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ROTARY FIELD CHILL-MOLD

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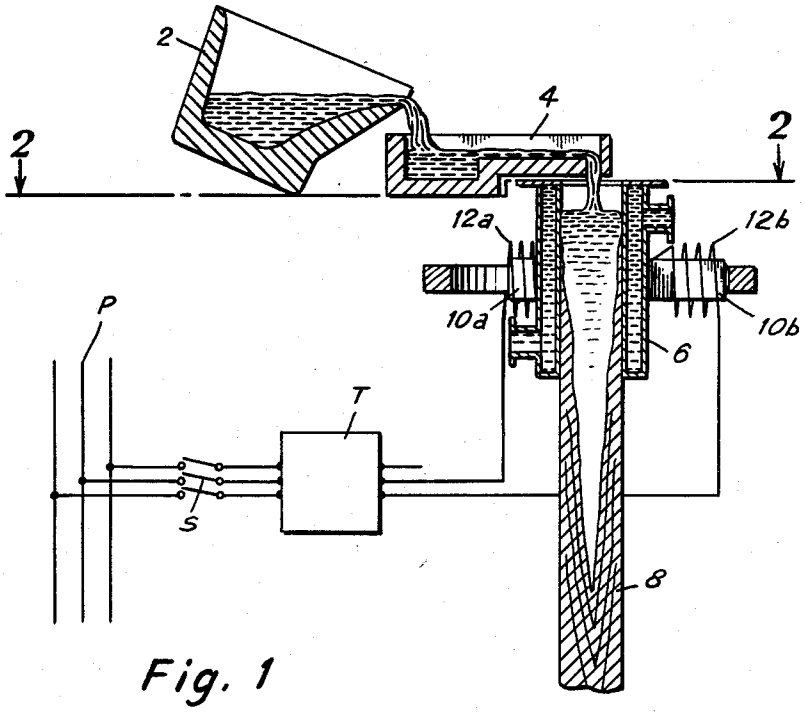
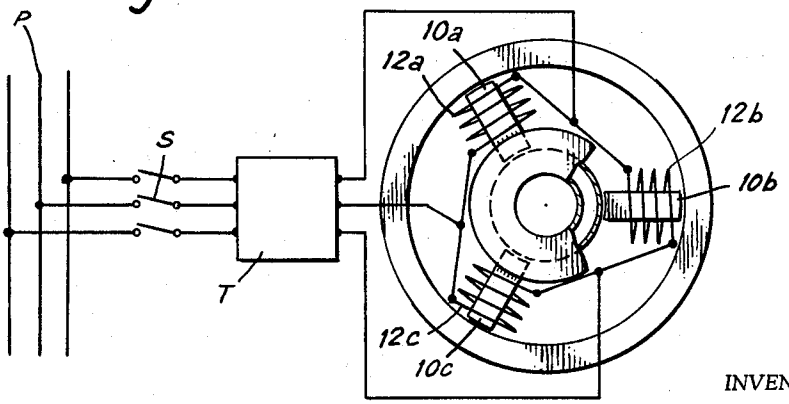


Fig. 1

Fig. 2



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ROTARY FIELD CHILL-MOLD

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It was hitherto customary when employing magnetic rotary fields in connection with chill-molds for metal casting either to provide a layer of insulating material between the iron poles serving for producing the rotary field or to separate the field producing parts from the liquid metal by a wall of non-magnetic steel and possibly by a brick lining.

Such measures are unsuitable when using magnetic rotary fields in water-cooled chill-molds and especially in the case of tubular molds such as are used in continuous casting, because the increase in output which it is endeavoured to obtain can only be achieved with these chill-molds if good heat conducting is insured between the molten metal and the cooling liquid. The use of magnetic rotary fields in continuous casting is similar to that described in my co-pending application Serial No. 376,917, filed August 27, 1953 for "Casting Process," now Patent 2,877,525, issued March 17, 1959 and in the Junghans and Schaaber application filed Sept. 4, 1951, Serial No. 245,014 for "Method for Casting Metals," now abandoned. The shaping or shape-giving portion of the mold must therefore be of a material having good heat conducting properties, such as are generally possessed by metals. Consequently a large percentage of the continuous casting chill-molds in practical use are made of pure copper.

