EUROPEAN PATENT APPLICATION

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A request for correction replacing page 2/2 of the drawings has been filed pursuant to Rule 88 EPC. A decision on the request will be taken during the proceedings before the Examining Division (Guidelines for Examination in the EPO, A-V, 2.2).

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Crystalliser, or inner portion, of a mould for the continuous curved casting of thin slabs.

Crystalliser, or inner portion, of a mould for the continuous curved casting of thin slabs, which has at least its outer curved extrados plate (10) containing a substantially central enlargement hollow (11) starting from the upper surface (13) of the outer plate (10) and being reduced progressively to zero in the curved inner surface (12) of the plate (10) for sliding of the molten metal, the enlargement hollow (11) being defined by a determined profile, the profile being determined lengthwise by an angle "α" and crosswise by an angle "β", wherein the angle "α" should not exceed a maximum value of 5° and may vary, from the centre line to the sides of the hollow (11), according to a linear development contained within a field limited at its upper end by that maximum value and at its lower end by zero.
This invention concerns a crystalliser, or inner portion, of a mould for the continuous curved casting of thin slabs. To be more exact, this invention concerns a crystalliser which contains in its upper portion at a position in the centre of the inner side of its longer sidewalls an enlargement hollow for introduction of the discharge nozzle of tundishes.

This enlargement hollow is necessary for introduction of the discharge nozzle since the width of the space for passage of the molten metal varies from 25 to 70 mm.; this enlargement hollow is disclosed in US-A-2,564,723, which teaches the symmetrical enlargement of a straight, vertical crystalliser and is therefore not suitable for curved crystallisers.

SU-A-143.215 teaches that this enlargement should be shaped with a substantially cylindrical development, and this document too concerns a straight, vertical crystalliser.

EP-A-0.230.886 is associated with a straight, vertical crystalliser and discloses a symmetrical enlargement with inclined, vertical walls having a substantially rectangular development.


EP-A-0.300.953 discloses a crystalliser of which the upper portion in which the discharge nozzle of the tundish is inserted is straight and vertical, whereas the lower portion is curved; the upper portion of the crystalliser may also include an arcuate part, which can be on one long side or the other, but the document does not give any geometric defining parameter; it does not in any way disclose the case of a wholly curved crystaliser but does provide for a change of direction of the skin of the thin slab being formed. This change of direction takes place where the straight, vertical portion is joined to the lower curved portion, and creates problems for the skin being formed owing to separations, interruptions in the surface, localized melting and reduced extraction speeds.

In the technology of the state of the art the steel during continuous casting with partly curved moulds of a known type undergoes dynamic effects due to the extraction movement and to the effects of shrinkage caused by cooling.

EP-A-0.276.418 and JP-A-5,897,466 disclose lateral closure elements to determine the length of the casting chamber; the former document concerns straight, vertical crystallisers, while the latter concerns curved crystallisers.

Next, it should be borne in mind that it has been deemed hitherto that an enlargement having a lenticular shape, that is to say, in enlargements shaped with a curve having a radius of a given value there remains a concentration of tensions, caused by the geometric configuration, in the skin forming in contact with the zone unifying the lenticular shape to the surrounding surfaces, DE-A-3,907.351 teaches the inclusion of connecting curves, which, however, are not quantified dimensionally and are therefore contained in the state of the art, which teaches that a union should be created and that a sharp edge should not be left.

Moreover, according to the teachings of the state of the art relating, in particular, to partly curved moulds there remains a tendency for the removal and/or tearing of the skin during the downward movement.

In fact, the skin tends to follow a line at a tangent to its own trajectory and the present applicants have found that if this line at a tangent forms, together with the surface of the crystalliser, an angle greater than a given value, separation may occur.

Such separation takes place when the skin is consolidated enough and the ferrostatic pressure is not high enough. In such cases a breakage of the skin by tearing may take place directly.

The present applicants have designed, tested and embodied this invention to overcome the shortcomings of the state of the art and to achieve further advantages.

