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(54) **METHOD FOR CASTING METAL STRIP WITH CROWN CONTROL**

GIESSVERFAHREN FÜR BLEICHSTREIFEN MIT BALLIGKEITSSTEUERUNG

PROCÉDÉ DE COULÉE DE BANDE DE MÉTAL À RÉGLAGE DE BOMBAGE

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Description

[0001] This application is an international application of U.S. Application No. 14/946,872, filed on November 20, 2015.

[0002] This invention relates to the casting of metal strip by continuous casting in a twin roll caster.

[0003] In a twin roll caster, molten metal is introduced between a pair of counter-rotated horizontal casting rolls that are cooled so that metal shells solidify on the moving casting roll surfaces and are brought together at a nip between them to produce a solidified strip product delivered downwardly from the nip between the casting rolls. The term "nip" is used herein to refer to the general region at which the casting rolls are closest together. The molten metal may be poured from a ladle into a smaller vessel or series of smaller vessels from which it flows through a metal delivery nozzle and nozzles located above the nip forming a casting pool of molten metal supported on the casting surfaces of the casting rolls immediately above the nip and extending along the length of the nip. This casting pool is usually confined between side plates or dams held in sliding engagement with end surfaces of the casting rolls so as to restrict the two ends of the casting pool against outflow.

[0004] The twin roll caster is capable of continuously producing cast strip from molten steel through a sequence of ladles positioned on a turret. The molten metal is poured from each ladle in turn into a tundish and then into a moveable tundish before flowing through the metal delivery nozzle into the casting pool. The tundish enables the exchange of an empty ladle for a full ladle on the turret without disrupting the production of the cast strip. In casting thin strip by a twin roll caster, the casting rolls generally made of copper or copper alloy, usually coated with chromium or nickel, are cooled internally with cooling water enabling high heat fluxes and in turn rapid solidification of strip during casting, where the casting rolls undergo substantial thermal deformation from exposure to the molten metal. The crown of the casting surfaces of the casting rolls varies during a casting campaign. The crown of the casting surfaces of the casting rolls, in turn, determines the strip thickness profile, i.e., cross-sectional shape, of the thin cast strip produced by the twin roll caster. Casting rolls with convex (i.e., positive crown) casting surfaces produce cast strip with a negative (i.e. center thermal fatigue from the cyclic heat flux experienced during twin roll casting on larger cylinder masses), and are much less responsive due to their large thermal mass.

[0005] It has also been proposed to position expansion rings directly on a cylindrical tube, for example, of 80 millimeters thickness of copper and copper alloy, optionally with a coating of chromium or chromium alloy thereon, and having a plurality of longitudinal water flow passages extending through the tube to form casting rolls. This proposal was tried and failed. The heat provided to the expansion rings transferred into the cylindrical tube so the rings were not effectively responsive to the heat to expand the cylindrical tube to commercially control the shape of the crown of the casting surfaces of the casting rolls. Accordingly, there remains a need for a reliable and effective way to directly and closely control the shape of the crown of the casting surfaces of the casting rolls during casting, and in turn, the cross-sectional thickness profile of the thin cast strip produced by the twin roll caster.

[0006] US 5560421, which is considered to represent the closest prior art, discloses a method of continuously casting thin strip in which a thin portion is formed close to an outer circumferential portion of each opposite end portion of a pair of water cooling drums, and a thin annular member having a hot water flow passage therein is formed in between the thin portion and a shaft, each thin annular member being expanded when hot water is supplied to the hot water flow passages so as to deform the thin ends of the water cooling drums.

[0007] Other prior art systems are disclosed in US 5996680 and US2004/256077.

Disclosed is a reliable and effective method of controlling casting roll crown and, in turn, the cross-sectional strip thickness profile, by controlling the crown of the casting surfaces of the casting rolls by expansion rings positioned within and adjacent cylindrical tubes forming the casting rolls.

Accordingly, the present invention provides a method of continuously casting thin strip by controlling roll crown according to claim 1. The at least two expansion rings are preferably spaced within 200 mm of edge portions of the cast strip.

[0008] The amount of power applied to the expansion rings may be varied based on the feedback from the at least one sensor, said sensor or sensors capable of sensing at least one of the following properties:

- temperature of the expansion ring or rings,
- thickness profile of the casting downstream,
- local thickness of the cast strip at a defined spot close to the cast strip edges,
- casting roll surface crown during the casting campaign, and
- radial casting roll expansion at a defined spot close to the cast strip edges;

and capable of generating digital or analogous (typically electrical) signals indicative of at least one of the above mentioned properties of the cast strip.

[0009] The insulating coating on each expansion ring is sufficiently thick to control or eliminate heat transfer from the expansion rings to the casting rolls. The insulating coating of at least 0.25mm (0.010) inch in thickness according to the invention (in one embodiment 0.63mm (0.025 inch)) is necessary to have an effective control of heat transfer from the expansion ring to the casting roll. The insulating coating on each expansion ring may be plasma sprayed on the expansion rings. The insulating coating may be plasma sprayed with zirconia spray such as 8% Yttria stabilized zirconia spray. Note that the insulating coating may additionally be applied to the cylindrical tube, but for economy and effectiveness the insulating coating should be applied to the expansion rings directly.

[0010] The at least one heating element of each expansion ring may be made of stainless steel, nickel or nickel alloy. The heating element or elements may be located as desired in each expansion ring. Each expansion ring may provide a heating input of up to 30 kW; preferably, of at least 3 kW.

[0011] Water flowing through the expansion rings may be regulated to expand or contract the expansion rings in radial dimension and, in turn, to increase or decrease the diameter of the cylindrical tube as desired to control the crown shape of the casting surfaces of the casting rolls during a campaign.

[0012] Moreover, the method of continuously casting thin strip by controlling roll crown may further comprise the step of controlling casting roll drive to vary the speed of rotation of the casting rolls while varying the radial dimension of the expansion rings responsive to at least one of the digital or analogous signals received from the at least one sensor and control roll crown of the casting surfaces of the casting rolls during the casting campaign.

