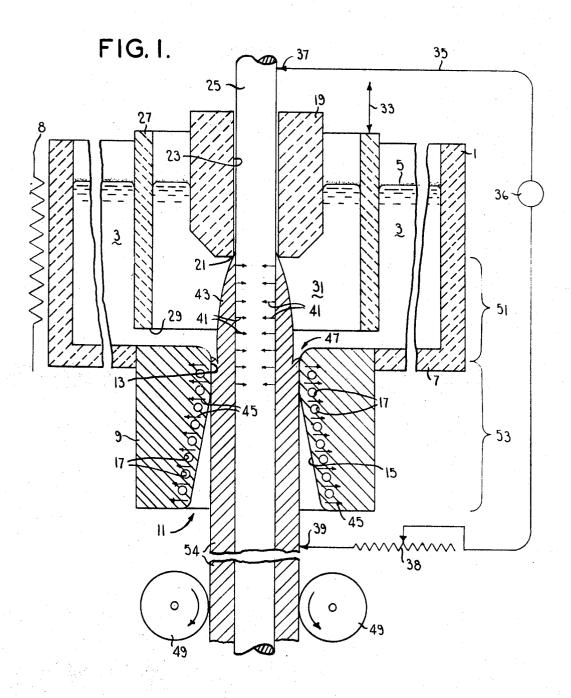
CONTINUOUS CHILL CASTING OF CLADDING ON A CONTINUOUS SUPPORT

Filed Nov. 8, 1965

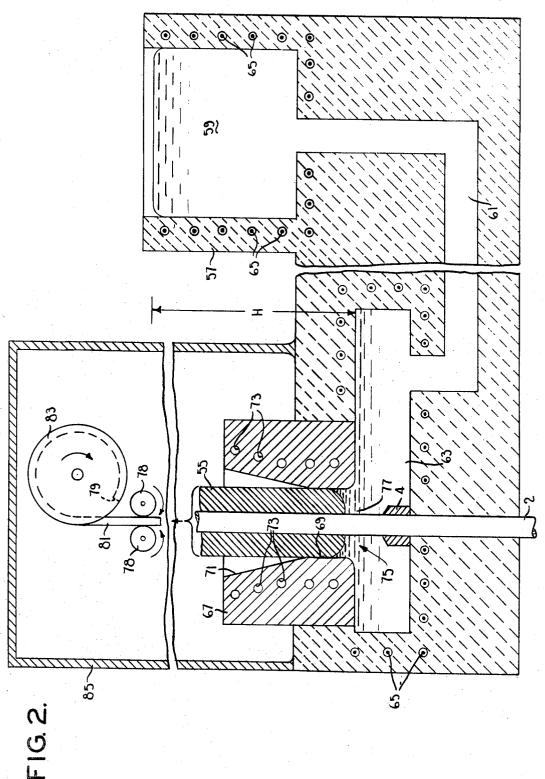
3 Sheets-Sheet 1



Brian C. Coad, Inventor. Joenig, Senniger, Powers and Leavite, attorneys. CONTINUOUS CHILL CASTING OF CLADDING ON A CONTINUOUS SUPPORT

