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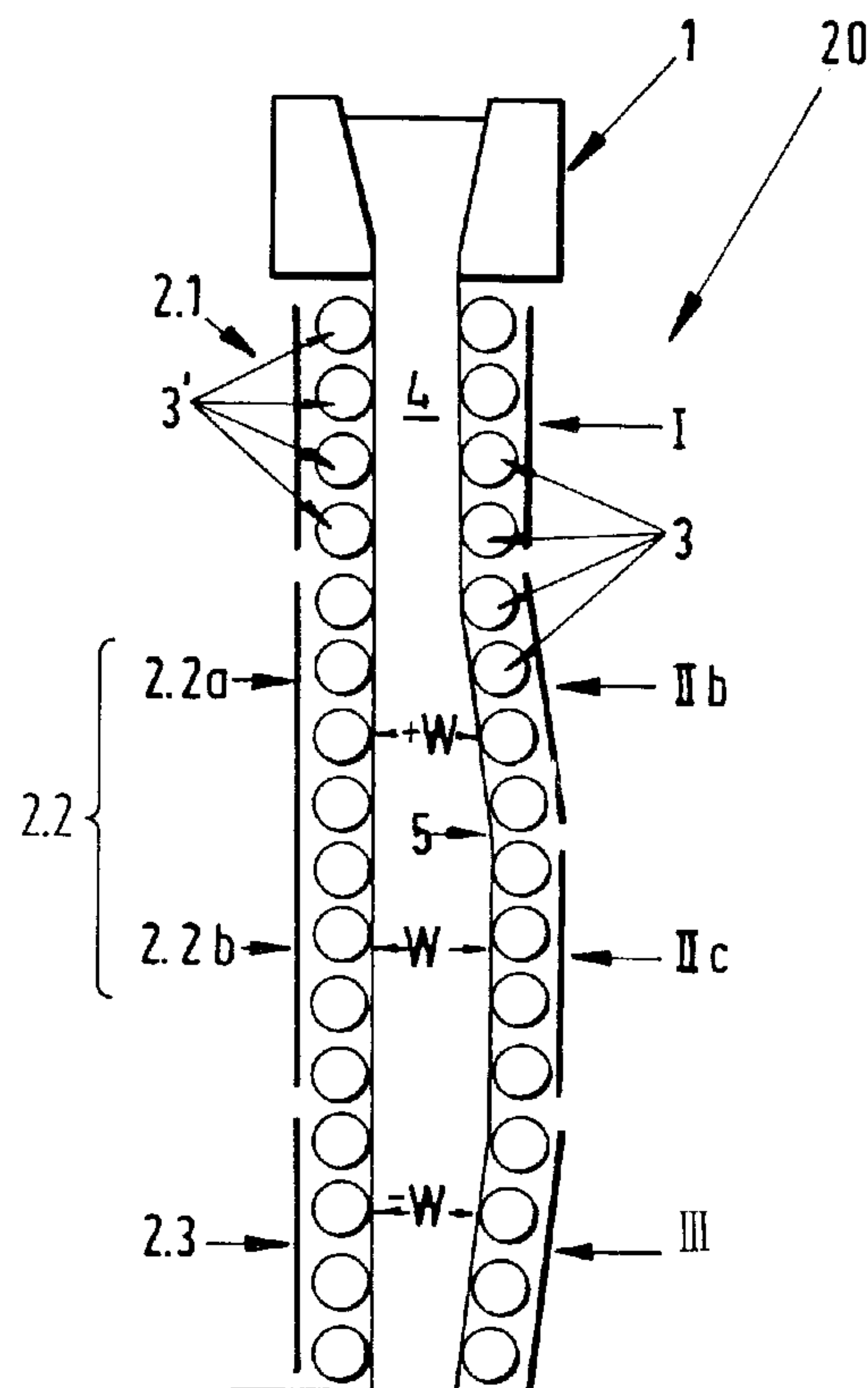
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(54) Titre : METHODE DE MOULAGE EN CONTINU AVEC REDUCTION DOUCE

(54) Title: CONTINUOUS CASTING METHOD WITH SOFT REDUCTION



(57) Abrégé/Abstract:

A continuous slab casting method whereby upstream of a soft reduction portion of a path of the strand and preferably downstream of a liquid core reduction portion, the strand is allowed to bulge by ferrostatic pressure of the liquid core, the bulge being pressed back during the soft reduction stage.