The invention is set forth and characterized in the main claim, while the dependent claims describe variants of the idea of the embodiment.

The applicants have found to their surprise that the above dangers and shortcomings are obviated by varying the inclination of the above tangential line which determines the development of the curve forming the enlargement hollow.

The applicants have also found to their surprise that this variation of the inclination of the tangential line should be progressive and should remain contained within a maximum value.

The applicants have also discovered to their surprise that this variation should affect the angles of departure from the lenticular surface on both the horizontal and vertical planes.

Furthermore, it has been surprisingly ascertained that this variation between one tangential line and the previous and/or successive tangential lines should be comprised within determined values.

The applicants thereafter conducted a wide and thorough practical research over a long period to obtain an experimental confirmation that their theoretical ideas correspond to the wide range of working conditions which are covered by practical operations.
According to the invention a regular downflow is ensured in practice by attributing a suitable development, comprised within an assigned field of admissibility, to the angles uniting the lenticular enlargement to the remaining surfaces; these angles are taken into consideration both in the planes of the lengthwise section (angles "a") and in the planes of the cross-section (angles "β").

The geometry which can be achieved with the invention is able to optimise the behaviour of the steel undergoing continuous casting and subjected to the dynamic effects due to the movement of extraction and the effects of shrinkage caused by cooling.

In particular, the conformation proposed for the zone uniting the lenticular surfaces makes possible:

- a) a reduction of the concentration of tensions (caused by geometric effects) in the skin formed in contact with the zone uniting the lenticular surfaces to the surrounding surfaces;
- b) a lessening of the tendency to removal (or tearing) of the skin during downward movement.

Hereinafter we shall denote as angle "α" the angle determined in a vertical plane and as angle "β" the angle determined in a horizontal plane.

For the sake of ease of description we shall always refer hereinafter to the extrados, or outer curved surface, the intrados, or inner curved plate.

According to the invention the angle of union "α" relating to the lengthwise section of the crystalliser should:

- vary in a linear manner (or with a development of which the values diverge by a maximum of ± 0.5° from the values describing a straight line) upon variation of the distance of the section being considered from the nearest end of the lenticular surface;
- be comprised within a field of admissible values which is substantially rectangular and limited at its upper end to the value:

\[ \alpha \text{ max. admissible } = 5° \]

Furthermore according to the invention the angle of union "β" relating to the cross-section of the crystalliser should:

- diminish from a maximum value to zero in a linear manner (or with a development of which the values diverge from a linear development by ± 0.5° at the most) upon variation of the distance of the section being considered from the upper plane of the crystalliser;
- be comprised within a field of admissible values which is substantially rectangular and limited at its upper end to the value:

\[ \beta \text{ max. admissible } = 4.5° \]

Let us now see with the help of the attached figures, which are given as a non-restrictive example, an embodiment of the invention as follows:

Figs.1a and 1b show the outer curved extrados plate together with the enlargement hollow and the angle "α";

Figs.2 and 3 show some possible developments of the angle "α" according to the invention;

Figs.4a and 4b show the outer curved extrados plate and identify the enlargement hollow and the angle "β";

Figs.5 and 6 show some possible developments of the angle "β" according to the invention;

Fig. 7 is a diagram of a vertical section of a curved mould with enlargements in the outer curved extrados plate and inner curved intrados plate;

Fig. 8 shows a variant of the invention.

Let us now see an example with the help of the attached figures.

Figs.1a and 4a show an outer extrados plate 10 with a curved development and with an enlargement hollow 11, which starts at the upper surface 13 of the plate 10 and ends at an intermediate position where it joins the curved surface 12 defining one side of the casting channel of the crystalliser.

The hollow 11 has a height "H" and a maximum width "A" and is defined by theoretical angles "α" and "β".

Fig.2 shows with lines of dots and dashes three possible developments of the angle "α", that is to say, three possible variations within a rectangle bounded at its upper side by a field of non-admissibility; this field corresponds to values of "α" greater than 5°.

The development 14 provides for the angle "α" to remain constant for any lengthwise section "α", while the development 16 provides for the angle "α" at the centre line (A/2) to have a maximum value of 5°.