[0013] Additionally, the method of continuously casting thin strip by controlling roll crown may comprise the step of positioning at least up to 15 expansion rings. Furthermore, the method of continuously casting thin strip by controlling roll crown may include the step of controlling casting roll drive to vary the speed of rotation of the casting rolls, while varying the radial dimension of the expansion rings with insulating coating spaced from the edge portions of the cast strip and the radial dimension of the expansion ring or rings with insulating coating corresponding to center portions of the cast strip responsive to electrical signals received from a sensor to control the roll crown of the casting surfaces of the casting rolls during the casting campaign.

[0014] In each embodiment, the expansion rings may be made of an austenitic stainless steel such as 18/8 austenitic stainless steel. Each expansion ring may have an annular dimension between 50 to 150 millimeters; preferably, 70 millimeters. Each expansion ring may have a width of up to 200 millimeters; preferably up to 100 mm, more preferably 83.5 millimeters.

[0015] In each embodiment of the method, the crown of the casting surfaces of the casting rolls can readily be varied to achieve a desired thickness profile of the cast strip. Each expansion ring with an insulating coating thereon is adapted to increase or decrease in radial dimension and cause the cylindrical tube to expand changing crown of the casting surfaces of the casting rolls and the thickness profile of the cast strip. The thickness of the cylindrical tube may range between 40 and 80 millimeters in thickness or between 60 and 80 millimeters in thickness.

[0016] In each embodiment of the method, at least one sensor may be positioned downstream adapted to sense the thickness profile of the cast strip and generate electrical signals indicative of the thickness profile of the cast strip. The sensor may be located adjacent to pinch rolls through which the strip passes after casting. Crown control of the casting surfaces of the casting rolls may be achieved by controlling the radial dimension of each expansion ring responsive to electrical signals received from said sensor. Furthermore, crown control of the casting surfaces of the casting rolls may be achieved by controlling the casting roll drive to vary the speed of rotation of the casting rolls while also varying the radial dimension of each expansion ring responsive to the electrical signals received from the sensor.

[0017] The radial dimension of each expansion ring may be controlled independently from the radial dimension of the other expansion ring or rings. The radial dimension of the expansion rings adjacent the strip edges on the casting surfaces of the casting rolls may be controlled independently from each other. Additionally, the radial dimension of the expansion rings adjacent the strip edges on the casting surfaces of the casting rolls may be controlled independently from the expansion ring or rings corresponding to the center portions of the cast strip.

[0018] The present invention further provides an apparatus for continuously casting thin strip for controlling roll crown according to claim 9.

[0019] The at least one sensor may be located adjacent to pinch rolls through which the strip passes after casting.

[0020] The at least one sensor is preferably positioned downstream of the nip capable of sensing the thickness profile of the cast strip and generating electrical signals indicative of the thickness profile of the cast strip to control radial dimension of the expansion rings responsive to the electrical signals received from the sensor to control the roll crown of the casting surfaces of the casting rolls during the casting campaign.

[0021] Furthermore, the apparatus for continuously casting thin strip by controlling roll crown may comprise a control system capable of controlling casting roll drive and varying the speed of rotation of the casting rolls, while varying the radial dimension of the expansion rings with an insulating coating thereon responsive to electrical signals received from the sensor to control the roll crown of the casting surfaces of the casting rolls during the casting campaign.

[0022] Moreover, the apparatus for continuously casting thin strip for controlling roll crown may further comprise a control system capable of controlling casting roll drive and varying the speed of rotation of the casting rolls, while varying the radial dimension of the expansion rings spaced from the edge portions of the cast strip and the radial dimension of the expansion ring or rings corresponding to center portions of the cast strip responsive to electrical signals received from the at least one sensor and control the roll crown of the casting surfaces of the casting rolls during the casting campaign.

[0023] In each embodiment of the apparatus, the expansion rings may be made of an austenitic stainless steel such as 18/8 austenitic stainless steel. Each expansion ring may have an annular dimension between 50 to 150 millimeters; (e.g., 70 millimeters). Each expansion ring may have a width of up to 200 millimeters; (e.g., 83.5 millimeters).

[0024] In each embodiment of the apparatus, each expansion ring with an insulating coating thereon is adapted to increase in radial dimension causing the cylindrical tube to expand and change crown of the casting surfaces of the casting rolls and the thickness profile of the cast strip during casting. Each expansion ring has at least one heating element that may be made of stainless steel, nickel or nickel alloy. The heating element or elements may be located around each expansion ring as desired. Each expansion ring may provide a heating input of up to 30 kW; preferably, of at least 3 kW.

[0025] Crown control of the casting surfaces of the casting rolls may be achieved by controlling the radial dimension of each expansion ring responsive to the electrical signals received from a sensor. Furthermore, crown control of the casting surfaces of the casting rolls may be achieved by controlling the casting roll drive to vary the speed of rotation of the casting rolls, while also varying the radial dimension of each expansion ring with an insulating coating thereon responsive to the electrical signals received from the sensor.

[0026] The radial dimension of the expansion rings adjacent the strip edges formed on the casting surfaces of the casting rolls may be controlled independently from each other. Additionally, the radial dimension of the expansion rings adjacent the strip edges formed on the casting surfaces of the casting rolls may be controlled independently from the expansion ring or rings corresponding to the center portions of the cast strip.

[0027] Again, in each of the embodiments of the method and the apparatus, the insulating coating of the expansion rings is sufficiently thick that the expansion ring can be heated to expand the expansion rings and control the crown shape of the casting rolls as desired during the casting campaign with a small amount of heat being conducted to the cylindrical tubing. An insulating coating of at least 0.25mm (0.010 inch) in thickness (e.g. 0.63mm (0.025 inch)) is effective. Note that the insulating coating may additionally be applied to the cylindrical tube, but for economy and effectiveness the insulating coating should be applied to the expansion rings directly during assembly for the expansion rings and casting rolls.

