May 28, 1957 S. JUNGHANS ET AL 2,793,410

METHOD AND APPARATUS FOR CONTINUOUSLY CASTING

Filed March 30, 1953 2 Sheets-Sheet 1

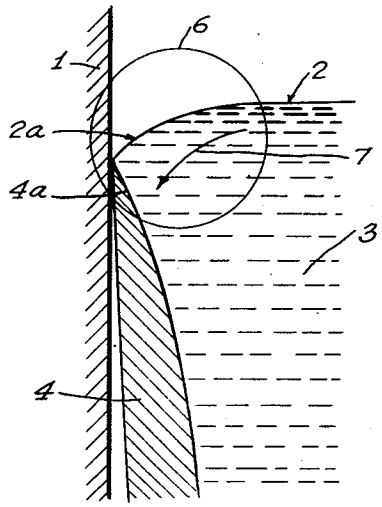


FIG. 1

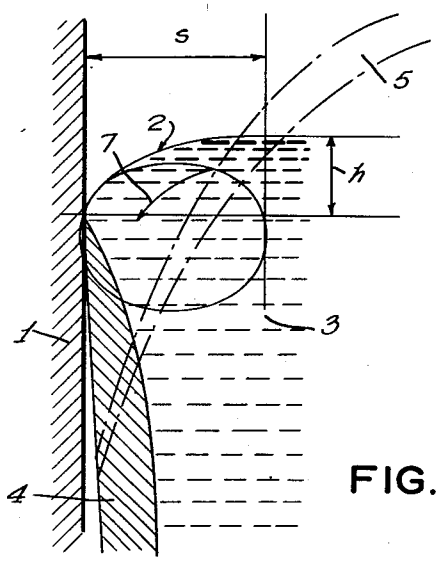


FIG. 2

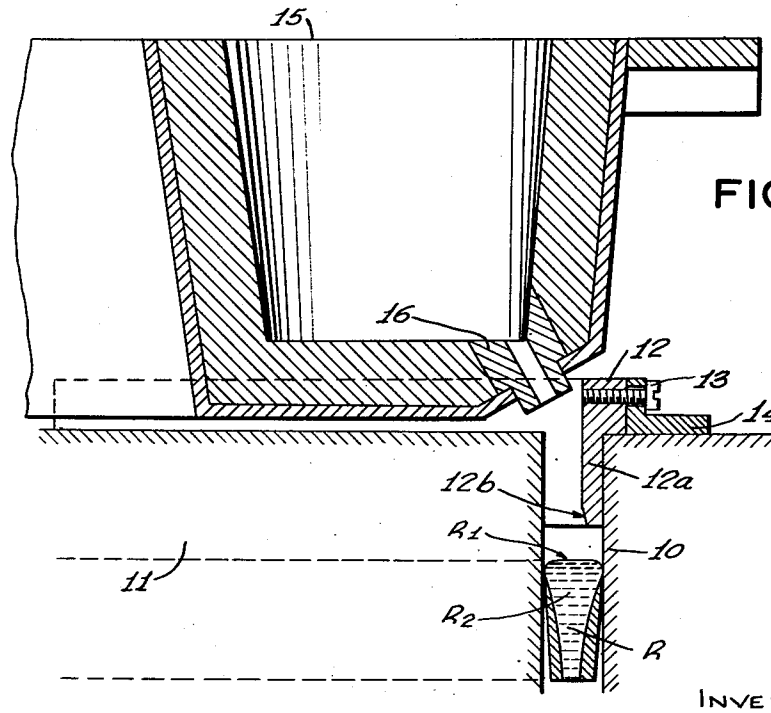


FIG. 3

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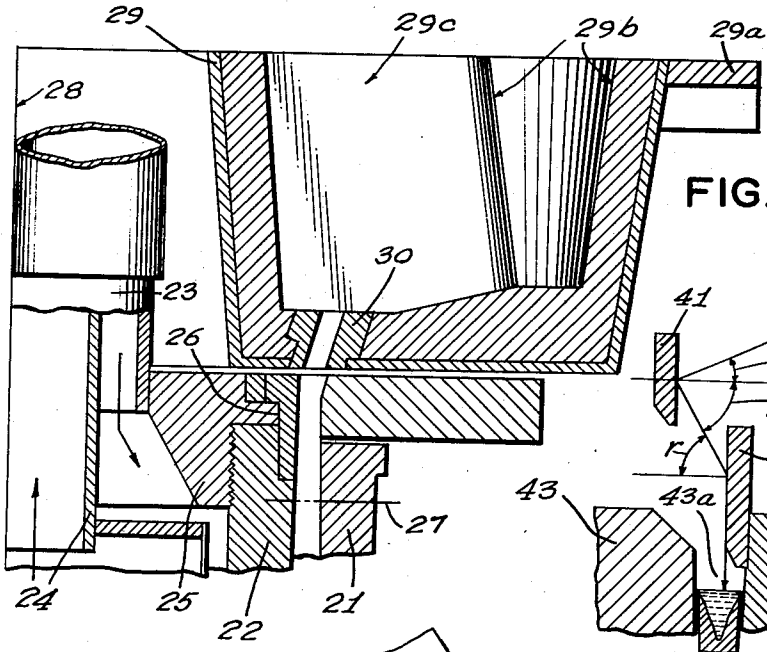
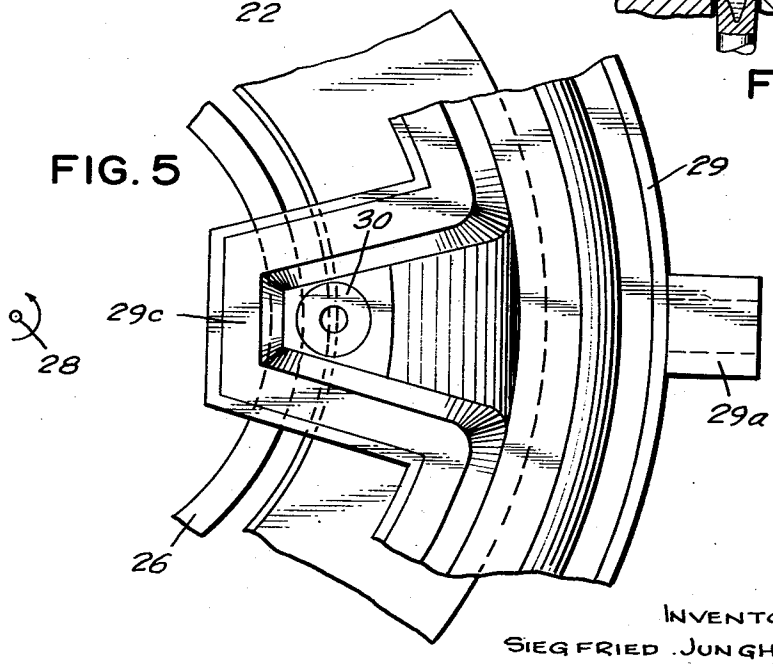


FIG. 4

FIG. 6

FIG. 5



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METHOD AND APPARATUS FOR CONTINUOUSLY CASTING

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3 Claims. (Cl. 22—57.2)

The invention relates to a method and apparatus for continuously casting thin cross-sections, for example, thin plates or thin-walled tubes, more especially from metals having a high melting point, using cooled continuous moulds. As far as is known, it has not hitherto been possible, although it would be very desirable, for sheets or rolled plates, for example, to be continuously cast in such a thickness that they can be further treated directly in finishing rolls. According to tests carried out by us, the reason for this failure is that the conditions and the peculiar nature of the solidification process in the marginal zone of the casting head with the supply of the casting material have not been sufficiently taken into account. If the method in accordance with the invention is followed, it is possible to produce cast members of thin wall thickness, for example, tubes with a diameter of 800 mm. and a wall thickness of 20 mm. or even less, which are excellent as regards their surface and internal nature. The process according to the invention consists in that the casting jet is aligned above the surface of the casting and its flow is adjusted in such manner that it enters the surface of the casting at such a distance from and in such a direction relatively to the mould wall and at such a speed that it is no longer able to unsettle that portion of the meniscus which is disposed directly in front of the solidification shell and is no longer able to damage the solidification shell itself. This requirement is based on the knowledge that the shape of the meniscus must not be destroyed by the flow movement of the casting jet entering the surface of the casting, but that it must be applied in a completely constant manner to the wall of the mould in order to avoid formation of irregularities, channels and overlaps on the surface. The casting material must therefore be so introduced into the surface of the casting that it is no longer able to disturb the meniscus. It has further been recognised by the inventor that when casting thin cross-sections, the casting jet after entering the surface of the casting can cause damage due to the fact that it penetrates to the depth of the liquid cavity or piping into the solidification shell already formed, so that liquid metal can penetrate into the shrinkage gap between the continuous casting and the wall of the mould. From this knowledge, there is derived the requirement that the flow of the casting jet is to be so adjusted and the jet so aligned that it can only reach predetermined parts of the liquid cavity or piping and cannot cause damage at other places either by mechanical or thermal action.