Fig.3 shows the divergence admitted for a pre-selected development, which in this example is the development 15 of Fig.2. In Fig.3 it can be seen that the angle "α" varies according to the development 15 while the vertical section passes from zero to A2 but can vary by ± 0.5° in relation to the development 15 so that it can take up the preferred development 15' within the band thus defined.

Fig.5 shows with lines of dots and dashes two possible developments of the angle "β", that is to
say, two possible variation within a rectangle bounded at its upper side by a field of non-admissibility; this field corresponds to values of $\beta$ greater than 4.5°.

A relative angle $\beta$ is defined by moving from the upper surface 13 towards a lower point distant by a value "h". The definition takes place by using the developments admitted by the invention; these developments are shown as an example in Fig.5 as being two in number, namely 17 and 18 respectively.

The development 18 defines a development which starts from a maximum value of the angle $\beta$ at the upper surface 13 and reaches the lowest point "H" with a minimum value of $\beta$, which is zero.

Fig.6 shows by how much the value $\beta$ can diverge in each section "h" from a fixed linear development, which is 18 in this case. The admitted divergence is ± 0.5° and the curves 18 and 18" represent two permitted developments.

Fig.7 shows the outer extrados plate 10 and the inner intrados plate 110, the former 10 containing the hollow 11 while the latter 110 contains the hollow 111. A discharge nozzle 19 of a tundish and the minimum level 20 of the molten metal can also be seen.

Both the hollows 11-111 are joined to the respective curves 12 and 112. The hollow 111 in the inner plate 110 is smaller than the hollow 11 in the outer plate 10 in this case although it has a depth which is substantially almost the same.

The applicants have ascertained that the discharge nozzle 19 has to be positioned in such a way that the distances $L'$ and $L''$ between the discharge nozzle 19 and the walls of the hollows are substantially equal.

The applicants have also ascertained that the distances "A" and "B" relating respectively (A) to the distance between the axis of the discharge nozzle 19 and the walls of the hollow 11 in the outer extrados plate 10, and (B) to the depth of the hollow 111 in the inner intrados plate 110 are connected to each other by the following ratio:

$\frac{B \alpha}{A} \approx 0.6 + 1.0$

This conformation arises from the fact that the applicants have found it advantageous that the axis of the discharge nozzle 19 should cooperate with the free space in a well defined position determined by the above parameters.

The applicants have also found to their surprise that, if a bevel 21 is made at least in the upper edge of the outer extrados plate 10, the working of the casting system (mould, discharge nozzle, feeder of covering powders, feed of lubricants, etc.) is greatly improved with appreciable improvements both on the surfaces and in the structure of thin slabs which can be produced continuously.

This bevel 21" in its smallest size is between 0.4 to 0.6 times the distance of the highest level 22 of the molten metal from the upper surface 13 of the crystalliser.

The bevel 21" in its greatest size may reach 2.5 times the distance of the highest level 22 of the molten metal from the upper surface 13 of the crystalliser.

The inclination $\alpha$ of the bevel 21 will be between 25° and 45°, and the bevel 21 may be included in the inner plate 110 too so as to facilitate the system even more.

According to the variant of Fig.8 a funnel-type flaring 23 may be provided instead of the bevel 21 but will be included only above the highest level 22 of the molten metal.

This flaring 23 takes the auxiliary elements such as powders and/or other elements independently towards the casting chamber defined by the hollow 11, so that those elements are then distributed at the sides in a progressive and differentiated manner.

The flaring 23 may cooperate with the upper edge (and be substantially at a tangent thereto, for instance) of the hollow 11 or may be located in an intermediate position between the upper edge of the hollow 11 and the outer edge of the outer extrados plate 10.

The flaring 23 may be included also in the inner intrados plate 110.