ABSTRACT OF THE DISCLOSURE

A continuous slab casting method whereby upstream of a soft reduction portion of a path of the strand and preferably downstream of a liquid core reduction portion, the strand is allowed to bulge by ferrostatic pressure of the liquid core, the bulge being pressed back during the soft reduction stage.

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CONTINUOUS CASTING METHOD WITH SOFT REDUCTION**SPECIFICATION****FIELD OF THE INVENTION**

The present invention relates to a continuous slab
5 casting method, especially for thin slabs, in which a soft
reduction is effected. More particularly this invention relates
to a continuous casting method for slabs and especially thin
slabs in which the path of the metal from below the mold includes
a plurality of strand-guide segments with adjustable gaps between
10 opposite sides, usually formed by roller pairs and whereby to
reduce segregation and core porosity, the cast strand is
subjected to a reduction in thickness in the region of residual
solidification by appropriate adjustment of the opening between
the opposite sides of the respective strand guide segment.

BACKGROUND OF THE INVENTION

15 In the method described in DE 41 38 740 A1 and U.S.
Patent 5,348,074, the strand is subjected to soft reduction in a
portion of its path prior to full hardening, the slab entering
that segment or stretch before it is hardened through its
20 thickness and leaving that stretch when it is fully hardened.
That requires particular care with respect to the casting
velocity. In the region of final hardening, the thickness
reduction, for example, for thin slabs is between 0.5 and 3 mm

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per meter of the slab length. The roller pair of the segments through which the strand passes are thus progressively more closely spaced in the soft reduction region so as to improve the internal quality of the strand in the residual hardening region.

5 EP 0 834 364 describes a method of and an apparatus for high speed continuous casting with a thickness reduction during hardening, whereby the melt is cast into an oscillating mold and the strand cross section is linearly reduced in thickness over a minimum length of the strand guide directly following the mold.

10 Thereafter a further reduction in the thickness of the strand is effected over the remainder of the strand guide by soft reduction until the most immediately before final solidification or the liquidus tip. The liquidus tip is the point at which the liquid core ends and at which thereafter, the slab is fully solidified.

15 In this system, the deformation density of the cross sectional reduction of the strand is such that the critical deformation of the strand shell (solidified material surrounding the liquid core) for a given high casting speed and steel quality, should not be exceeded.

20 EP 0 177 796 B1 discloses a method of guiding and straightening a cast strand in the straightening an outlet region of an arcuate continuous caster, whereby opposite rollers of the segments are biased by a spring force against the ferrostatic pressure within the strand, the rollers being spaced apart at a
25 distance corresponding to the thickness of the strand as it emerges from the mold. This region of the guide is followed by a

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region in which the strand is compressed to a greater extent and over these regions the spring force is reduced. In this technique, the gap between opposite sides of the guide and thus the spacing of the opposite rollers can be adjusted in a stepless manner by hydraulic cylinders and servovalves using inductive displacement measurements based upon the computer-determined or measured location of the liquidus tip.

The slabs or billets resulting from the processes described and produced by continuous casting are starting materials for rolled products, especially for the production of strip or plates in the rolling mill.

In continuous casting and especially the continuous casting of thin slabs, the aforementioned soft reduction can reduce segregation in the strand and produce a relatively optimum lattice or grain structure in the solidified slab when the thickness reduction immediately upstream of the liquidus point is between 0.5 and 3 mm per meter of the strand. The upper yokes of the strand guide can thus have their rollers mounted with an inclination between the inlet and outlet sides so that the guides provided a smaller mouth width or clear opening at the outlet side than at the inlet side. In many cases, the already solidified edge portions of the strand are subjected to further reduction by the rollers of the strand guides. This can give rise to an unnecessary increase in the stressing of the rollers and their bearings without positively affecting the internal quality of the slab structure in the edge regions.

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OBJECTS OF THE INVENTION

It is an object of the invention to provide a more effective method of improving the internal structure of a continuously cast slab and especially a continuously cast thin slab which is to undergo soft reduction in the manner described, but without the increased roller and bearing loading hitherto encountered.

Another object of the invention is to provide an improved method of continuously casting slabs and especially thin slabs which will allow the thickness reduction to act on the central part of the strand, sparing the already hardened edge regions from the thickness reduction action.

Still another object of this invention is to provide an improved method of producing continuously cast slabs in which soft reduction is used without the heavy wear of the rollers and bearings characterizing earlier systems.

SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the invention in that the cast strand, upstream of the soft reduction stretch is permitted to bulge by a corresponding opening or gap between the opposite sides or rollers of a guide segment by ferrostatic internal pressure and the bulge is then completely or partly pressed back down in the soft reduction stretch to the slab

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thickness which is maintained in the residual solidification region.

More particularly, a continuous slab casting method can comprise the steps of:

5 (a) continuously casting a molten metal into a continuous casting mold and solidifying a shell of the metal around a liquid core in a solidifying strand emerging downwardly from the mold;

10 (b) passing the solidifying strand in succession through a plurality of strand guide segments each having an adjustable gap between opposite sides thereof thereby applying compression to opposite sides of the solidifying strand to reduce a thickness thereof by soft reduction over to limit segregation and core porosity in the slab produced over a soft-reduction
15 portion of a path of the strand immediately upstream from a liquid-core tip representing a boundary between full solidification and partial solidification of the strand;

20 (c) upstream of the soft-reduction portion of the path increasing the gap between the opposite sides of at least one of the strand guide segments from the gap between a more upstream strand guide segment to produce a bulge in the shell as a result of internal ferrostatic pressure on the shell; and

(d) pressing the bulge inwardly to a slab thickness in the soft-reduction portion of the path.

25 The bulging which is permitted, referred to here as targeted bulging since the extent thereof is controlled, is

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determined by the corresponding setting of the width of the guide upstream of the soft reduction stretch and thus the mouth width or roller spacing in the bulging region. Only in the soft reduction stretch is the bulge completely or partly pressed back to the strand thickness which prevails at residual solidification.

By comparison with the earlier approaches, for the same thickness reduction and core compaction, a reduced compaction force is required with the invention and the roller and bearing loading is reduced.

This allows the support structure for the guide segments to be less complicated and dimensioned so as to be smaller while enhancing strand quality in terms of reduction of segregation and core porosity. If a force similar to that used in earlier systems can be maintained, greater thickness reduction and core compaction can be achieved.

According to a feature of the invention, the cast strand prior to reaching the soft reduction stretch is initially subjected to a compaction by reduction in the mouth width of a respective guide segment and while a substantial core of liquid is present in a form of liquid-core reduction and only thereafter, in a subsequent stretch upstream of the soft reduction region, is the strand permitted to bulge by ferrostatic pressure and a widening of the mouth width. The soft reduction is effected in a further guide segment to the liquidus point

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previously described.

The mouth width of the segments can be parallel to the sides of the strand or at an inclination to the sides of the strand and upstream of the soft reduction zone can linearly increase or nonlinearly increase.

In the production of thin slabs, the enlargement of the mouth width beyond the width of the strand can be between 1 and 8 mm and in the production of slabs which are not thin slabs, that enlargement can be between 3 and 20 mm.

The strand can initially pass through a parallel stretch directly below the mold in at least a first segment, followed by the liquid core reduction, bulge and soft reduction segments.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects, features, and advantages will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a highly diagrammatic illustration of the guide segments below a continuous casting mold according to the invention in which a soft reduction stretch follows the targeted bulging stretch;

FIG. 2 is a view similar to FIG. 1 but with a system in which a liquid core reduction stretch precedes the targeted bulge forming stretch; and

FIG. 3 is a cross section of a strand.

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SPECIFIC DESCRIPTION

FIG. 1 shows a continuous casting mold 1 above a plurality of strand guide segments 2.1, 2.2, 2.3 each of which consists of a pair of segments on opposite sides of the strand 4, each having a plurality of rollers 3, 3' which are disposed opposite one another in pairs defining the gap or opening of the segment through which the strand passes.

The segment 2.2 is subdivided into the segments sections 2.2a and 2.2b.

The gap between the rollers of each pair can be adjusted by adjusting the relative positions of the segment halves via hydraulic units known in the art (see, for example, U.S. Patent 5,348,074).

To avoid segregation in the strand 4 during the solidification and to insure a compact internal structure of the slab, a soft reduction stretch III is provided in the strand guide 20 in the region of the final solidification. At the lowest point in this region III, the thickness of the strand has been reduced to that of the continuously cast slab or thin slab as desired and this point can correspond to the liquidus point previously mentioned. In the soft reduction zone III the thickness reduction is 0.5 to 3 mm per meter.

