

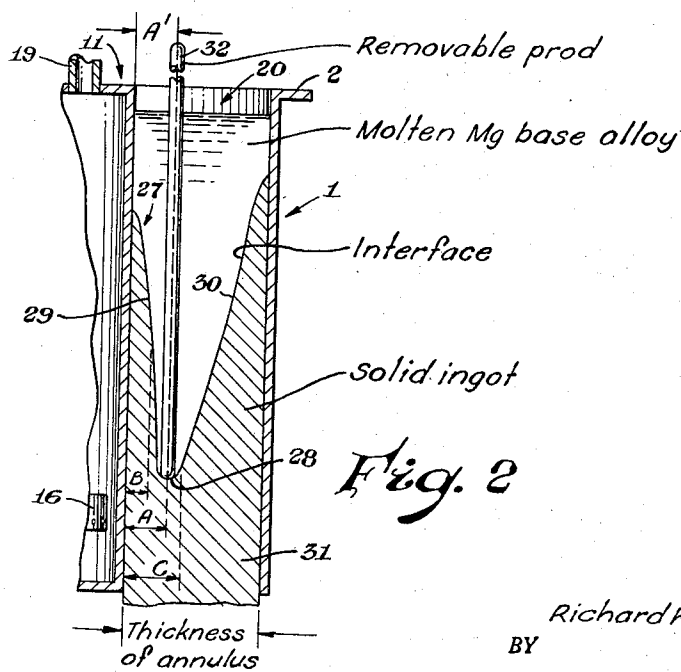
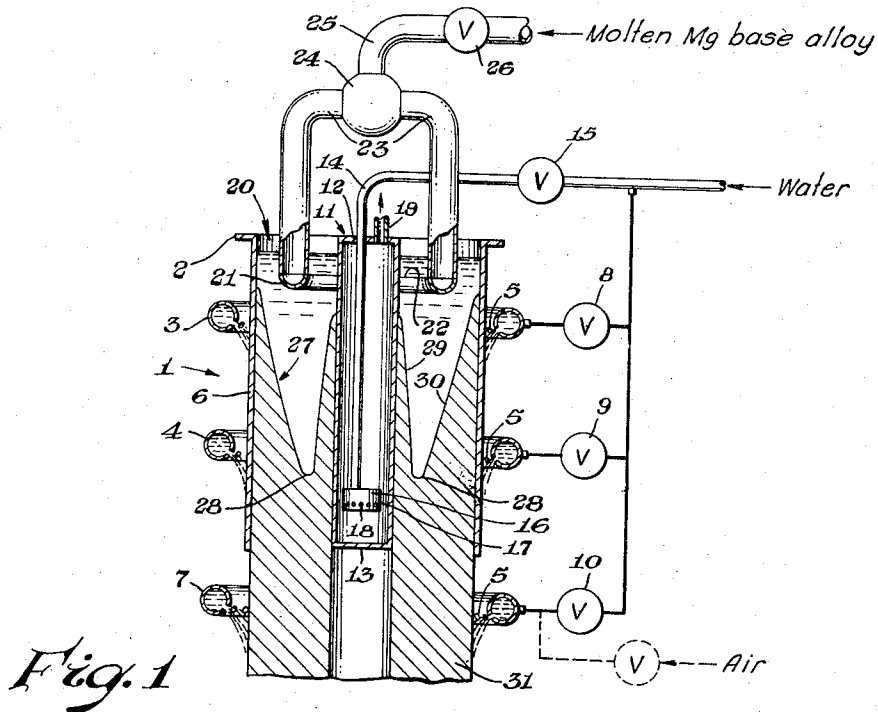
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CONTINUOUS HOLLOW CASTING

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CONTINUOUS HOLLOW CASTING

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The invention relates to casting hollow ingot continuously of a magnesium-base alloy and is particularly concerned with ingot of cylindrical form with a longitudinal central cylindrical passageway from end to end as in a thick walled tubular ingot.

