composition continuously into said mold cavity of uniform cross-section to completely encase said core and initially contacting said mold cavity surfaces adjacent the terminal end of said shaping means, whereby said cladding metal contacts said mold members to commence chilling the same to stabilize it and encase said metallic core member in a sheath thereof only after said composite sheath and core have been delivered to and are moving with the uniform cross-sectional part of said mold cavity.

2. The casting machine according to claim 1 in which said shaping means is tubular and the inner diameter thereof is less than the inner diameter of the sheath of metal formed on said core and spaced radially from said cladding metal delivery means, whereby said molten core metal flows and fills said sheath radially upon discharge from said shaping means and air in said space oxidizes the outer surface of said core a limited amount to provide a slight boundary between said core and sheath members but insufficient to prevent bonding by the latent heat of fusion in said members at the time of interengagement thereof.

3. A machine for casting continuous lengths of composite metallic rods and the like comprising a core member of predetermined cross-sectional shape to which a cladding sheath member complementary in shape to said core member and completely enrobing the same is united integrally therewith, said machine comprising in combination, molding means mounted for continuous movement and having longitudinally extending molding cavity means to form the exterior shape of said continuous lengths of composite rod product, tubular stationary shaping means mounted adjacent said molding means and having a substantially uniform cross-section longitudinally, means to deliver molten metal of one composition to said shaping means and flow the same longitudinally thereof to form a continuous length of core member provided with a desired cross-sectional shape and feed it substantially coaxially into said molding cavity means, and means sloping downwardly toward the path of said core member and operable to receive and deliver molten metal of another composition to the exterior of said shaping means and cause the same to flow downwardly along said shaping means and continuously flow entirely around said core member to form a sheath thereon immediately upon the formation of said core member and move longitudinally into said movable molding means to chill and form the exterior surface of a continuous length of composite metallic rod and unite said core and cladding sheath members integrally while maintaining a desired substantially constant interface shape at the union of said members and also provide a constant exterior shape by said molding means.

4. The machine according to claim 3 in which said shaping means comprises a member having a tubular opening through which said core material is delivered and by which a preliminary cross-sectional shape is imparted thereto, and a delivery channel means extending along the upper portion of said member to direct the flow of cladding material to the core member at a level above the same and thereby permit it to flow therearound.

5. The machine according to claim 4 in which the cavity in said movable molding means is tubular and complementary in shape to said tubular opening of said shaping means but of larger cross-sectional dimensions and arranged to cooperate co-axially with said stationary shaping means to form the exterior surface of the composite rod product and stabilize the same.

6. The machine according to claim 5 in which said molding means comprises a pair of grooved means mounted for movement into cooperation with each other to form a longitudinally extending molding cavity of substantially uniform cross-section within which said composite clad core rod product is carried for a predetermined distance and then discharged.

7. The machine according to claim 6 in which said pair of grooved means respectively comprise a circular member having an annular groove in the perimiter thereof and mounted for rotation about its axis, and a series of members arranged to cooperate in end-to-end relationship with each other and each having grooves therein substantially complementary to the groove in said circular member and arranged to be positioned sequentially against the perimeter of said circular member for a substantial portion of the circumference thereof with the grooves thereof directly opposite the groove in said circular member, thereby to form an elongated molding cavity with similar opposed surfaces.

8. The machine according to claim 5 in which the delivery end of said stationary shaping means extends into the entrance end of said cavity in said movable molding means.

9. The machine according to claim 8 in which said tubular opening in said shaping means has a discharge member comprising a tube, the outer end of which extends into the entrance of said cavity in said molding means a greater distance than said delivery channel means, thereby facilitating the shaping of the cladding sheath on said product.

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