In the embodiment of FIG. 1, the strand 4, prior to reaching the soft reduction stretch III is permitted to bulge outwardly at 5 by an appropriate adjustment of the spacing between the rollers 3, 3' of each pair.

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The bulge 5 is then reduced by a corresponding conical (wedge-shaped) roller arrangement in the soft reduction stretch III to the strand thickness which is to be achieved at final solidification.

5 With this bulge formation in the regions IIb and IIc by appropriate spreading of the segments 2.2a and 2.2b, the segregation can be reduced and the compaction of the internal structure of the slab can be assured without the excessive roller and bearing loading at the edges resulting from complete
10 solidification there. The rollers in the regions 2.2a, 2.b and 2.3, effectively act on the bulging central portion of the strand and the edge portions which have already fully solidified are not compacted by the rollers.

15 In the embodiment of FIG. 2, the cast strand 4 is provided upstream of the soft reduction stretch III by adjustment of the mouth width (W) of the rollers 3, 3', an initial parallel stretch I directly below the mold 1 in at least 1 first guide segment 2.1. In a subsequent or following segment 2.2, an initial compression is provided, e.g. in the region IIa
20 over the segment portion 2.2a by a reduction in the mouth width (-W) to effect a liquid-core reduction. The guide path then widens in the region IIb to a mouth width (+W), greater than W, to form the bulge in the region IIb in the further segment 2.2.

25 From the maximum bulge location represented at 5 in FIG. 2, the strand undergoes soft reduction in the zone III in at least one further segment 2.3 until the liquidus point is

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reached, whereupon the slab is at its final thickness. The enlarged mouth region (+W) is thus a stretch IIb between the liquid core reduction at IIa and the soft reduction at III.

According to a feature of the invention, the width (W) upstream of the soft reduction region III can increase linearly. Alternatively, it maybe advantageous to provide a nonlinear bulging.

It is advantageous for the production of thin slabs to avoid a critical deformation of the shelf of the strand surrounding the liquid core by providing the increase in the mouth width so that it will be between 1 and 8 mm.

With the continuous casting of slabs which are thicker than thin slabs and thus may be of a thickness of 250 mm and more, the widening (+W) in the bulge region can be between 3 and 20 mm.

FIG. 3 shows the cast strand in cross section. The bulges 5 on either side are obtained by an increased setting of the mouth of the respective guide segment upstream of the soft reduction stretch III. This bulge 5 is pressed fully or partially back in during the soft reduction stretch III. The solid lines in FIG. 3 show the contour of the bulging strand. The broken lines 5' show the contour of the strand after it leaves the soft reduction stretch.

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I CLAIM:

2 1. A continuous slab-casting method comprising the
3 steps of:

4 (a) continuously casting a molten metal into a
5 continuous casting mold and solidifying a shell of said metal
6 around a liquid core in a solidifying strand emerging downwardly
7 from said mold;

8 (b) passing the solidifying strand in succession
9 through a plurality of strand guide segments each having an
10 adjustable gap between opposite sides thereof thereby applying
11 compression to opposite sides of said solidifying strand to
12 reduce a thickness thereof by soft reduction over to limit
13 segregation and core porosity in the slab produced over a soft-
14 reduction portion of a path of said strand immediately upstream
15 from a liquid-core tip representing a boundary between full
16 solidification and partial solidification of said strand;

17 (c) upstream of said soft-reduction portion of said
18 path increasing the gap between the opposite sides of at least
19 one of said strand guide segments from the gap between a more
20 upstream strand guide segment to produce a bulge in said shell as
21 a result of internal ferrostatic pressure on said shell; and

22 (d) pressing said bulge inwardly to a slab thickness in
23 said soft-reduction portion of said path.

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2. The method defined in claim 1 wherein the mouth width of at least one of said segments prior to said soft reduction portion of said path is increased to a spacing greater than the outlet thickness of the strand at an outlet end of said mold.

3. The method defined in claim 1 wherein said strand is initially compressed upon leaving said mold in a liquid-core reduction portion of said path and then permitted to bulge upstream of said soft reduction portion of said path to form said bulge in said shell, said soft reduction of said path extending to a liquidus point forming a transition between said liquid core and a solid strand.

4. The method defined in claim 3 wherein the mouth width of one of said segments is set to an amount greater than a thickness of said strand following said liquid core reduction portion.

5. The method defined in claim 4 wherein the mouth width setting of said one segment of said segments is parallel to or conical with respect to said strand.