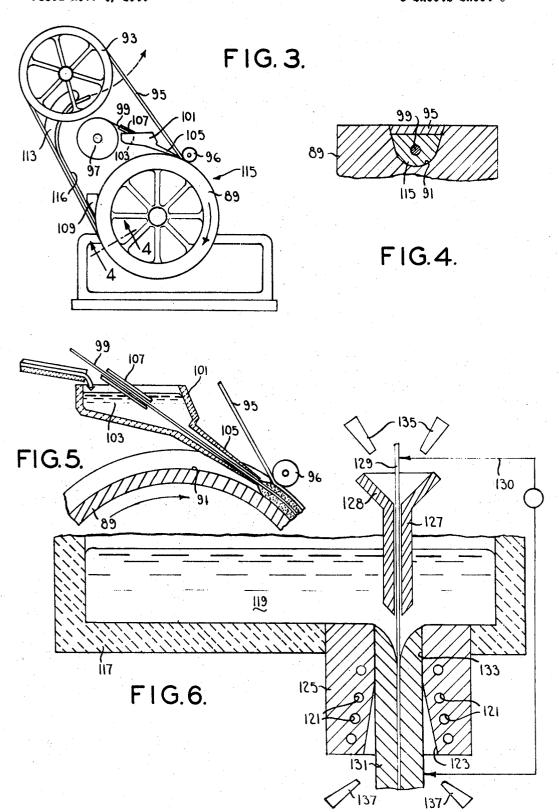
Filed Nov. 8, 1965

3 Sheets-Sheet 2



CONTINUOUS CHILL CASTING OF CLADDING ON A CONTINUOUS SUPPORT
Filed Nov. 8, 1965

3 Sheets-Sheet 3



## United States Patent Office

1

3,470,939 CONTINUOUS CHILL CASTING OF CLADDING ON A CONTINUOUS SUPPORT

Brian C. Coad, Oakland, Calif., assignor to Texas Instruments Incorporated, Dallas, Tex., a corporation of Delaware

Filed Nov. 8, 1965, Ser. No. 506,743 Int. Cl. B22d 11/06, 11/12; B05c 3/12 U.S. Cl. 164—275 6 Claims

## ABSTRACT OF THE DISCLOSURE

In one arrangement a hot melt of metallic cladding material is contained in a crucible to the bottom of which is connected a cooling die which has a short inlet throat 15 having parallel sides, a lower outlet flare and cooling passages around the throat and the flare. An electrical resistance heated metal core is drawn through the melt and spacedly through the die throat. Gate means in the melt controls its flow to the die. Initially some of the hot melt 20partially freezes on the cooler substrate before it moves into the die and additional melt partially freezes thereon which results in a very smooth finish on the cladding without sticking in the die. Completion of freezing occurs in the flare of the die. In another form a length of the 25 substrate is drawn up through a lower heated dish of the melt, the latter being under pressure head from an elevated melt supply. In this case the die is inverted and located at the top above the melt for the upward passage of the core therethrough. In another form the core is guided along with some of the melt under a band and into the groove of a casting wheel wherein it freezes around the substrate and is then drawn from the groove and the band stripped therefrom. In all forms a protective atmosphere may be maintained around the core and 35 the freezing cladding material, if required.

This invention relates to casting, and with regard to 40 certain more specific features, to continuous chill casting, that is, continuous casting of liquid metal or nonmetal around a core of solid metal or nonmetal which acts as a heat-sink, abstracting heat from the liquid metal, causing it to freeze; and which is fed continuously to the 45 melt, to make continuous lengths of wire, rod, strip, tubing and the like, and reinforced or cored articles of that nature.

Among the several objects of the invention may be noted the provision of rapid processes and means for obtaining more accurately dimensioned continuously cast products at higher rates of casting and smaller finished size, such as wires, rods, strips and the like; the provision of means for more reliably making such products; and the provision of means for producing thicker cladding in cases in which inner cores or reinforcements are employed. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the apparatus, products and methods hereinafter described, the scope of 60 the invention being indicated in the following claims.

In the accompanying drawings, in which several of various possible embodiments of the invention are illustrated

2

FIG. 1 is a diagrammatic section illustrating one form of the invention;

FIG. 2 is a diagrammatic section showing a second form of the invention;

FIG. 3 is a side view illustrating a continuous casting machine for carrying out another form of the invention.

FIG. 4 is an enlarged cross section taken on line 4—4 of FIG. 3:

FIG. 5 is a diagrammatic section illustrating a part 10 a part of the machine shown in FIG. 3; and

FIG. 6 is a diagrammatic cross-sectional view showing another form of the invention.

Corersponding reference characters indicate corresponding parts throughout the several views of the drawings. The drawings are not to scale, being diagrammatic.

Problems have been encountered in continuous casting in the undesirable sticking of cast material to the chilling dies employed. Another problem was concerned with continuous casting of small cross sections. Such cross sections when on the order of 1.0 square inch or less were subject to easy breakage. The present invention overcomes these various difficulties.