Claims

1. Crystalliser, or inner portion, of a mould for the continuous curved casting of thin slabs, which has at least its outer curved extrados plate (10) containing a substantially central enlargement hollow (11) starting from the upper surface (13) of the outer plate (10) and being reduced progressively to zero in the curved inner surface (12) of the plate (10) for sliding of the molten metal, the enlargement hollow (11) being defined by a determined profile, the crystalliser being characterized in that the profile is determined lengthwise by an angle $\alpha$ and crosswise by an angle $\beta$, and in that the angle $\alpha$ should not exceed a maximum value of 5° and may vary, from the centre line to the sides of the hollow (11), according to a linear development contained within a field limited at its upper end by that maximum value and at its lower end by zero.

2. Crystalliser as in Claim 1, in which the development of the angle $\alpha$ may diverge by ± 0.5° from the above described development.
3. Crystalliser as in Claim 1 or 2, in which the angle "β" should not exceed a maximum value of 4.5° and may vary, from the upper surface (13) of the crystalliser to the lower end (H) of the hollow (11), according to a linear development contained within a field limited at its upper end by that maximum value and at its lower end by zero.

4. Crystalliser as in Claim 3, in which the development of the angle "β" may diverge by ± 0.5° from the above described linear development.

5. Crystalliser as in any claim hereinbefore, in which the hollow (11) in the outer extrados plate (10) is greater than the hollow (111) in the inner intrados plate (110).

6. Crystalliser as in any claim hereinbefore, in which the hollows (11-111) in the extrados and intrados plates (10-110) have substantially the same depth.

7. Crystalliser as in any claim hereinbefore, in which the axis of the discharge nozzle (19) of a tundish runs in the vicinity of the centre line of the free space at the height of the lowest point of the hollows (11-111).

8. Crystalliser as in any claim hereinbefore, in which the distance "A" of the axis of the discharge nozzle (19) from the wall of the hollow (11) of the outer extrados plate (10) and the depth "B" of the hollow (111) of the inner intrados plate are connected by the equation:

\[ \frac{A}{B} = 0.6 \pm 1.0 \]

9. Crystalliser as in any claim hereinbefore, in which the distances L' and L" between the lower corners of the discharge nozzle (19) and the walls of the respective hollows (11-111) are substantially equal.

10. Crystalliser as in any claim hereinbefore, in which the upper surface (13) of the crystalliser contains a bevel (21) running along the whole of that upper surface (13) and facing towards the casting channel.

11. Crystalliser as in any claim hereinbefore, in which the bevel (21) is inclined at an angle "α" between 25° and 45° and has a height between 0.4 to 0.6 times and 2.5 times the distance of the highest level (22) of the molten metal from the upper surface (13) of the crystalliser.

12. Crystalliser as in any of Claims 1 to 9 inclusive, in which a funnel-type flaring (23) cooperating with the hollows (11-111) is included in the upper surface (13) of the crystalliser.

13. Crystalliser as in Claim 12, in which the funnel-type flaring (23) ends above the highest level (22) of the molten metal.
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document with indication, where appropriate, of relevant passages</th>
<th>Relevant to claim</th>
<th>CLASSIFICATION OF THE APPLICATION (Int. Cl.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>EP-A-0 149 734 (SMS-SCHLOEMANN-SIEMAG A.G.) * abstract; figures 1-5 *</td>
<td>1-6</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>EP-A-0 230 886 (SMS-SCHLOEMANN-SIEMAG A.G.) * page 3, line 20 - page 4, line 33; figures 1-5 *</td>
<td>1-6</td>
<td></td>
</tr>
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<td>A</td>
<td>DE-A-3 501 422 (VOEST-ALPINE MONTAN AG) * abstract; figures 1-6 *</td>
<td>1-6</td>
<td></td>
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<tr>
<td>A</td>
<td>DE-A-3 907 351 (SMS-SCHLOEMANN-SIEMAG A.G.) * abstract; figures 1-5 *</td>
<td>1-6</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>EP-A-0 276 418 (SMS-SCHLOEMANN-SIEMAG A.G.) * abstract; figures 1-3 *</td>
<td>1-6</td>
<td>B22D</td>
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The present search report has been drawn up for all claims.