Magnesium-base alloys, generally containing over 85 percent of magnesium, particularly those containing one or more alloying metals, e. g. aluminum, manganese, zinc, and zirconium, as in alloys having the ASTM Designations AZ31, AZ61, ZK60, and the like, have been cast successfully continuously in open ended chill molds into ingot when of solid form. On the other hand difficulties arise when an attempt is made to apply known methods of continuous casting of hollow or tubular ingot of these alloys in similar molds. Among the difficulties observed are that the surface of the ingot is rough and uneven, the inside wall is oftentimes cracked, crystal structure is not uniform, and the metal is excessively porous. Cylindrical ingot having a longitudinal cylindrical passageway from end to end, that is tubular ingot, of magnesium-base alloy is used in the manufacture of tubular goods by die expressing the ingot using a central mandrel located in the passageway to form the bore of the tube as it extrudes.

Because sound hollow or tubular ingot suitable for this use of magnesium-base alloy cannot be produced by the known continuous casting methods recourse is had to the use of a batch casting process for making the ingot. This is laborious and time-consuming. Accordingly, it is an object of the invention to provide a continuous casting method which overcomes these drawbacks. Other objects and advantages will appear as the description of the invention proceeds.

According to the invention, smooth tubular non-porous ingot free from shrink or other forms of cracks which form on applying conventional methods of continuous casting of hollow ingot, is obtained by delivering at a particular rate a continuous flow of the molten alloy to be cast in the annular space between a cooled cylindrical open ended vertically disposed mold and a cooled mandrel therein vertically disposed, the molten metal being at usual casting temperature, e. g. 1200° F. to 1400° F., depending upon the composition of the alloy. In addition to feeding the molten metal into the annular space at a particular rate, the feeding is conducted in a manner such that the molten metal is introduced beneath the surface of the molten metal already in the mold before solidification and distributed around the annulus. While so controlling the feed of molten metal to the mold, heat is abstracted from the so-introduced metal so as to bring about solidification. The abstraction of heat from the metal is carried out through the mold and mandrel in a manner such that there is produced in the annulus a particular form of interface between the molten metal in the mold and the solidified metal. The form of the interface in the annulus between the mold and mandrel, viewed in vertical cross section, is a V extending around

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the mandrel with the bottom of the V pointing downwardly. In carrying out the heat abstraction, it has been discovered that the location of the bottom of the V, with reference to the mandrel, can be varied according to the amount of cooling applied to both the mold and mandrel and that the location of the bottom of the V can be used as a guide to the production of sound ingot. By so cooling the mandrel and mold that the bottom of the V is spaced from the mandrel a distance, measured horizontally, of from $\frac{1}{8}$ to $\frac{3}{8}$ of the thickness of the annulus of metal sound ingot is obtained.

The invention may be further understood and explained by reference to the accompanying drawing showing a preferred embodiment of apparatus suitable for carrying out the invention.

In the said drawing,

Fig. 1 is a vertical section of the apparatus showing the casting operation.

Fig. 2 is an enlarged fragmentary view of Fig. 1 showing the annulus in vertical section and the form and location therein of the interface between the molten and solidified metal.

Referring to the drawing in detail, there is shown a vertically disposed open ended cylindrical mold 1 provided with a rim 2 by which it may be supported in a suitable frame (not shown). Surrounding the outside of the mold a short distance (e. g. 2 inches) from it are rings 3 and 4 of perforated pipe for cooling water, the perforations 5 facing downwardly and toward the outside wall 6 of the mold. A similar ring 7 of perforated pipe is provided below the mold for directing cooling water (optionally air may be used) against the ingot as it emerges from the mold as will be described later. These rings are connected through control valves 8, 9, and 10, respectively, to a source (not shown) of cooling water. Vertically disposed inside the mold along the central vertical axis thereof is a mandrel 11. This is in the form of a hollow cylinder as shown closed at the top and bottom with end members 12 and 13, respectively. Through the top end member extends a cooling water inlet pipe 14 connected through a control valve 15 to the water source. The lower end of pipe 14 terminates in a water distributing cylindrical box 16. The vertical wall 17 of the box is perforated with a series of holes 18 evenly spaced around the box. An outlet 19 is provided in the end member 12 for the spent cooling water from the mandrel. The upper end 12 of the mandrel is at substantially the same height as the rim 2 of the mold while the lower end 13 extends downwardly substantially the same distance as the mold.