Referring now more particularly to FIG. 1, there is shown at numeral 1 a part of a suitably heated container or refractory crucible for a melt 3. Heating means is diagrammatically indicated at 8. The melt may be of a metal or nonmetal which will solidify upon cooling. Such a melt, if metallic, may carry oxidation products such as slag or the like on the hot liquid surface. Such oxidation products are illustrated at 5.

Connected to the bottom 7 of the chamber 1 is an open cooling die 9. The throat 11 of this die includes a comparatively short upper inlet or forming portion 13 which has substantially parallel sides, thus producing a cylindrical form of the correct cross section for the shape of the product desired. Its lower or outlet portion 15 flares out as shown. Contained in the die around its cylindrical and flared portions 13 and 15 are passages 17 for the circulation of a suitable coolant such as water. Thus the die 9 is cooled throughout its length.

Projecting downwardly into the melt 5 is a guide nozzle 19 composed of a suitable heat-resistant or refractory material. Its outlet 21 is positioned below the upper surface of the melt 3, which is to say, below the layer of oxidation products 5. The passage 23 through the nozzle 19 is of a proper cross section to admit and freely guide core material 25 for downward movement through the melt 3. Thus if the core material is round, as shown, the passage 23 in the nozzle 19 may be circular in cross section. For core materials of other cross sections, the passage may have other suitable cross sections for proper guiding action. The cross section of the inlet portion 13 of the die 9 is larger and of a shape to provide for passage of the core material after application to it of an amount of whatever cladding material is desired. In the drawings the section is circular for example, but other appropriate sections may be employed.

At numeral 27 is shown a stopper in the form of gate means, also made of heat-resistant or refractory material. The stopper 27 surrounds and extends below the lower end of the nozzle 19. Its lower margin 29 is near but spaced from the container bottom 7. Thus what may be referred to as a coating chamber 31 is provided around

3

the core 25 in its downward movement from the nozzle 19 to the die 9. The stopper 27 is vertically adjustable. Any suitable means known in the art may be employed for adjustment, this being illustrated by the double dart 33. Thus the rate of flow of the melt 3 and of heat into the coating chamber 31 may be controlled. The liquid level carried in this coating chamber 31 may be at (as shown) or below that in the remainder of container 1.

Suitable means for heating the core material 25 as it passes through the apparatus is provided, although not always necessary. Such means in the drawing is illustrated as an electrical circuit 35 having slide contacts 37 and 39, the former engaging the surface of the core 25 before it enters the nozzle 19 and the latter engaging the surface of the finished cladding to be described. A voltage supply is shown at 36 and a current control at 38. As an alternative, the contact 39 may be made with the die 9, in which case it need not be in brush form.

Operation of the form as shown in FIG. 1 is as follows, assuming for example (but without limitation) that the 20 core 25 is a continuous steel wire or rod and that the melt 3 is of copper:

The core is moved downward through the nozzle 19, coating chamber 31 and the die 9, being at a comparatively cool temperature in its solid state relative to the temperature of the hot melt 3. Thus the core will absorb heat from the melt as the core leaves the nozzle 19 and passes through the coating chamber 31. This heat flow is illustrated by the horizontal darts 41. It has a partial freezing effect upon the melt around the core in the coating chamber 31. As a result, there will occur a more or less solidified coating or collar of the melt 3 within the coating chamber 31 continuously forming as an attachment to the moving core 25 as illustrated at 43.

If the core 25 is small in section, the amount of heat  $^{35}$ that it can absorb in passing is limited, so that the collar 43 in the coating chamber 31 remains comparatively small in section. This is desirable for reasons to appear. In order to place a limitation upon the diameter of the collar 43 in cases in which the core is capable of absorbing large amounts of heat (a large-section core, for example) or in which the specific heat of the melt 3 is comparatively small, it may be desirable to heat the core by exciting the circuit 35, so that the amount of heat that the core will absorb will be controllably limited. Thus the 45 size of the collar 43 in the coating chamber 31 may be limited. Control of the elevation of the stopper 27 also has an effect in this regard, because it forms a resistance to heat and metal flow from the mass of liquid outside of stopper 27 to the liquid in the coating chamber 31. 50 The hotter the core and the higher the stopper 27, the smaller will be the formation of the collar 43 and vice versa.