[0028] In each of these latest embodiments of the method and apparatus, the expansion rings may also have water passages there through to permit the flow of water through the passages in the rings, and regulate the water flow through those passages. The water flowing through the expansion rings may be regulated to expand or contract the expansion rings in radial dimension and, in turn, to increase or decrease the diameter of the cylindrical tube as desired to control the crown shape of the casting surfaces of the casting rolls during a campaign.

[0029] Various aspects of the invention will become apparent to those skilled in the art from the following detailed description, drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] In order that the invention may be well understood, there will now be described embodiments thereof, given by way of example, reference being made to the accompanying drawings, in which:

FIG. 1 is a diagrammatical side view of a twin roll caster of the present disclosure;

FIG. 2 is an enlarged partial sectional view of a portion of the twin roll caster of FIG. 1 including a strip inspection device for measuring strip profile;

FIG 2A is a schematic view of a portion of twin roll caster of Fig. 2;

FIG. 3A is a cross sectional view longitudinally through a portion of one of the casting rolls of FIG. 2 with an expansion ring corresponding to center portions of the cast strip;

FIG. 3B is a cross sectional view longitudinally through the remaining portion of the casting roll of FIG. 3A joined on line A-A;

FIG. 4 is an end view of the casting roll of FIG. 3A on line 4-4 shown in partial interior detail in phantom;

FIG. 5 is a cross sectional view of the casting roll of FIG. 3A on line 5-5;

FIG. 6 is a cross sectional view of the casting roll of FIG. 3A on line 6-6;

FIG. 7 is a cross sectional view of the casting roll of FIG. 3A on line 7-7;

FIG. 8 is a cross sectional view longitudinally through a portion of one of the casting rolls of FIG. 2 with two expansion rings spaced from the edge portions of the cast strip;

FIG. 9 is a cross sectional view longitudinally through a portion of a casting roll with an expansion ring spaced from the edge portions of the cast strip;

FIG. 10 is a cross sectional view longitudinally through a portion of one of the casting rolls of FIG. 2 with two expansion rings spaced from the edge portions of the cast strip and an expansion ring corresponding to center portions of the cast strip;

FIG. 11 is a cross sectional view of an expansion ring with water passages;

FIG. 12 is a graph of delta RTD temperature vs. time;

FIG. 13 is a graph of the average expansion ring temperature vs. edge drop;

FIG. 14 is a graph of heated ring expansion vs. temperature in the caster; and

FIG. 15 is a side and cross sectional view of an expansion ring with heating elements.

DETAILED DESCRIPTION OF THE DRAWINGS

[0031] Referring now to FIGS. 1, 2, and 2A, a twin roll caster is illustrated that comprises a main machine frame 10 that stands up from the factory floor and supports a pair of counter-rotatable casting rolls 12 mounted in a module in a roll cassette 11. The casting rolls 12 are mounted in the roll cassette 11 for ease of operation and movement as described below. The roll cassette 11 facilitates rapid movement of the casting rolls 12 ready for casting from a setup position into an operative casting position as a unit in the caster, and ready removal of the casting rolls 12 from the casting position when the casting rolls 12 are to be replaced. There is no particular configuration of the roll cassette 11 that is desired, so long as it performs that function of facilitating movement and positioning of the casting rolls 12 as described herein.

[0032] The casting apparatus for continuously casting thin steel strip includes the pair of counter-rotatable casting rolls 12 having casting surfaces 12A laterally positioned to form a nip 18 there between. Molten metal is supplied from a ladle 13 through a metal delivery system to a metal delivery nozzle 17 (core nozzle) positioned between the casting rolls 12 above the nip 18. Molten metal thus delivered forms a casting pool 19 of molten metal above the nip 18 supported on the casting surfaces 12A of the casting rolls 12. This casting pool 19 is confined in the casting area at the ends of the casting rolls 12 by a pair of side closure plates, or side dams 20 (shown in dotted line in FIG. 2A). The upper surface of the casting pool 19 (generally referred to as the "meniscus" level) may rise above the lower end of the delivery nozzle 17 so that the lower end of the delivery nozzle 17 is immersed within the casting pool 19. The casting area includes the addition of a protective atmosphere above the casting pool 19 to inhibit oxidation of the molten metal in the casting area.

[0033] The ladle 13 typically is of a conventional construction supported on a rotating turret 40. For metal delivery, the ladle 13 is positioned over a movable tundish 14 in the casting position to fill the tundish 14 with molten metal. The movable tundish 14 may be positioned on a tundish car 66 capable of transferring the tundish 14 from a heating station (not shown), where the tundish 14 is heated to near a casting temperature, to the casting position. A tundish guide, such as rails 39, may be positioned beneath the tundish car 66 to enable moving the movable tundish 14 from the heating station to the casting position.

[0034] The movable tundish 14 may be fitted with a slide gate 25, actuable by a servo mechanism, to allow molten metal to flow from the tundish 14 through the slide gate 25, and then through a refractory outlet shroud 15 to a transition piece or distributor 16 in the casting position. From the distributor 16, the molten metal flows to the delivery nozzle 17 positioned between the casting rolls 12 above the nip 18.

[0035] The side dams 20 may be made from a refractory material such as zirconia graphite, graphite alumina, boron nitride, boron nitride-zirconia, or other suitable composites. The side dams 20 have a face surface capable of physical contact with the casting rolls 12 and molten metal in the casting pool 19. The side dams 20 are mounted in side dam holders (not shown), which are movable by side dam actuators (not shown), such as a hydraulic or pneumatic cylinder, servo mechanism, or other actuator to bring the side dams 20 into engagement with the ends of the casting rolls 12. Additionally, the side dam actuators are capable of positioning the side dams 20 during casting. The side dams 20 form end closures for the molten pool of metal on the casting rolls 12 during the casting operation.

