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[54] **METHOD OF CONTINUOUS CASTING MOLTEN COPPER IN A SEAMLESS-PIPE-SHAPED MOULD**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **164/69,** 29/527.5, 164/86

[51] **Int. Cl.** **B22d 11/00**

[58] **Field of Search** 164/86, 263, 69, 70; 29/527.5, 527.6

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[57] **ABSTRACT**

A casting method for the continuous production of elongated ingots of metal, whereby the metal to be cast is passed in a fluid state into the interior of a generally pipe-shaped mould of metal or other heat resistant, easily extruded material, which is continuously manufactured by extrusion at the same rate as the casting and thoroughly cooled on its outside. Subsequent to the cooling the mould may be removed from the ingot.

4 Claims, 2 Drawing Figures

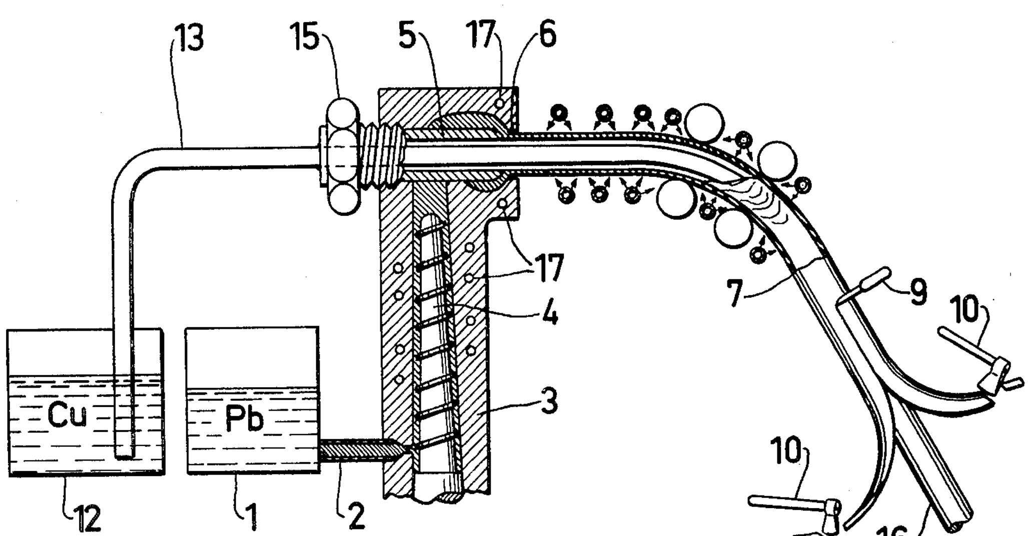


FIG. 1

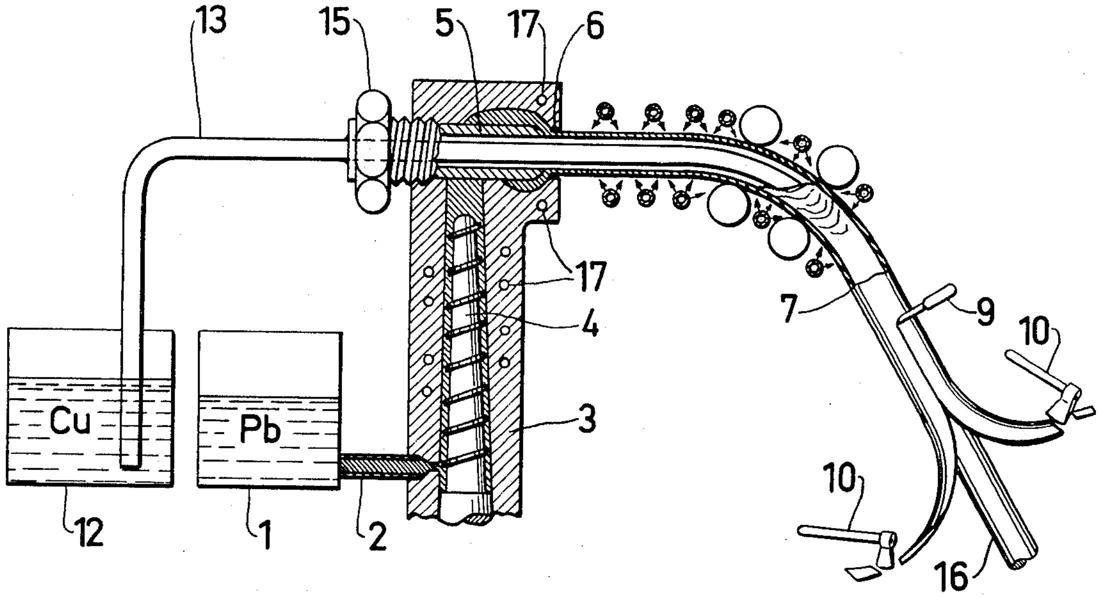
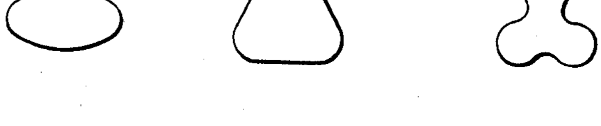