As the core 25 moves down, the clinging collar 43 continuously forms and moves down with it into the com- 55 paratively large cylindrical annular space within inlet portion or section 13 of the die 9. This space receives a peripheral inflow of hot liquid at 47 to add to the collar 43. Since the die abstracts heat as shown by the darts 45, this tends to more or less freeze the peripheral inflow 60 to form additional material on the collar 43. The exterior shape of this additional material is determined by the shape of the comparatively short parallel sides of the inlet section 13 of the die 9. The axial extent of the cylindrical inlet 13 of the die is short, so that in the com- 65 paratively short time of passage there will not occur a hard freeze in the die which might cause sticking. In other words, the section 13 of the die forms the outside of the product by a smooth wiping or smearing action on a partially solid consistency of the passing material, 70 which may be called putty-like. Consequently, there is obtained a smooth accurate form without blemishes which passes down through the cooled flaring portion 15 of the die, where it is further cooled and solidification is

4

cladding or matrix 54 is capable of contact with the brush such as 39 for delivering heating current (if needed) to the core 25. In its completely solidified state the product is capable of being drawn down by draw rolls such as shown at 49.

On the right-hand side of FIG. 1, the line bracket 51 indicates the chill-cladding zone in which the collar 43 is formed. The line bracket 53 indicates what may be referred to as a continuous casting zone in the upper end of which accurate shaping is accomplished and in the lower end of which completion of solidification to the solid state is accomplished.

It will be understood that although in FIG. 1 a plain cylindrical core is illustrated, this may be of other forms such as woven or twisted cable, a solid strip, woven strip, multiple wires, rods or the like of any desired cross sections. As to materials that may be used, the range is wide, such as, for example, steel tungsten, aluminum, molybdenum or the like for the core material, and any appropriate metal such as copper, zinc, lead, et cetera for the cladding material. Moreover, the invention is applicable to the use of nonmetals. For example, the core may be composed of carbon, being covered with materials such as aluminum, copper, the carbon to be burned out later to form a tubular product. Also, the core may be of metal and the cladding or matrix 54 composed of one of the thermoplastic materials such as polystyrene, polyethylene, acrylics, fluorocarbons and the like.

The use of the straight and flared completely cooled form of the die 9 shown in FIG. 1 is not limited to its location at the bottom of the melt. This is illustrated in FIG. 2, in which a clad wire 81 is shown as being made. In this case, numeral 57 indicates the heating chamber or pot for the liquid melt 59. This has a connection 61 to a dish or cavity 63, the latter being at a lower elevation than the pot 57, so that a head of liquid will maintain some pressure on the liquid in the dish 63. Heating coils 65 keep the melt in a liquid state in 57 and 63.

Attached to the upper side of the dish 63 is an open cooling die 67 which is shown to an enlarged scale relative to other parts in FIG. 2. It is built like the die 9 in FIG. 1. However, it is inverted in position. The die 67 again has a comparatively short straight-sided throat 69 and a flaring portion 71 extending therefrom. It is cooled throughout its length by passages 73 which carry coolant. The die 67 surrounds an opening 75 in the top of the cavity 63. There is a tendency under the pressure established by the liquid head H to push molten material through the opening 75 and through the die 67, as illustrated at 55. As shown on a reduced scale at 81, the wire or shape as it is finished may be drawn up by draw rolls 78 and placed on a reel 83. In this case the core material 2 is fed up through a sealing die 4 and then up through die 67 where the cladding material 55 freezes to it.

Sometimes it is desired to make a continuous cored product in which the surrounding matrix material is comparatively thick or bulky. In such cases the rate of freezing of such matrix material must be made sufficiently fast so that virtually no reaction occurs between it and the core material. In order to introduce the reinforcing material into such thick matrix material, a conventional continuous casting method is used, as, for example, that shown in FIGS. 3 and 4.

In FIGS. 3–5 is shown another form of the invention hard freeze in the die which might cause sticking. In other words, the section 13 of the die forms the outside of the product by a smooth wiping or smearing action on a partially solid consistency of the passing material, which may be called putty-like. Consequently, there is obtained a smooth accurate form without blemishes which passes down through the cooled flaring portion 15 of the die, where it is further cooled and solidification is completed. In its completely solidified state the resulting 75

is numbered 103. Extending from the bottom of the container 101 is a spout 105 which reaches into the groove 91 under the steel band 95.