[0036] FIG. 1 shows the twin roll caster producing the cast strip 21, which passes across a guide table 30 to a pinch roll stand 31, comprising pinch rolls 31A. Upon exiting the pinch roll stand 31, the thin cast strip 21 may pass through a hot rolling mill 32, comprising a pair of work rolls 32A, and backup rolls 32B, forming a gap capable of hot rolling the cast strip 21 delivered from the casting rolls 12, where the cast strip 21 is hot rolled to reduce the strip to a desired thickness, improve the strip surface, and improve the strip flatness. The work rolls 32A have work surfaces relating to the desired strip profile across the work rolls 32A. The hot rolled cast strip 21 then passes onto a run-out table 33, where it may be cooled by contact with a coolant, such as water, supplied via water jets 90 or other suitable means, and by convection and radiation. In any event, the hot rolled cast strip 21 may then pass through a second pinch roll stand 91 to provide tension of the cast strip 21, and then to a coiler 92. The cast strip 21 may be between about 0.3 and 2.0 millimeters in thickness before hot rolling.

[0037] At the start of the casting operation, a short length of imperfect strip is typically produced as casting conditions stabilize. After continuous casting is established, the casting rolls 12 are moved apart slightly and then brought together again to cause this leading end of the cast strip 21 to break away forming a clean head end of the following cast strip 21. The imperfect material drops into a scrap receptacle 26, which is movable on a scrap receptacle guide. The scrap receptacle 26 is located in a scrap receiving position beneath the caster and forms part of a sealed enclosure 27 as described below. The enclosure 27 is typically water cooled. At this time, a water-cooled apron 28 that normally hangs downwardly from a pivot 29 to one side in the enclosure 27 is swung into position to guide the clean end of the cast strip 21 onto the guide table 30 that feeds it to the pinch roll stand 31. The apron 28 is then retracted back to its hanging position to allow the cast strip 21 to hang in a loop beneath the casting rolls 12 in enclosure 27 before it passes to the guide table 30 where it engages a succession of guide rollers.

[0038] An overflow container 38 may be provided beneath the movable tundish 14 to receive molten material that may spill from the tundish 14. As shown in FIG. 1, the overflow container 38 may be movable on rails 39 or another guide such that the overflow container 38 may be placed beneath the movable tundish 14 as desired in casting locations. Additionally, an optional overflow container (not shown) may be provided for the distributor 16 adjacent the distributor 16.

[0039] The sealed enclosure 27 is formed by a number of separate wall sections that fit together at various seal connections to form a continuous enclosure wall that permits control of the atmosphere within the enclosure 27. Additionally, the scrap receptacle 26 may be capable of attaching with the enclosure 27 so that the enclosure 27 is capable of supporting a protective atmosphere immediately beneath the casting rolls 12 in the casting position. The enclosure 27 includes an opening in the lower portion of the enclosure 27, lower enclosure portion 44, providing an outlet for scrap to pass from the enclosure 27 into the scrap receptacle 26 in the scrap receiving position. The lower enclosure portion 44 may extend downwardly as a part of the enclosure 27, the opening being positioned above the scrap receptacle 26 in the scrap receiving position. As used in the specification and claims herein, "seal," "sealed," "sealing," and "sealingly" in reference to the scrap receptacle 26, enclosure 27, and related features may not be a complete seal so as to prevent leakage, but rather is usually less than a perfect seal as appropriate to allow control and support of the atmosphere within the enclosure 27 as desired with some tolerable leakage.

[0040] A rim portion 45 may surround the opening of the lower enclosure portion 44 and may be movably positioned above the scrap receptacle 26, capable of sealingly engaging and/or attaching to the scrap receptacle 26 in the scrap receiving position. The rim portion 45 may be movable between a sealing position in which the rim portion 45 engages the scrap receptacle 26, and a clearance position in which the rim portion 45 is disengaged from the scrap receptacle 26. Alternately, the caster or the scrap receptacle 26 may include a lifting mechanism to raise the scrap receptacle 26 into sealing engagement with the rim portion 45 of the enclosure 27, and then lower the scrap receptacle 26 into the clearance position. When sealed, the enclosure 27 and scrap receptacle 26 are filled with a desired gas, such as nitrogen, to reduce the amount of oxygen in the enclosure 27 and provide a protective atmosphere for the cast strip 21.

[0041] The enclosure 27 may include an upper collar portion 43 supporting a protective atmosphere immediately beneath the casting rolls 12 in the casting position. When the casting rolls 12 are in the casting position, the upper collar portion 43 is moved to the extended position closing the space between a housing portion 53 adjacent the casting rolls 12, as shown in FIG. 2, and the enclosure 27. The upper collar portion 43 may be provided within or adjacent the enclosure 27 and adjacent the casting rolls 12, and may be moved by a plurality of actuators (not shown) such as servo-mechanisms, hydraulic mechanisms, pneumatic mechanisms, and rotating actuators.

[0042] The casting rolls 12 are internally water cooled as described below so that as the casting rolls 12 are counter-rotated, shells solidify on the casting surfaces 12A, as the casting surfaces 12A move into contact with and through the casting pool 19 with each revolution of the casting rolls 12. The shells are brought close together at the nip 18 between the casting rolls 12 to produce a thin cast strip product 21 delivered downwardly from the nip 18. The thin cast strip product 21 is formed from the shells at the nip 18 between the casting rolls 12 and delivered downwardly and moved downstream as described above.