FIG. 2



METHOD OF CONTINUOUS CASTING MOLTEN COPPER IN A SEAMLESS-PIPE-SHAPED MOULD

BACKGROUND

Like other continuous manufacturing methods the continuous casting of long ingots gives high and uniform quality as well as permitting low manufacturing cost. However, the continuous casting methods now used have some limitations, especially for the casting of small cross sections. If for small cross sections one strives for high axial speeds difficulties are encountered in cooling the metal down to solidification and to a temperature suitable for handling the ingot. In order to overcome such difficulties it is necessary to use auxiliary means, which however, have a limited life. For example, in the Hazlett and Properzi methods the casing wheel is an auxiliary means with a short life.

THE PRESENT INVENTION

According to the casting method of the present invention an auxiliary means is used as a casting mould, but this mould is inexpensive to manufacture and moreover gives so many advantages that it may be used just once. It is produced just before or simultaneously with the casting and is stripped off after the casting. This mould preferably consists of a continuous thin walled pipe of a metal such as lead or a lead alloy. While this mould is manufactured e.g., by extrusion it is thoroughly cooled down and continuously filled with the molten casting metal and from the outside of the mould further cooled during and after the casting. This extrusion, casting and cooling may be followed by stripping off the metal mould from the ingot and the removed metal mould material is then returned to the melting kettle of the extrusion machine and remelted for reuse.

As is further explained below, the mould should have good heat conductivity and thin walls, have close tolerances and, while it is extruded, have enough strength that a vacuum or a small overpressure may be maintained inside the mould. It is also important that the mould may be manufactured with high axial speed - and with constant speed. Continuous extrusion is a manufacturing process which meets all those demands.

The invention will be further described below with reference to the accompanying drawing, in which:

FIG. 1 shows one embodiment of the present invention, partly in cross section; and

FIG. 2 shows examples of some contours that can be produced with the arrangement of FIG. 1.

In the following description reference is mainly made to a wholly continuous lead extrusion machine, which hour after hour, day after day and without stoppage can extrude a perfect lead pipe at constant speed. However, it is also possible to use a hydraulic extrusion machine which is repeatedly charged with large billets and thus may repeatedly extrude relatively long moulds in a continuous way. Both the continuous screw machine shown on FIG. 1 and the semicontinuous hydraulic machines are so arranged that the metal mould which is to be extruded, is solidified and relatively cold and thus has good mechanical strength both inside the machine and outside the shaping dies.

FIG. 1 shows how a continuous ingot (e.g., of copper) is cast inside a continuously extruded lead pipe. The lead is melted in a melting kettle **1** and from the kettle it flows through the feeding pipe **2** to a continuous screw extruder. In the screw chamber **3** of this extruder the molten lead is cooled down to solidification by means of the (water-)cooling channels **17** so that a "nut" is formed around the screw **4.** This nut of lead is forced upwards by the threads of the rotating screw, and dies **5, 6** shape the inner and outer surfaces of the extruded mould or pipe **7.** It is important to note that the lead on its way to the dies **5, 6** has a rather long way to travel and thus may be conveniently cooled down so that, first of all the solidification heat is dissipated away from the metal.