Within the annular space 20 between the mold 1 and mandrel 11 at the upper end of the mold is a ring shaped trough 21 open at the top 22. The trough 21 is connected to and supported by the bifurcated feed pipe 23 leading from the header box 24 which is connected to the molten metal supply line 25 through a valve 26 leading from a source (not shown) of molten alloy to be cast.

In operation a dummy block (not shown) of some kind, such as a precast portion of ingot, is inserted into the bottom of the mold 1 in order to form a seal between the mold and mandrel to hold molten metal in the mold when first starting the apparatus. With the dummy block in place, some cooling water is directed against the mold by partially opening valves 8 and 9 and the mandrel 11 is cooled more or less by partially opening valve 15. The dummy block also may be cooled to some extent by opening partially valve 10 or by directing air against it. Molten magnesium-base alloy is introduced into the annular space 20 by suitably opening valve 26.

The level of the molten metal in the mold is allowed

to rise until near the rim as shown and then the dummy block is lowered while maintaining a flow of alloy into the mold at a rate which keeps the mold more or less full, the lowering being at a rate of about 2 to 4 inches per minute. As the lowering proceeds, molten metal solidifies against the mold wall, against the mandrel, and dummy block. The metal so-solidified is lowered from the mold at the desired rate and the dummy block is discarded. The introduction of molten alloy into the mold and lowering of the resulting cast ingot is continued as desired.

The solidification process which produces the ingot gives rise to an interface between the liquid metal in the upper part of the mold and metal already solidified from the molten state and seals the mold against leakage of molten metal. A form of interface which can be produced when appropriate operating conditions are obtained in accordance with the invention is shown at 27. As the casting proceeds, cast ingot is moved from the bottom of the mold at a rate to maintain the top of the interface submerged in the molten metal in the mold.

As shown in Fig. 1 and in greater detail in Fig. 2, the lowermost portion 28 of the interface together with the portions 29 and 30 adjacent to the mandrel and mold wall, respectively, have generally a V shape as aforementioned. This shape is maintained by appropriately cooling both the mandrel and the mold wall.

The desired ingot 31 is obtained when the lowermost portion 28 or V of the interface is within a certain distance measured horizontally of the mandrel. As shown in Fig. 2, the distance A represents the distance between the lowermost portion of the interface 27 from the mandrel 11 and is used as the control for the method of the invention. In order to obtain sound crack-free smooth non-porous uniformly crystalline ingot continuously, the distance A, it has been discovered, must lie between the distances B and C where B is $\frac{1}{8}$ and C is $\frac{3}{8}$ of the thickness of the annulus 20.

When steady operation is obtained, that is, when ingot 31 is emerging from the mold at the rate of about 2 to 4 inches per minute and molten metal is introduced at a rate corresponding to this, the cooling water flow through the mandrel is maintained at a rate such that the distance A is kept within the limits B and C as shown. This is accomplished by adjusting the flow of cooling water particularly to the mandrel. The position of the lowermost portion of the interface is ascertained by a prod which may consist of a steel rod 32. This is manipulated by hand as by inserting it into the molten metal and feeling for the position of 28. By holding the prod vertical when its lower end is at the bottom of the V, as shown in Fig. 2, the distance A is readily obtained by measuring the distance A'.

It is manifest that the position of 28 can be moved toward either the mandrel or the mold by controlling the flow of cooling water to these parts of the apparatus. Substantially more cooling must be applied to the mold wall and ingot surface than to the mandrel in order to maintain 28 within the limits found to produce sound ingot. When the position of 28 has been brought within the prescribed limits and steady operation obtains the prod is removed. In this connection, it is found that the temperature of the cooling water leaving the mandrel can be used as a reliable indication of the proper position of the lowermost portion of the interface to produce sound ingot. More particularly, it has been found, using cooling water of the usual range of temperature of potable water, that when a steady state of casting obtains, as when cooling water is being applied to the outside of the mold, the outside of the ingot, and the inside of the mandrel, the desired position of the bottom of the V is obtained when the mandrel cooling water exit temperature is between about 140° and 170° F.

It will be observed that in carrying out the method, the molten metal in the mold is always annular in shape

because the upper end of the mandrel extends above the working level of the molten metal in the mold as shown.

The following examples, runs 1 to 5, inclusive, the pertinent data of which are set forth in the table, are illustrative of the practice of the invention. Two runs, 5 and 6, outside the range of the operating conditions for the invention are detailed for comparison.