[0043] Referring now to FIGS. 3A-10, each casting roll 12 includes a cylindrical tube 120 of a metal selected from the group consisting of copper and copper alloy, optionally with a metal or metal alloy coating thereon, e.g., chromium or nickel, to form the casting surfaces 12A. Each cylindrical tube 120 may be mounted between a pair of stub shaft assemblies 121 and 122. The stub shaft assemblies 121 and 122 have end portions 127 and 128, respectively (shown in FIGS 4-6),which fit snugly within the ends of cylindrical tube 120 to form the casting roll 12. The cylindrical tube 120 is thus supported by end portions 127 and 128 having flange portions 129 and 130, respectively, to form internal cavity 163 therein, and support the assembled casting roll between the stub shaft assemblies 121 and 122.

[0044] The outer cylindrical surface of each cylindrical tube 120 is a roll casting surface 12A. The radial thickness of the cylindrical tube 120 may be no more than 80 millimeters thick. The thickness of the tube 120 may range between 40 and 80 millimeters in thickness or between 60 and 80 millimeters in thickness.

[0045] Each cylindrical tube 120 is provided with a series of longitudinal water flow passages 126, which may be formed by drilling long holes through the circumferential thickness of the cylindrical tube 120 from one end to the other. The ends of the holes are subsequently closed by end plugs 141 attached to the end portions 127 and 128 of stub shaft assemblies 121 and 122 by fasteners 171. The water flow passages 126 are formed through the thickness of the cylindrical tube 120 with end plugs 141. The number of stub shaft fasteners 171 and end plugs 141 may be selected as desired. End plugs 141 may be arranged to provide, with water passage in the stub shaft assemblies described below, in single pass cooling from one end to the other of the casting roll 12, or alternatively, to provide multi-pass cooling where, for example, the flow passages 126 are connected to provide three passes of cooling water through adjacent flow passages 126 before returning the water to the water supply directly or through the cavity 163.

[0046] The water flow passages 126 through the thickness of the cylindrical tube 120 may be connected to water supply in series with cavity 163. The water passages 126 may be connected to the water supply so that the cooling water first passes through cavity 163 and then the water supply passages 126 to the return lines, or first through the water supply passages 126 and then through cavity 163 to the return lines.

[0047] The cylindrical tube 120 may be provided with circumferential steps 123 at end to form shoulders 124 with the working portion of the roll casting surface 12A of the casting roll 12 there between. The shoulders 124 are arranged to engage the side dams 20 and confine the casting pool 19 as described above during the casting operation.

[0048] End portions 127 and 128 of stub shaft assemblies 121 and 122, respectively, typically sealingly engage the ends of cylindrical tube 120 and have radially extending water passages 135 and 136 shown in FIGS. 4-6 to deliver water to the water flow passages 126 extending through the cylindrical tube 120. The radial flow passages 135 and 136 are connected to the ends of at least some of the water flow passages 126, for example, in threaded arrangement, depending on whether the cooling is a single pass or multi-pass cooling system. The remaining ends of the water flow passages 126 may be closed by, for example, threaded end plugs 141 as described where the water cooling is a multi-pass system.

[0049] As shown in detail by FIG. 7, cylindrical tube 120 may be positioned in annular arrays in the thickness of cylindrical tube 120 either in single pass or multi-pass arrays of water flow passages 126 as desired. The water flow passages 126 are connected at one end of the casting roll 12 by radial ports 160 to the annular gallery 140 and in turn radially flow passages 135 of end portion 127 in stub shaft assembly 121, and are connected at the other end of the casting roll 12 by radial ports 161 to annular gallery 150 and in turn radial flow passages 136 of end portions 128 in stub shaft assembly 121. Water supplied through one annular gallery, 140 or 150, at one end of the roll 12 can flow in parallel through all of the water flow passages 126 in a single pass to the other end of the roll 12 and out through the radial passages, 135 or 136, and the other annular gallery, 150 or 140, at that other end of the cylindrical tube 120. The directional flow may be reversed by appropriate connections of the supply and return line(s) as desired. Alternatively or additionally, selective ones of the water flow passages 126 may be optionally connected or blocked from the radial passages 135 and 136 to provide a multi pass arrangement, such as a three pass.

[0050] The stub shaft assembly 122 may be longer than the stub shaft assembly 121. As illustrated in FIG. 3B, the stub shaft assembly 122 may be provided with two sets of water flow ports 133 and 134. Water flow ports 133 and 134 are capable of connection with rotary water flow couplings 131 and 132 by which water is delivered to and from the casting roll 12 axially through stub shaft assembly 122. In operation, cooling water passes to and from the water flow passages 126 in the cylindrical tube 120 through radial passages 135 and 136 extending through end portions 127 and 128 of the stub shaft assemblies 121 and 122, respectively. The stub shaft assembly 121 is fitted with axial tube 137 to provide fluid communication between the radial passages 135 in end portions 127 and the central cavity within the casting roll 12. The stub shaft assembly 122 is fitted with an axial space tube, to separate a central water duct 138, in fluid communication with the central cavity 163, and from annular water flow duct 139 in fluid communication with radial passages 136 in end portion 122 of stub shaft assembly 122. Central water duct 138 and annular water duct 139 are capable of providing inflow and outflow of cooling water to and from the casting roll 12.

[0051] In operation, incoming cooling water may be supplied through supply line 131 to annular duct 139 through ports 133, which is in turn in fluid communication with the radial passages 136, gallery 150 and water flow passages 126, and then returned through the gallery 140, the radial passages 135, axial tube 137, central cavity 163, and central water duct 138 to outflow line 132 through water flow ports 134. Alternatively, the water flow to, from and through the casting roll 12 may be in the reverse direction as desired. The water flow ports 133 and 134 may be connected to water supply and return lines so that water may flow to and from water flow passages 126 in the cylindrical tube 120 of the casting roll 12 in either direction, as desired. Depending on the direction of flow, the cooling water flows through the cavity 163 either before or after flow through the water flow passages 126.