I provide at numeral 97 a drum for a coil of reinforcing wire 99 to be fed beneath the band 95 and ultimately into the groove 91. At numeral 107 is a hollow refractory core guide for guiding core wire 99 through the melt 103 and into the spout 105. The lower end of the guide 107 is located beneath the surface of the melt 103 in the container 101, as shown in FIG. 5.

Referring to FIGS. 3-5, operation is as follows:

The casting wheel 89 is driven to rotate by appropriate means (not shown). The melt flows out of the container 101 through the spout 105 into the cool groove 91 under The core wire 99 is fed down through the guide 107 and the spout 105 and into position surrounded by freezing material in the groove. Thus the wire 99 is drawn into the freezing matrix at the rate of matrix movement as the latter is carried around the wheel 89 and becomes 20 tageous results attained. solid around the wire. The reinforced composite 116 thus obtained passes some distance around wheel 89 and then is stripped therefrom by a stripper 109, being drawn off from belt 95 by a takeoff guide 113. The groove 91 cools as the composite 116 leaves it. This form of the invention 25 provides a high-speed means for rapidly freezing comparatively large amounts of matrix-forming metal, whereby virtually no reaction occurs between the reinforcing material 99 and the matrix material surrounding it.

It is to be understood that the groove 91 may be of 30 any form to give any appropriate shape (without reentrant angles) desired for the matrix material, and that several core wires 99 may be fed by obvious modifications, or the core may be in the form of a solid ribbon, or woven mesh or network of strip form. Various other shapes will suggest themselves, both for the matrix material 115 and the contained reinforcement.

In FIG. 6 is shown a form of the invention wherein the collar-forming means of FIG. 1 is omitted. At 117 is shown a basin for a melt 119. Attached to the bottom 40of the basin 117 is a cooling die 125, having cooling passages 121. At numeral 127 is shown a guide nozzle, the outlet of which is below the surface of the melt 103. This is for guiding reinforcing material 129 through the opening 33 and die 125. This core material 129 may con- 45 sist of wire, rod, strip, mesh or the like, as will be clear from what has been stated above, the guide 127 being appropriately shaped in cross section for the purpose. The core 129 is fed down as the melt runs through and freezes in passage through the die 125 to form a solid 50 matrix 131 around the core 129.

It is contemplated that in some cases the core material which is fed through the guide 127 shall be of the same composition as the melt 119 and resulting matrix material 131. In such case the core material may be preheated. It will form a support for the weight of the product as it lengthens and hangs from the die, thus avoiding tearing of any semifrozen material in the forming throat 133 of the die 125 and permitting higher casting speeds than possible without reinforcement or support. A heating circuit is illustrated at 130.

Another example of a strip such as 129 that may be used as core material is one composed of surface-anodized aluminum. Surface anodization of aluminum consists of an oxide skin and acts as a barrier between the aluminum strip and the matrix-forming melt 119, such as, for example, copper. Thus even though the anodized aluminum may be melted as it enters throat 133, there will be no alloying with the copper melt before both of them solidify. 70 It will be understood that this principle may also be applied to the FIG. 1 form of the invention in which the core 25 may be made of anodized aluminum and the melt 3 composed of copper.

It will be understood that in all forms of the invention, 75

if a protective inert or other atmosphere or vacuum is required for working any particular materials or metals, such can be obtained in known manner by placing the apparatus or appropriate parts thereof in a chamber, containing such an atmosphere or in which a vacuum is formed. Or in the case of a gaseous atmosphere appropriate jets of the same may be employed, as illustrated for example at numerals 135 and 137 in FIG. 6.

It will be understood from the above that the invention 10 contemplates that the matrix-forming melt and the core or reinforcing material when used may be selected from a wide category of both metals and nonmetals. Both may be the same material. Or either may be metal and the other a nonmetal. For example, in the form of the inventhe belt 95. As it enters the groove it freezes as at 115. 15 tion shown in FIG. 1, the core 25 may be a good electrical conductor, while the matrix-forming material may be a poor conductor or an insulator.