When the outer end of the extruded pipe is tightened the pipe may be evacuated by means of e.g., a vacuum pump (not shown) which is connected to a channel in an outer part **15** of the die **5.** This vacuum, maintained in the lead pipe, will then suck molten lead (e.g., copper) from the kettle **12** to and into the mould or pipe **7,** where this molten copper is cooled down to solidification e.g., by means of water cooling on the outside of the pipe **7.** Here much cooling is needed, which e.g., may be achieved by means of evaporation of the water which dissipates 539 kilocalories per kg of water evaporated. Alternatively, it is possible to supply cool water flowing around the mould in such quantities that all the water remains in a fluid state at such temperature that there is no risk of overheating. After cooling the lead mould (pipe) with its ingot moves further forwards (while being further cooled) until its temperature permits handling and the mould (pipe) is then cut open, stripped off, cut into pieces and returned to the melting kettle **1** for re-use. In FIG. **1,** this stripping and cutting is schematically illustrated by a knife and two axes. Industrially such stripping can be done by machines which for many years have been used by the cable industry for stripping and cutting.

The filling of the mould with molten metal may be carried out in various ways depending on the dimensions of the ingot. For instance, a few examples might be as follows:

a. When manufacturing ingots with comparatively large cross sections the filling of the mould with molten metal may be monitored visually by looking into the mould pipe from the back side of the extruder. Usually, auxiliary illumination means are required.

b. By maintaining a suitable difference between the atmospheric pressure within the pipe shaped mould and the pressure above the free surface of the molten metal in the kettle **12** the filling of the mould may be controlled.

c. The filling may be monitored by measuring the electrical resistance between two points on the outer surface of the pipe-shaped mould, whereby the distance between these two points is predetermined.

d. Supersonic waves may be used for the monitoring of the filling.

e. A sensor such as a cog wheel pressed against the outside of the mould and thus rotating with its progress, will by indentations on the mould detect irregularities on the ingot.

Re-use of the lead may also be arranged as follows:

The lead pipe with its ingot is at first cooled until a tight shell of solidified copper is formed at the outer surface of the ingot. If the interior of the ingot still holds sufficient heat, this heat will creep out to the outside surface and there melt off the lead mould and this molten lead may then be directly returned to the lead melting kettle, whereafter the ingot is further cooled down to suitable handling temperature (e.g., by a water spray).

If, as in this example, copper is cast in a lead pipe the wall of the lead pipe must be thin. Otherwise the outer cooling will not reach the inside of the lead pipe quickly enough and the lead pipe may melt prematurely. If on the other hand one wishes to cast a lead ingot in a pipe-shaped lead mould it is possible to use as a mould a thicker lead pipe and intentionally arrange the cooling so that the mould and the ingot form a common cast.

In this way it is possible to make lead ingots of high purity inexpensively and conveniently. The melting, the extrusion and the casting may be arranged in vacuum or under a protective atmosphere, and the outside surface of the extruded lead mould may be held at the temperature of the cooling water.

It presently seems that lead is the best metal for the mould but continuous moulds of other metals (e.g., aluminum) may also be used. Lead extrusion machines are, however, considerably less expensive and easier to handle. Also inexpensive and maintenance-free stripping machines for lead are available.

According to FIG. 1 the lead is fed to the extrusion machine by gravity forces from a melting kettle at atmospheric pressure, and the copper is sucked into the mould by a syphon. If an ingot of high purity is desired, both kettles may have a vacuum or a protective atmosphere over the free metal surfaces.