[0052] Each cylindrical tube 120 may be provided with at least one expansion ring with insulating coating thereon. As illustrated in FIG. 8, cylindrical tube 120 may be provided with at least two expansion rings 210 each with an insulating coating 350 thereon spaced on opposite end portions of the cylindrical tube 120 inward within 450 mm of edge portions of the cast strip formed during the casting campaign. FIG. 9 shows a cross sectional view longitudinally through a portion of a casting roll with expansion ring 210 with insulating coating 350 thereon spaced from the edge portions of the cast strip and having heating elements 370.

[0053] Alternatively, as illustrated in FIG. 10, at least two expansion rings 210 with insulating coating 350 thereon are spaced on opposite end portions of the cylindrical tube 120 within 450 mm of edge portions of the cast strip on opposite end portions of the casting rolls during the casting campaign, and an additional expansion ring 220 with insulating coating 330 thereon is positioned within cylindrical tube 120 at a position corresponding to center portions of the cast strip formed on the casting surfaces during casting.

[0054] In another alternative, as illustrated back in FIG. 3A, expansion ring 220 with insulating coating 330 thereon may be positioned within the cylindrical tube 120, at a position corresponding to center portions of the cast strip formed on the casting surfaces of the casting rolls during casting.

[0055] As illustrated in FIGS. 8-10, expansion rings with an insulating coating thereon may be position within and adjacent the cylindrical tube and spaced from the edge portions of the cast strip. Each expansion ring may have an annular dimension between 50 and 150 mm; (e.g. 70 mm). Similarly, the expansion ring or rings with an insulating coating thereon positioned at corresponding to center portions of the cast strip formed during casting may have an annular dimension between 50 and 150 mm; (e.g. 70 mm).

[0056] Each expansion ring with an insulating coating spaced from the edge portions of the cast strip may have a width of up to 200 mm (e.g., 83.5 mm). Similarly, the expansion ring or rings with an insulating coating thereon positioned in the center portions of the cast strip during casting may have a width of up to 200 mm (e.g., 83.5 mm).

[0057] Deformation of the crown of the casting surfaces of the casting rolls may be controlled by regulating the radial dimension of the at least one expansion ring located inside the cylindrical tube. The radial dimension of the at least one expansion ring with an insulating coating thereon may be controlled by regulating the temperature of the expansion ring. In turn, the thickness profile of the cast strip may be controlled with the radius of the expansion ring and in turn the crown of the casting surfaces of the casting rolls. Since the circumferential thickness of the cylindrical tube is made to a thickness of no more than 80 mm, the crown of the casting surfaces may be deformed responsive to changes in the radial dimension of the expansion ring.

[0058] Each expansion ring with an insulating coating thereon is adapted to increase in radial dimension causing the cylindrical tube to expand changing the crown of the casting surfaces and the thickness profile of the cast strip during casting. Power wire 222 and control wire 224 extend from slip ring 240 to each expansion ring. Power wire 222 supplies electrical power to the expansion ring. Control wire 224 provides the temperature feedback that is then used to control the power of the expansion ring.

[0059] As shown in FIG. 11, each expansion ring may have water passages 340 therein wherein water can flow through. The water flow may be controlled to regulate the expansion of the expansion rings.

[0060] Each expansion ring may be electrically heated increasing in radial dimension. As illustrated in FIG. 15, each expansion ring may have at least one heating element positioned as desired to effectively heat the ring. Expansion ring 300 has heating element 310 on the right side and heating element 320 on the left side for that purpose. Each expansion ring may provide a heating input of up to 30 kW; preferably, of at least 3 kW. The force generated from the increase in radial dimension will be applied on the cylindrical tube causing the cylindrical tube to expand changing the crown of the casting surfaces and the thickness profile of the cast strip. To achieve a desired thickness profile by control of the radial dimension of the expansion rings and control of the casting speed, a strip thickness profile sensor 71 may be positioned downstream to detect the thickness profile of the cast strip 21 as shown in FIGS. 2 and 2A. The strip thickness sensor 71 is provided typically between the nip 18 and the pinch rolls 31A to provide for direct control of the casting roll 12. The sensor may be an x-ray gauge or other suitable device capable of directly measuring the thickness profile across the width of the strip periodically or continuously. Alternatively, a plurality of non-contact type sensors are arranged across the cast strip 21 at the roller table 30 and the combination of thickness measurements from the plurality of positions across the cast strip 21 are processed by a controller 72 to determine the thickness profile of the strip periodically or continuously. The thickness profile of the cast strip 21 may be determined from this data periodically or continuously as desired.

[0061] The radial dimension of each expansion ring may be controlled independently from the radial dimension of the other expansion ring or rings. The radial dimension of the each expansion ring with an insulating coating thereon within and adjacent the strip edges of the casting rolls may be controlled independently from each other. Additionally, the radial dimension of the expansion rings within and adjacent the strip edges of the casting rolls may be controlled independently from the expansion ring or rings with insulating coating thereon corresponding to the center portions of the cast strip. The sensor 71 generates signals indicative of the thickness profile of the cast strip. The radial dimension of each expansion ring with an insulating coating thereon is controlled according to the signals generated by the sensor, which in turns control roll crown of the casting surfaces of the casting rolls during the casting campaign.

[0062] Furthermore, the casting roll drive may be controlled to vary the speed of rotation of the casting rolls, while also varying the radial dimension of the expansion ring responsive to the electrical signals received from the sensor 71 controlling in turn the roll crown of the casting surfaces of the casting rolls during the casting campaign.

[0063] It was found that an insulating coating is necessary to control heat transfer from the expansion ring to the casting roll. Conducted tests showed that the heat transfer from the expansion rings to the casting rolls during casting is minimal with the insulating coating thereon and the expansion rings can reach the desired temperature and expansion and, in turn, the desired cross-sectional strip thickness profile to commercially control the crown of the casting surfaces.