> In view of the above, it will be seen that the several objects of the invention are achieved and other advan-

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

What is claimed is:

1. Continuous chill-casting apparatus comprising a vessel having an outlet and containing a heated melt of cladding material under pressure at said outlet, a fixed die connected at said outlet shaped for spacedly receiving therethrough a continuous solid substrate material, said die having substantially parallel axially disposed sides in a comparatively short inlet throat portion and having a comparatively longer flaring outlet portion extending from the throat portion, said throat portion receiving cladding material from the vessel and around the substrate material, said die having heat-exchange coolant circulating passages disposed both around said short inlet throat and the flaring oultet, means for continuously moving the substrate through the melt and the die in that order, said substrate being in a comparatively cool condition with respace to that of the melt of cladding material as it approaches the die thereby to abstract heat from the melt and tending to freeze it as it approaches said inlet throat, said cooled throat of the die semifreezing the melt to form a putty-like collar in moving the contact with the throat wall thereby to shape the putty-like collar by exteriorly smearing it in its putty-like condition as it moves through and emerges from the throat into said flaring outlet portion of the die, the cooled flaring portion freezing to a solid condition the smear-finished cladding material emerging from the throat and without contact therewith, thereby to preserve intact its solid finish.

2. Apparatus according to claim 1 wherein the die is located below the melt for receiving material therefrom, said pressure being established by the hydrostatic pressure of the melt.

- 3. Apparatus according to claim 1 wherein the die 60 is located above a portion of the melt, and means for generating said pressure to force the molten material up through the die throat.
- 4. Apparatus according to claim 1 including a verticaly adjustable gate means in the pool for controlling 65 flow of the melt therefrom into the die.
  - 5. Apparatus according to claim 1 including electrical resistance heating means for the core as it passes through the melt and the die for controlling the thickness of said initially paratially frozen material.
  - 6. Apparatus according to claim 3 wherein said lastnamed means comprises a volume of the molten material connected with said portion of the melt to provide hydrostatic pressure therein to force the melt up through the die.

		7		,= 00		8	
	Re	ferences Cited		457,482	8/1891	_	
	UNITED	STATES PATENTS		1,862,947	6/1932		
443,536	12/1890	Norman 164—275 XR		3,382,535	5/1968		
2,072,060	2/1937	Schultz 164—64 XR		2,181,987	12/1939	Beaver et al	_ 164—275 X
2,123,660	7/1938	Pike 164—275 XR	5		FOR	EIGN PATENTS	
2,128,942	9/1938	Hudson 164—275		22 600			
2,231,142	2/1941	Schultz 164—275		22,600	3/1948	Suomi.	
2,543,936	3/1951	Reynolds 164—275 XR		I SPENCE	S OVER	HOLSER, Primary Ex	zaminor
3,134,149	5/1964	Priaroggia et al 164—86 X				•	vanninei
910,674	1/1909	Hancock 164—86	10	V. RISING,	Assistant	Examiner	
944,370	12/1909	Monnot 164—282 X					
3,099,053	7/1963	Eliot.				U.S. Cl. X.R.	
2,692,410	10/1954	Chadwick et al 164-283 X		18-12; 117	<b>—114</b> ; 11	8-101, 59, 68, 69,	125: 164—86.
2,702,408	2/1955	Hartland.	1 =	278. 283		, , , , , , , , , , , , , , , , , , , ,	,

P0-1050 (5/69)

## UNITED STATES PATENT OFFICE CERTIFICATE OF CORRECTION

Patent No. 3,470,939	Dated October 7, 1969
Inventor(s) Brian C. Coad	
It is certified that error appears and that said Letters Patent are hereby	in the above-identified patent corrected as shown below:

Column 6, line 40, for "oultet" read "outlet"; lines 42-43, for "respace" read "respect"; line 47, for "moving the contact" read "moving contact"; lines 63-64, for "verticaly" read "vertically"; line 69, for "paratially" read "partially".

SEALED FEB 1 7 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr. Attesting Officer

WILLIAM E. SCHUYLER, JR. Commissioner of Patents