In the preferred embodiment of the invention, the casting jet is shaped on the guide surface to correspond to the cross-section to be cast, that is to say, is spread out into a thin layer when casting thin cross-sections. In such a case, the guide surface expediently extends parallel to or as a continuation of the next adjacent wall of the mould. It is possible to arrange a plurality of guide surfaces in series, preferably in such manner that the casting jet is reflected at the first guide surface, falls from the latter on to the second surface on which it then runs down smoothly without being reflected.

When not working with a casting jet of substantially the same longitudinal extent as that of the cross-section to be cast, it is recommended to operate with at least one travelling casting jet, provision being made in order to be able to adjust the travelling speed in accordance with the casting conditions.

The arrangement of a guide surface for the casting jet offers the possibility of supplying heat to the latter or, on the contrary, withdrawing heat therefrom, and also of influencing the casting jet chemically and/or metallurgically by suitable choice of the material of the guide surface.

In order to carry the process of the invention into effect, it is recommended to use an arrangement in which at least one guide surface is arranged above the level of the casting as a continuation of or parallel to one wall of the mould, which surface is so shaped and is capable of being so aligned relatively to the mould that the metal jet flowing down thereon enters the surface of the casting at a distance from and in a direction towards the wall of the mould, and at a speed at which the casting jet is no longer able to unsettle the meniscus or to damage the solidification shell.

The guide surface expediently extends parallel to the wall of the mould, it being possible for its effective part to be shaped the same as or similar to the cross-section to be cast in order suitably to change the shape of the casting jet, which usually will have a round or in any case composite cross-section.

The guide surfaces can be arranged in sections or continuously around the entire inlet opening of the mould the continuous arrangement being used when the casting jet covers the entire cross-section, for example in the casting of tubes.

The guide means may also serve for chemically and/or metallurgically influencing the casting material if they are made of a suitable substance.

The supply means for the casting jet and the guide surface can be arranged movable relatively to one another. However, it is also possible to conceive cases where it is expedient to connect the supply means for the casting jet and the guide surface rigidly with one another and to move them over the casting cross-section.

A number of devices for carrying out the process according to the invention are hereinafter explained by way of example and with reference to the drawings, wherein:

Figures 1 and 2 show diagrammatically a section through the marginal solidification zone of a cooled continuous mould, Figure 2 indicating the method for the approximate determination of the dangerous zone of the casting head,

Figure 3 is a fragmentary section through a mould for casting thin-walled iron tubes with an associated rotating casting vessel,

Figures 4 and 5 are respectively a vertical section and a plan view of the upper portion of a continuous mould for casting iron tubes with the rotating casting vessel arranged above the same, the casting jet being directed towards the core,

Figure 6 is a diagrammatic view showing the series arrangement of two guide surfaces, the first being a reflecting surface and the second a non-reflecting surface.

In Figures 1 and 2, **1** is the cooled wall of a continuous mould, **2** is the casting surface which is curved at the margin under the surface tension and which is referred to hereinafter as the meniscus, **3** is the liquid portion of the casting head, **4** is the solidification shell and **5** is the casting jet.

The endangered zone of the marginal zone is indicated as regards its extent by a circular line **6**; this endangered zone comprises essentially the curved portion **2***a* of the

meniscus and the initial portion 4*a* of the solidification shell.

The exact shape of the meniscus is capable of being observed during casting. In addition, however, it is also possible to calculate the meniscus shape by means of measured physical properties of casting metal and the wall of the mould or lubricants. For this purpose, it is necessary to know the surface tensions or the marginal angles.