[0064] To illustrate, FIG. 12 shows tests conducted with and without the insulating coating on the expansion rings. An insulating coating of 8% Yttria stabilized zirconia was plasma sprayed onto the outside of the expansion ring obtaining an insulating coating of thickness of 0.64 mm (0.025 inch). Each expansion ring had a section of casting roll of approximately 85 mm in width shrink fitted on to the expansion ring. Each casting roll section had water passages there through. Water was supplied at approximately 1.0 bar (15 psi) and the water flow varied between 8.6 and 8.9 gpm. The inlet water temperature was 20 °C (68 °F). Separate tests were conducted at 50 % power and at 100 % power. As illustrated in FIG. 12, when tested at 50 % power, the expansion ring resulted in a peak delta temperature of 54 °C. While the expansion ring with the insulating coating thereon resulted in a peak delta temperature of 90 °C, namely an increase of 67 % in the peak delta temperature. As illustrated in FIG. 12, during the testing, heating of the uncoated expansion ring at 100 % power failed; whereas, the testing of the expansion ring with the insulating coating thereon at 100 % power resulted in a peak delta temperature of approximately 130 °C.

[0065] FIG. 13 shows a graph of the average expansion ring temperature versus the edge drop. The edge drop correlates to the thickness of the cast strip. As illustrated in FIG. 13, the edge drop appears to respond each time to the changes in the heated expansion ring temperatures. As the temperature increases, the expansion ring expands; the cast trip thickness at the edge of the casting roll decreases and the edge drop increases.

[0066] FIG. 14 shows a graph of heated ring expansion versus temperature for expansion rings coated with an insulating coating. The expansion rings were located adjacent and within casting rolls provided with water passages there through and water flowing there through in normal casting operations. The coated expansion rings were heated from 29.8 °C to 48.9 °C (85.6 °F to 120 °F). After holding briefly at 48.9 °C (120 °F), the expansion rings with the insulating coating were heated to 71 °C (160 °F) and 93 °C (200 °F). As evidenced, over 100 μm of dimensional expansion was achieved when the coated expansion rings were heated by 46 °C (115 °F). As illustrated, these results would have not been possible with uncoated expansion rings because of the heat transfer to the casting rolls. The expansion of the expansion ring is directly correlated to the temperature to which the expansion ring can be heated. As illustrated expansion rings coated with an insulating coating may be heated rapidly and achieve high effective temperature. As such, an insulating coating of at least .25mm (0.010 inch) in thickness (e.g. 0.64mm (0.025 inch)) is essential to control or eliminate heat transfer from the expansion ring to the casting roll.

[0067] In each of these embodiments of the method and apparatus, the expansion rings may also have water passages there through to permit the flow of water through the passages in the rings, and regulate the water flow through those passages. The water flow is regulated to increase or decrease the diameter of the expansion rings and in turn cylindrical tube as desired, and control the shape of the casting rolls during a campaign.

Claims

1. A method of continuously casting thin strip by controlling roll crown comprising the steps of:

a. assembling a caster having a pair of counter rotating casting rolls (12) with a nip (18) there between capable of delivering cast strip downwardly from the nip (18), each casting roll (12) having a casting surface (12A) formed by a cylindrical tube (120) having thickness of no more than 80 millimeters of a material selected from the group consisting of copper and copper alloy, optionally with a metal or metal alloy coating thereon, and having a plurality of longitudinal water flow passages (126) extending through the cylindrical tube (120);

b. positioning at least two expansion rings (210) within and adjacent the cylindrical tube (120) and spaced within 450 mm of edge portions of the cast strip formed on opposite end portions of the casting rolls (12) during a casting campaign, and/or positioning at least one expansion ring (210) within the cylindrical tube (120) corresponding to center portions of the cast strip formed on the casting rolls (12) during casting, each expansion ring (210) having at least one heating element (370) and an insulating coating (350) of at least 0.25mm (0.010 inches), with the insulating coating (350) being such that when the cylindrical tube (120) is cooled with the longitudinal water flow passages (126) and the heating element (370) operated, one said expansion ring (210) with an insulating coating of 0.64mm (0.025 inches) is capable of achieving a temperature difference relative to the cylindrical tube (120) at least 67% greater than a temperature difference that a similar but uncoated expansion ring could achieve under similar operating conditions;

c. assembling a metal delivery system capable of forming a casting pool (19) supported on the casting surfaces (12A) of the casting rolls (12) above the nip (18) with side dams (20) adjacent

to the ends of the nip (18) to confine the casting pool (19); and
d. controlling the radial dimension of the expansion rings (210) responsive to at least one of digital or analogous signal received from at least one sensor (71) to control the roll crown of the casting surfaces (12A) of the casting rolls (12) during the casting campaign.

2. The method of continuously casting thin strip by controlling roll crown as claimed in claim 1 further comprising the step of:
e. providing water passages in each expansion ring, wherein water can flow through said water passages, and controlling said water flow and regulating the expansion of the expansion rings (210).

3. The method of continuously casting thin strip by controlling roll crown as claimed in claim 1 or claim 2 further comprising the step of:
f. positioning at least one sensor capable of sensing at least one of the following properties:

- temperature of the expansion rings (210);
- thickness profile of the cast strip downstream;
- local thickness of the cast strip at a defined spot close to the cast strip edges;
- casting roll surface crown during the casting campaign;
- radial casting roll expansion at a defined spot close to the cast strip edges;

and generating digital or analogous signal or signals indicative of at least one of the above mentioned properties of the cast strip.

4. The method of continuously casting thin strip by controlling roll crown as claimed in any of the preceding claims, further comprising the step of:
g. controlling casting roll drive to vary the speed of rotation of the casting rolls (12) while varying the radial dimension of the expansion rings (210) with insulating coating (350) thereon responsive to at least one of digital or analogous signals received from the at least one sensor (71) to control roll crown of the casting surfaces (12A) of the casting rolls (12) during the casting campaign.

5. The method of continuously casting thin strip by controlling roll crown as claimed in any one of the preceding claims where each expansion ring (210) with insulating coating (350) thereon has an annular dimension between 50 and 150 mm.