6. The method defined in claim 1 wherein the mouth width of a segment upstream of said soft reduction portion linearly increases.

7. The method defined in claim 1 wherein the mouth width of a segment upstream of said soft reduction portion nonlinearly increases.

8. The method defined in claim 1 for the production of a thin slab wherein a mouth width of said one of said guide segments increases between 1 and 8 mm to form said bulge.

9. The method defined in claim 1 for the production of slabs having a thickness of at least 250 mm, wherein a mouth width of said one of said strand guide segments increases between 3 and 20 mm to produce said bulge.

10. The method defined in claim 1, wherein step b) comprises reducing the liquid-core tip to form a liquid-core reduction portion, and wherein said bulge is formed between said liquid-core reduction portion and said soft reduction portion of said path.

11. The method defined in claim 10 wherein said strand is passed through a parallel stretch upstream of said liquid-core reduction portion.

FIG.1

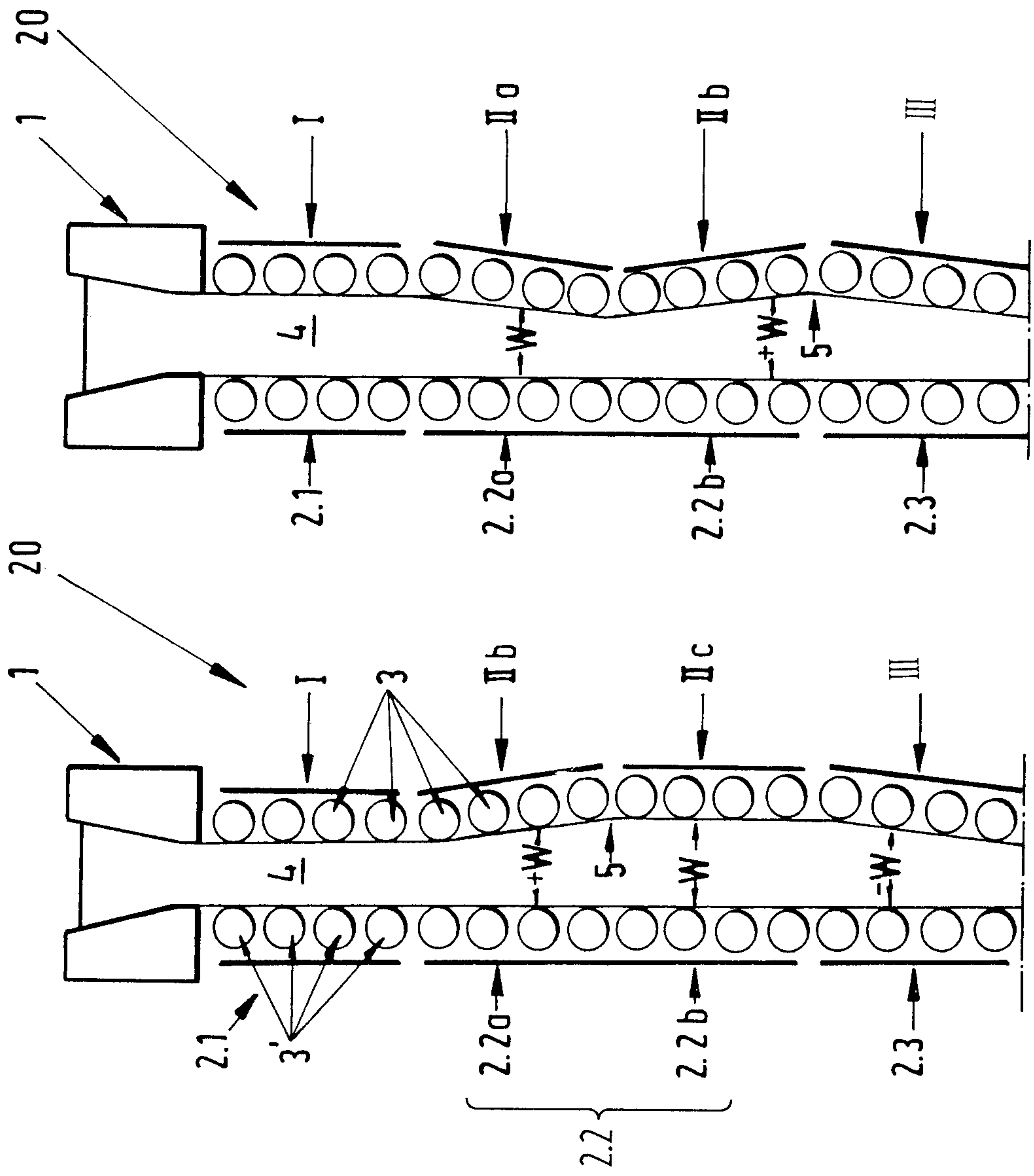


FIG.2

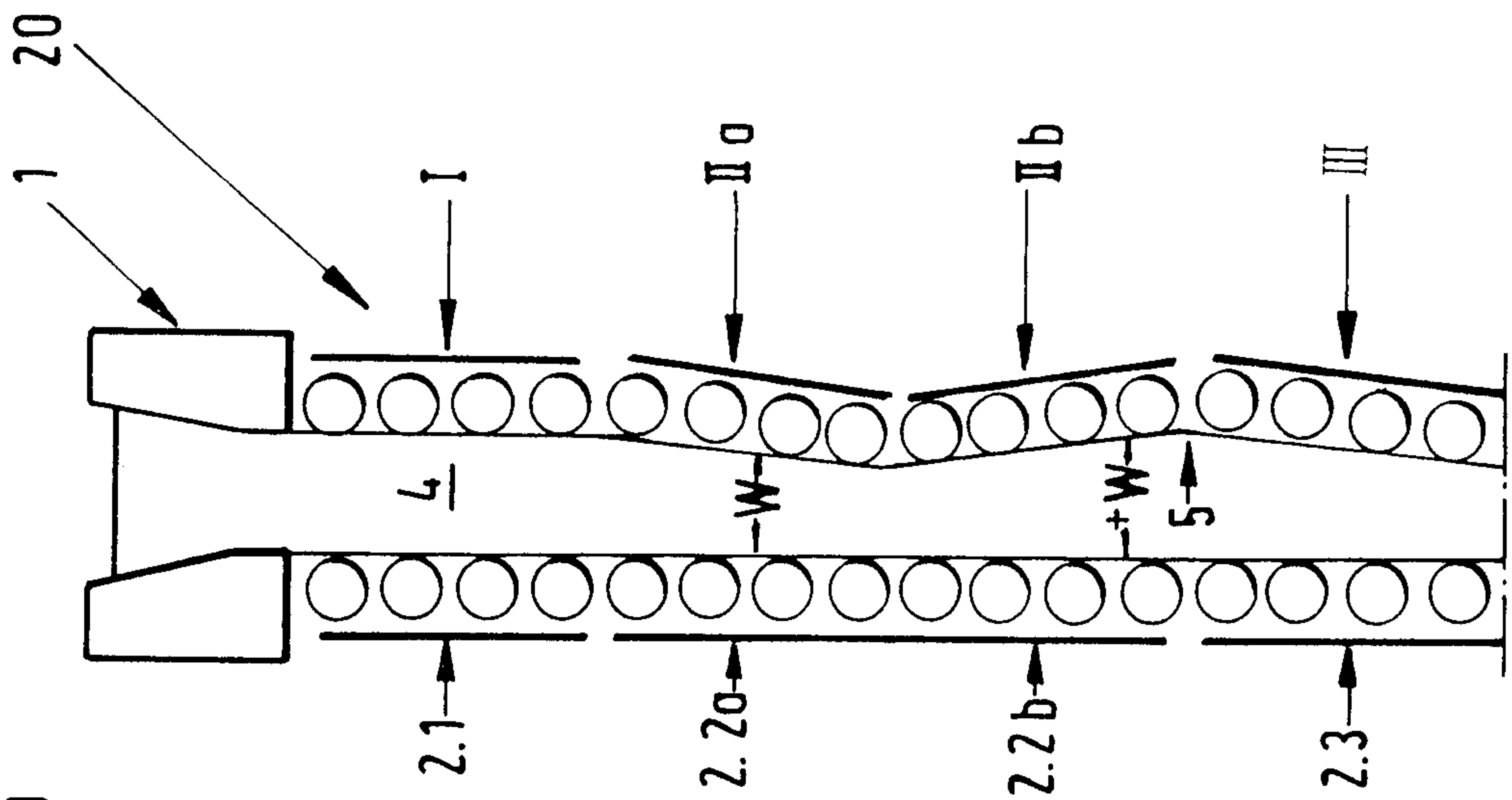


FIG. 3