The basic data for this calculation, the formation of the differential equation of the surface and the solution thereof under the different limiting conditions are found, for example in Joos, "Lehrbuch der Theoretischen Physik," 1st edition, Leipzig 1932, pages 187–191, and in volume 7 of the "Handbuch der Physik" by H. Geiger and K. Scheel, "Mechanik der gasformigen und flussigen Korper," chapter 6, Capillarity, by A. Gyemant Springer, Berlin, 1927.

From the data given therein, it is possible to deduce that the sectional figure of the meniscus with a normal plane to the wall of the mould can be approximated with good accuracy by a circular arc or better still by an elliptical arc, if one is limited to the portion in the vicinity of the wall of the mould. This possibility of approximation is also provided by simple observation of the meniscus (see Figure 3).

The endangered region of the meniscus surface can then be considered as the portion of the metal surface which is disposed above the major horizontal axis of the ellipse. It is also possible to refer to the entire ellipse surface as the endangered portion of the casting bed.

On the basis of this definition, assuming the usual casting conditions and the usual casting metals, it is finally also possible to establish the endangered region as being the portion of the casting head which is within a certain distance from the wall of the mould, this distance *s* being a certain multiple C of the height *h* of the meniscus and the value of C being substantially between 2 and 4, according to the casting conditions; therefore,

$$s=Ch \text{ and } C=2 \text{ to } 4$$

In prolonged tests, it was ascertained that the endangered zone 2*a*, 4*a* must not be disturbed by the incident casting stream or jet in such manner that the curved portion 2*a* of the meniscus 2 becomes unsettled by flow forces. The portion 2*a* must rather be constantly renewed with absolute smoothness, that is to say, be able to progress and be applied to the wall 1 of the mould; if its shape is disturbed, that is to say, if portions of the meniscus curvature 2*a* are rolled down on to the wall of the mould sooner or later than other portions, they then solidify at a different time and form a solidification shell with strong transverse grooves, fissures and overlaps.

In order to avoid such harmful effects, it is necessary that the casting material is supplied outside the endangered zone 6 and is brought into the endangered zone in a steady flow in the direction of the arrow 7.

In the course of prolonged experiments in the continuous casting of thin tubes of iron and steel, it has been found that it is necessary to fulfil a second condition, which is that it is necessary to avoid the casting jet 5 (see Figure 2) melting and penetrating the depth of the solidification shell 4 after it has entered the casting head. It is obviously on this account that it has not hitherto been possible to cast thin-walled cast products from high-melting metals in continuous form, because the liquid casting head is enclosed by two extremely thin solidification shells which are adjacent one another with a small spacing, but the extent of which in the depth of the casting head is, however ten or more times its spacing. Under the peculiar flow conditions which obtain when operating with a liquid metal jet, it is not possible in practice, as becomes apparent from the known supply means, to introduce this jet into the casting head in such manner that it always enters the casting head at the same spacing from the inner and outer solidification shells and loses its energy of movement in the depth of the liquid cavity or piping and only penetrates forwardly with its heating effect to such an extent that a stable edge solidification can be formed. As shown from experience, the casting jet will vary its direction according to the composition of the casting material, its temperature and the condition of the supply means, with the danger of melting and breaking through the solidification shell.

The arrangements which are hereinafter described render it possible for the conditions explained with reference to Figures 1 and 2 to be met and for tubes with comparatively small wall thicknesses to be produced, which tubes are at least comparable with the tubes hitherto produced in accordance with other processes as regards their surface quality and their internal nature.

The arrangement shown in Figure 3, which for sake of simplicity is only partly illustrated, serves for the casting of tubes, and **10** represents the outside wall of a cooled continuous casting mould, **11** the core thereof, which is also cooled, and R the cast member. Fitted on the upper edge of the mould wall **10** is a graphite ring **12**, said ring being secured by means of screws **13** to a supporting ring **14**. The graphite ring **12** engages for some distance by means of its flange **12***a* serving as a guide surface over the wall **10** of the mould and terminates just above the casting surface R_1; the flange is bevelled outwardly at **12***b*.