Run No.	Ingot Alloy Designation	Casting Rate, Inches Per Minute	Water Rates, Gal./Min.		Temp., °F., of Water Leaving Mandrel	Mandrel Diameter, Inches	Quality of Ingot
			to outside of mold ¹	to ingot below mold			
1	ZK60	3.2	14	5	165	4.75	good.
2	ZK60	2.8	16	air	165	4.75	good.
3	ZK60	3.25	16	5	165	3.25	good.
4	AZ31	2.75	12	5	143	2.25	good.
5	AZ31	4.0	11	5	143	10.5	good.
6	AZ31	2.5	14	5	185	4.75	bad.
7	AZ31	4.0	14	5	130	4.75	bad.

¹ O. D. of mold 16.1875". Molten alloy input temperature 1275° F. for ZK60, 1300° F. for AZ31.

Runs 6 and 7 are blanks for comparison. Good means the ingot was smooth, free from cracks, of uniform crystal structure, non-porous. Bad means the ingot was rough cracked, non-uniform in crystal structure and porous.

Referring to the table, runs 1 to 5, inclusive, in which the mandrel cooling water exit temperature was in the range of 143° to 165° F. produced good smooth non-porous uniformly crystalline ingot; whereas when the mandrel cooling water exit temperature was allowed to go as high as 185° F. or as low as 130° F. cracked, rough, porous, irregularly crystalline ingot resulted. Concomitantly, the lowermost portion of the interface, i. e., the bottom of the V as located by prod 32, was shifted from the limits between B and C in runs 6 and 7; while during the production of sound ingot as in runs 1 to 5 the position of the bottom of the V was within the range of $\frac{1}{8}$ to $\frac{3}{8}$ of the thickness of the annulus. The water used for cooling had a temperature in the range of 50° to 80° F.

I claim:

1. The method of producing a sound tubular heavy walled ingot continuously of a magnesium-base alloy containing at least 85 percent of magnesium, which comprises delivering the molten magnesium-base alloy to a vertically disposed open ended cooled mold having a centrally disposed mandrel therein at a rate sufficient to fill the mold to a depth of from 2 to 4 inches per minute when closed at the bottom cooling the outside of the mold and the inside of the mandrel at a rate such that the lowermost portion of the resulting interface between the molten and solidified metal in the mold is at a distance from the mandrel of $\frac{1}{8}$ to $\frac{3}{8}$ of the wall thickness of the ingot while withdrawing ingot from below the mold at a rate sufficient to maintain the mold sealed against leakage of molten metal and the uppermost portion of the interface below the upper surface of the molten metal in the mold.

2. The method according to claim 1 in which the outside of the mold and the inside of the mandrel are cooled with water having a temperature between 50° and 80° F. at a rate such that the exit temperature of the water from the mandrel is between 140° and 170° F.

3. The method according to claim 2 in which the molten magnesium-base alloy is delivered to the mold at a temperature between 1200° and 1400° F.

4. The method according to claim 3 in which the molten magnesium-base alloy is delivered beneath the surface of the molten magnesium-base alloy in the mold.

5. In a method of producing sound tubular heavy walled ingot continuously of a magnesium-base alloy containing at least 85 percent of magnesium, the steps which consist in delivering the molten magnesium-base alloy at a temperature of 1200° to 1400° F. to a vertically disposed open ended cooled mold having a centrally dis-

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posed cooled mandrel therein at a rate sufficient to fill the mold to a depth of from 2 to 4 inches per minute when closed at the bottom, cooling the outside of the mold and the inside of the mandrel with water having a temperature of from 50° to 80° F. at a rate such that the exit temperature of the water from the mandrel is between 140° to 170° F. whereby the lowermost portion of the interface between the molten metal and the solidified metal in the mold is spaced from the mandrel a dis-

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tance equal to from $\frac{1}{8}$ to $\frac{3}{8}$ of the wall thickness of the ingot, the delivery of the molten alloy being beneath the surface of the molten alloy in the mold.

References Cited in the file of this patent

UNITED STATES PATENTS

2,225,415	Junghans	Dec. 17, 1940
2,473,221	Rossi	June 14, 1949