From the point of view of the lowest possible resistance to the passage of heat it is endeavoured to make the walls as thin as possible; practical requirements, however, oppose any reduction in wall thickness because the chill-molds must not become distorted under relatively great differences in temperature and must therefore be sufficiently stable. Furthermore, continuous casting molds are subjected to considerable mechanical stressing when introducing and removing the control pin. Finally, the chill-molds must have a sufficiently great wall thickness to compensate for wear of the shape-giving surfaces by reconditioning, on which account the walls must not be too thin.

This invention is described with reference to the accompanying drawings in which:

Figure 1 is a longitudinal sectional view through a continuous casting mold having a rotating magnetic field applied thereto; and

Figure 2 is a cross-sectional view taken on the line 2—2 of Figure 1.

Molten metal is poured from ladle 2 into runner 4 from which it flows into the continuous casting chill-mold 6 having a water-cooled jacket surrounding at least the part of the mold body giving shape to the ingot being formed in the mold. The metal solidifies in the mold to form an at least partially solid ingot 8 which is withdrawn from the lower open end of the mold.

Surrounding the body of mold 6 are a plurality of rotary field poles 10*a*, 10*b* and 10*c*, each having its respective coil 12*a*, 12*b* and 12*c*, the coils in turn being connected through transformer T and switch S to alternating current electric power line P. Upon the closing of switch S, coils 12*a*, 12*b* and 12*c* are successively energized and thereby induced a rotating magnetic field within the interior of mold 6. The heat conductivity and magnetic shielding characteristics of the material forming the body of mold 6 thus are of considerable importance.

Tests carried out with tubular chill-molds of electrolytic copper, which material was chosen on account of its high heat conductivity, showed that it was not possible to obtain a rotary field of suitable strength in the interior of the mold. Obviously this is due to the screening of the magnetic field as a result of induced eddy currents. Measurements taken with the aid of a rotary field measuring instrument (see Kohlrausch, 1951 edition, volume 2, page 163) gave the results of the screening effect of a copper tube with an internal diameter of 112 mms. indicated in Table I, column 2.

Table I

ROTATION MOMENT IN THE TUBE

Wall thickness, mms.	Rotation moment undisturbed	
	Cu-tube	MS 63-tube
10	0.01	0.30
9	0.02	0.33
8	0.027	0.40
7	0.04	0.436
6	0.06	0.516
5	0.11	0.60
4	0.18	0.634
3.5	0.23	0.70
3	0.28	0.714

The table shows that even with a wall thickness of only 3 mms. the rotation moment forming in the interior of the copper tube (designated as "Rotation moment in the tube" in the table)—for the production of which alternating current of 50 Hertz was used—amounted to only about 28% of the rotation moment produced without using the copper cylinder (in the table designated as "Rotation moment undisturbed"). The screening effect of the copper tube therefore amounted to 72%. Moreover a wall thickness of 3 mms. is undesirably low for practical foundry work.

In order to obtain less screening of the rotary field within the mold wall, the problem arising is to use metals having a lower electrical conductivity without the heat conductivity dropping at the same time too steeply.

According to the Wiedemann and Frantz law a certain constant relation exists theoretically for all scales between the heat conductivity λ and the specific electric resistance ρ at a given absolute temperature T. Actually, however, the relation between heat conductivity and electrical conductivity deviates not inconsiderably for some scales; see Table II in which for different metals the heat conductivity λ is given in cal./°C.cm.sec., specific electric resistance ρ in $\mu\Omega\cdot$cm. and the product of both divided by absolute temperature $T=293°K$. Theoretically

$$\frac{\lambda\rho}{T}=2\cdot44\cdot10^{-8}\left(\frac{\text{Volt}}{°\text{C.}}\right)^2$$

$$=0.588\cdot10^{-2}\frac{\text{cal.}\cdot\mu\Omega}{°\text{C.}^2\cdot\text{sec.}}$$

Table II

	$\rho\mu\Omega$·cm.	λ cal./°C.cm.sec.	$10^2.\frac{\lambda\rho}{T}$ cal.·$\mu\Omega$/°C.²sec.
Cu	1.673	0.94	0.520
MS 63	6.6	0.28	0.62
W	5.5	0.48	0.88
Cr	13	0.16	0.60
Graphite	1375	0.057	26
Be	5.9	0.38	0.75
Mo	5.17	0.35	0.60
Si	20000	0.20	6666
Beryllium-Copper	9.8	0.25	0.82

For rotary field chill-molds, especially those for continuous casting, materials appear appropriate which, with a heat conductivity which is lower than that of copper but preferably not below 10% of that of copper, have a specific electric resistance so much higher than copper that the product of heat conductivity and specific resistance is higher than that for copper alone.