An annular casting vessel **15** is rotatable above the mould about an axis which is not shown and which coincides with the axis of the mould. The metal to be cast is supplied to the said vessel by way of a channel or directly from a heat retaining ladle. At its bottom, the casting vessel is formed with a discharge nozzle directed at an inclination towards the graphite ring **12**, the angle of incidence of the nozzle in relation to the inner peripheral surface of the graphite ring and the spacing between the nozzle **16** and the ring **12** being so adjusted that the jet of metal issuing from the vessel **15** is braked and deformed on the surface of the ring **12** in such manner that the casting metal runs down in a thin strip on the annular flange **12***a* and steadily enters the casting head R_2 without spraying or moving out laterally. It has been found that the bevel **12***b* on the bottom edge of the annular flange **12***a* contributes to enabling the thin liquid metal strip to be detached smoothly from the flange **12***a*.

In contrast to the arrangement which has just been described, the casting jet in the constructional example shown in Figures 4 and 5 is directed towards the core of the mould; in these figures, **21** is the outer wall of the mould, **22** the core, **23** a pipe for supplying cooling medium, **24** a pipe for discharging the cooling medium and **25** is a metal plate closing the core of the mould. The graphite ring **26** is placed around the upper edge of the core **22/25** of the mould to serve as a guide surface. The surface of the casting has to be imagined as being approximately at the level **27**.

The casting vessel **29** is rotatably arranged about the axis **28** of the mould and above the latter, said vessel being supported by means of arms **29***a* on an annular mounting (not shown). The channel-shaped cross-section **29***b* of the vessel **29** comprises three bulged portions **29***c* which are directed towards the axis and which open at the bottom into discharge nozzles **30**. The nozzles **30** are directed at an inclination towards the graphite ring **26** and are arranged close in front of the latter so that the jet of metal which issues from the nozzle is braked on the graphite ring **26**, steadied and spread out to form a thin strip which enters the liquid casting head in a steady manner and exactly parallel to the walls **21** and **22** of the mould. The arrangement of the nozzles **30** in bulges **29***c* of the rotating casting vessel **29** has the advantage that it is possible to have a substantially free view of the surface of the casting.

Means (not shown in the drawing) are provided for varying the speed of rotation of the vessel **29**. In order to prevent the action of air oxygen, more especially on the thin metal layer, which runs down on the guide surfaces of the devices in accordance with the invention, it is recommended that the entire metal supply or parts thereof be in certain cases arranged in gas-tight manner.

Whereas hitherto supply devices with a single guide surface have been described, there is hereinafter referred to (see Figure 6) an arrangement with two guide surfaces arranged in series. The casting metal falls in a free jet **40** on to the first guide surface **41** at an angle α which is such that the jet is reflected at an angle β and now reaches the second guide surface **42**, but this time at an angle γ, at which surface there is no further reflection, but the jet **40** runs down substantially tangentially into the mould cavity **43***a* of the mould **43**.

We claim:

1. A process for the continuous casting of thin wall metal tubes in an open top continuous casting mold comprising pouring molten metal in the mold at a rate to form a head of metal adjacent the top edge of the mold, solidifying a metal shell in said mold with the upper edge of said shell starting at substantially the lower edge of the meniscus of the molten metal head, and further pouring said molten metal in a jet entering the head of molten metal immediately adjacent to but outside of the portion of the meniscus contacting the upper edge of the solidified shell at a distance s from the wall of the mold wherein $s=Ch$, C being from 2 to 4, and h being the height of the meniscus.

2. An apparatus for the continuous casting of thin wall metal tubes comprising a continuous casting mold adapted to hold molten metal having a meniscus near the upper edge of the mold and a solidified shell immediately below the meniscus, guide surface means mounted in said mold above the meniscus level at a distance $s=Ch$ from the wall of the mold, wherein $C=2$ to 4, and h is the height of the meniscus, for guiding molten metal into said mold as close as possible to the wall of the mold but outside of the portion of the meniscus disposed directly in front of said solidified shell, a ladle mounted above said mold, and nozzle means in said ladle for directing a stream of molten metal at an angle onto said guide surface means.

3. An apparatus as in claim 2, further comprising a means rotatably mounting said ladle above said mold, sidewall bulged portion in said ladle, and said nozzle means being mounted in said bulged portion.

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