The casting method may be varied depending on what metal is used in the mould or in the ingot. As an indication of the material constants of some metals which have been considered for mould and ingot, reference is made to the following table:

Metal	Density	Specific heat	Melting point	Latent heats of fusion	Heat conductivity	Temp. conductivity
Pb	11.34	0.031	327°C	5.9	0.083	0.23
Al	2.69	0.214	858°C	77	0.50	0.87
Cu	8.93	0.092	1083°C	42	0.91	1.09
Fe	7.86	0.107	1538°C	66	0.17	
H_2O	1.0	1.0		80	13.4	

This table shows that it is obviously more difficult using lead moulds to cast copper than to cast aluminum. The melting temperature of Cu is higher, the heat conductivity is 80 percent higher, the per unit of volume of the specific heat is 40 percent and the fusion heat 80 percent higher than for aluminum. However, by means of our casting method those difficulties may be overcome if, above all, the wall of the mould is thin and the cross sectional area of the ingot is not too large. With a modern extrusion machine (e.g., the Hansson-Robertsson lead extruder No. 5), small diameter pipes are extruded with about the same metal volume per hour as large diameter pipes. That machine extrudes about 50 kg/min = ca.4.4 dm³/min. for various diameters and with wall thicknesses which, as to mechanical strength, correspond to the diameter.

Lead pipe Diam. mm	Wall thickness. mm	Extrusion speed dm/min	Volume of the ingot dm³/min	Cooling surface of the ingot dm²/min.
30	2	230	162	217
15	1	920	162	434

In the 15 mm mould there is thus cast the same quantity of metal as in the 30 mm mould but the cooling surface is double. Also the wall thickness through which the heat must travel to the surface is halved both in the lead mould and in the ingot itself when a 15 mm mould is used.

Further improvement of the cooling of mould and ingot is rendered possible by the versatility of a continuous lead extruder. By simple die changing in the extruder the mould may e.g., be equipped with cooling fins or the mould may be given a shape which is more adapted for rapid conduction of heat from the interior of the ingot to the outside of the mould than the mould with a circular cross section. Such shapes are shown in FIG. 2. They will for a short time withstand sufficient vacuum or pressure inside the mould.

It will be seen that the use of a continuous lead extruder allows adjustment of the inclination of the casting mould from horizontal to vertical and angles therebetween simply by bending the pipe (mould) or by changing the inclination of the extruder.

What we claim is:

1. A casting method for the continuous production of elongated copper ingots which comprises

a. continuously extruding lead so as to form a solid thin-walled mould having the general shape of a seamless pipe,

b. continuously injecting into the interior of said solid pipe-shaped lead mould a molten mass of copper,

c. regulating the rate of extrusion of the lead and the rate of injection of copper so that the linear speed of said solid pipe-shaped lead mould and linear speed of the molten mass of copper contained therein are substantially the same,

d. continuously regulating both the thickness of the pipe-shaped lead mould and the amount of cooling applied to its outside surface so that:

1. the inner surface of the solid pipe-lead mould will not melt from the heat contained in the mass of copper that has been injected therein, and
2. the inner surface of the lead pipe-mould will not clad to the mass of copper that has been injected therein,

e. said lead having a lower melting point than said copper, and

f. removing the pipe-shaped lead mould from around said injected copper after said copper has solidified.

2. A casting method according to claim **1** wherein vacuum is maintained within the lead mould during filling with copper.

3. A casting method according to claim **1** wherein an inert or reducing atmosphere is maintained in the lead mould during filling.

4. A casting method for the continuous production of elongated metal ingots which comprises

a. continuously extruding a first metal so as to form a solid thin-walled mould having the general shape of a seamless pipe,

b. continuously injecting into the interior of said solid pipe-shaped mould a molten mass of a second metal,

c. regulating the rate of extrusion of said first metal and the rate of injection of said second metal so that the linear speed of said solid pipe-shaped mould and linear speed of the molten mass of second metal contained therein are substantially the same,

d. continuously regulating both the thickness of the pipe-shaped mould and the amount of cooling applied to its outside surface so that:

1. the inner surface of the solid pipe-mould will not melt from the heat contained in the mass of second metal that has been injected therein, and

2. the inner surface of the pipe-mould will not clad to the mass of second-metal that has been injected therein,

e. said first metal having a lower melting point than said second metal, and

f. removing the pipe-shaped mould from around said injected second metal after said second metal has solidified.

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