Measurements taken on continuous casting chill-molds with the rotary field measuring instrument showed the values also set forth in Table I for the screening of the rotary field in a tube made of brass alloy MS 63 having the same internal diameter and the same length as the Cu-tube mentioned above. It will be recognized that with a wall thickness of 6 mms. a screening as regards the rotation moment obtained is less than 50%, and in this connection it should be mentioned that this wall thickness is entirely satisfactory from the point of view of foundry work. Table II also shows that of the materials mentioned therein, in addition to brass and beryllium-copper, chrome, tungsten and silicon appear very suitable. In Table II brass with 63% copper and 37% zinc content is designated by MS 63. The values given for beryllium-copper apply for the copper alloy AT hardened by precipitation hardening and quenching and with a content of 2% beryllium and 0.25% cobalt.

Particularly in the case of semi-conductors, of which silicon is a typical example, it is found that a relatively high heat conducting capacity is combined with a very low electricity conducting capacity.

In the same way as semi-conductors, certain metal oxides, sintered oxides and sintered metals also appear very promising.

Beryllium copper, preferably the above mentioned beryllium copper with a content of 2% beryllium and 0.2% cobalt, would seem to be particularly suitable for the above-mentioned purpose.

The physical data for beryllium copper are more favorable for the construction of rotary field chill-molds than the physical data which come into question of electrolytic copper and even of brass, which latter is already more advantageous than copper.

The heat conductivity of beryllium copper is 0.25 cal./cm.°C. sec., that is about 26% that of copper. The electric conductivity of beryllium copper amounts to about 17 to 20% of that of copper. This means a favorable relationship between electric and thermic conductivity, even more favorable than, for example, in the case of brass. In accordance therewith, the Wiedmann-Frantz constant for beryllium copper lies about 1.3 to 1.5 times higher than for copper.

In addition, there is the fact that the tensile strength of hardened beryllium copper is much higher than that of copper. Whereas the tensile strength of hardened beryllium copper is about 130 kgs./mm.², the tensile strength of electrolytic copper, if it is annealed, is 20 kgs./mm.²; if cold rolled copper, has a tensile strength of 35 kgs./mm.².

Compared with a chill-mold made of copper plates in semi-hardened condition, for which a tensile strength of 30 kgs./mm.² can be assumed, the same rigidity is therefore to be expected if, in the case of a beryllium copper mold, a wall thickness of only 23% of that of copper is used.

It must also be taken into consideration that the elastic limit of hardened out beryllium copper amounts to about 98 kgs./mm.² whereas in the case of electrolytic copper it is reached at a tension of only 15 kgs./mm.². In the case of brass the tensile strength is about 50 kgs./mm.² and the elastic limit about 35 kgs./mm.². The elastic limit of the material is the determining factor as to whether under constant heating the reversibility of the expansion process would be exceeded. A body becomes distorted when during the process of heating and recooling the elastic limit is exceeded as a result of the body being unequally heated. In this respect a high elastic limit is advantageous for the material from which the mold is made.

It is therefore to be expected that the same rigidity as that of the former chill-molds with a wall thickness of 35 mms. can be obtained in a beryllium copper chill mold with a wall thickness of about 8 mms. Such a mold would not weaken the magnetic rotary field more than a brass tube with a wall thickness of 6 to 7 mms.

I claim:

1. A continuous casting mold for casting metal comprising a mold body having a cooled shape-giving part, electrical means surrounding said part for forming an exteriorly applied rotating magnetic field for producing a rotating electrical field in the metal being cast in the mold, said body being composed of a material which has a heat conductivity greater than 0.094 but less than that of copper and which has a higher Wiedemann-Frantz law constant than that for copper alone.

2. A continuous casting mold as in claim 1, said mold having a shape-giving cooled part at least 6 mm. thick.

3. A continuous casting mold as in claim 1, further comprising a shape-giving portion composed of brass.

4. A continuous casting mold as in claim 1, further comprising a shape-giving portion composed of MS 63 brass.

5. A continuous casting mold as in claim 1, further comprising a shape-giving part composed of a material selected from the group consisting of W, Cr, Be, and Mo.

6. A continuous casting mold as in claim 1, further comprising a shape-giving part composed of silicon.

7. A continuous casting mold as in claim 1, further comprising hardened beryllium copper containing 2 percent beryllium.

8. A continuous casting mold as in claim 7, said shape-giving part having a wall thickness of about 8 mm.

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