6. The method of continuously casting thin strip by controlling roll crown as claimed in any one of the preceding claims where each expansion ring (210) with insulating coating (350) thereon provides a heating input of up to 30 kW.

7. The method of continuously casting thin strip by controlling roll crown as claimed in any one of the preceding claims where the radial dimension of each expansion ring (210) with insulating coating (350) thereon can be controlled independently by independently controlling water flow through water passages in each expansion ring to control the roll crown of the casting surfaces (12A) of the casting rolls (12).

8. The method of continuously casting thin strip by controlling roll crown as claimed in any one of the preceding claims further comprising the step of:
h. controlling the position of the casting roll (12) to vary the horizontal distance between the casting roll axial centerlines while varying the radial dimension of the expansion rings (210), each expansion ring (210) with insulating coating (350) thereon corresponding to at least one property in a center portion or edge portion of the cast strip responsive to at least one of digital or analogous signals received from the at least one sensor (71) to control roll crown of the casting surfaces (12A) of the casting rolls (12) during the casting campaign.

9. An apparatus for continuously casting thin strip by controlling roll crown comprising:

a. a pair of counter rotating casting rolls (12) with a nip (18) there between capable of delivering cast strip downwardly from the nip (18), each casting roll (12) having a casting surface (12A) formed by a cylindrical tube (120) having thickness of no more than 80 millimeters of a material selected from the group consisting of copper and copper alloy, optionally with a metal or metal alloy coating thereon, and having a plurality of longitudinal water flow passages (126) extending through the cylindrical tube (120);
b. at least two expansion rings (210) positioned within and adjacent the cylindrical tube (120) and spaced within 450 mm of edge portions of the cast strip formed on opposite end portions of the casting rolls (12) during a casting campaign, and/or at least one expansion ring (210) within the cylindrical tube (120) at a position corresponding to center portions of the cast strip formed on the casting rolls (12) during a casting campaign, each expansion ring (210) having at least one heating element (370) and an insulating coating (350) of at least 0.25mm (0.010 inches), with the insulating coating (350) being such that when the cylindrical tube (120) is cooled with the longitudinal water flow passages (126) and the heating element (370) operated, one said expansion ring with an insulating coating of 0.64mm (0.025 inches) is capable of achieving

a temperature difference relative to the cylindrical tube (120) at least 67% greater than a temperature difference that a similar but uncoated expansion ring could achieve under similar operating conditions;
c. a metal delivery system positioned above the nip (18) and capable of forming a casting pool (19) supported on the casting surfaces (12A) of the casting rolls (12) with side dams (20) adjacent ends of the nip (18) to confine the casting pool (19); and
d. at least one sensor capable of sensing the thickness profile of the cast strip and capable of generating electrical signals indicative of the thickness profile of the cast strip may be positioned downstream.

10. The apparatus for continuously casting thin strip by controlling roll crown as claimed in claim 9 further comprising: each expansion ring (210) having water passages wherein water can flow through said water passages (126) and regulate the expansion of the expansion ring (210),

11. The apparatus for continuously casting thin strip by controlling roll crown as claimed in claim 9 or claim 10 further comprising:
e. at least one sensor capable of sensing at least one of the following properties:

- temperature of the expansion rings (210);
- thickness profile of the cast strip positioned downstream of the nip (18);
- local thickness of the cast strip at a defined spot close to the cast strip edges;
- casting roll surface crown during the casting campaign;
- radial casting roll expansion at a defined spot close to the cast strip edges;

and capable of generating digital or analogous signal or signals indicative of at least one of the above properties to control radial dimension of the expansion rings (210) responsive to the signals received from the at least one sensor to control the roll crown of the casting surfaces of the casting rolls during the casting campaign.

12. The apparatus for continuously casting thin strip by controlling roll crown as claimed in any one of claims 9 to 11 further comprising:
f. a control system capable of controlling casting roll drive and varying the speed of rotation of the casting rolls (12) while varying the radial dimension of the expansion rings (210) with an insulating coating (350) thereon responsive to electrical signals received from the at least one sensor (71) to control the roll crown of the casting surfaces (12A) of the casting rolls (12) during the casting campaign.

13. The apparatus for continuously casting thin strip by controlling roll crown as claimed in any one of claims 9 to 12 where each expansion ring (210) with an insulating coating (350) thereon has an annular dimension between 50 and 150 mm.

14. The apparatus for continuously casting thin strip by controlling roll crown as claimed in any one of claims 9 to 13 where each expansion ring (210) with an insulating coating (350) thereon and spaced from the edge portions of the cast strip has a width of up to 200 mm.

15. The apparatus for continuously casting thin strip by controlling roll crown as claimed in any one of claims 9 to 14 where each expansion ring (210) with an insulating coating (350) thereon and spaced from the edge portions of the cast strip provides a heating input of up to 30 kW.

16. The apparatus for continuously casting thin strip by controlling roll crown as claimed in any one of claims 9 to 15 where the radial dimension of each expansion ring (210) with an insulating coating (350) thereon and spaced from the edge portions of the cast strip can be controlled independently to control the roll crown of the casting surfaces (12A) of the casting rolls (12).

Patentansprüche

1. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone, umfassend die folgenden Schritte:

a. Zusammenbauen einer Gießvorrichtung mit einem Paar gegenläufig rotierender Gießwalzen (12) mit einem Walzenspalt (18) dazwischen, die in der Lage sind, das gegossene Band von dem Walzenspalt (18) nach unten abzugeben, wobei jede Gießwalze (12) eine Gießfläche (12A) aufweist, die durch ein zylindrisches Rohr (120) mit einer Dicke von nicht mehr als 80 mm eines Materials gebildet ist, das aus der Gruppe ausgewählt ist, die aus Kupfer und Kupferlegierung besteht, gegebenenfalls mit einer Metall- oder Metalllegierungsbeschichtung darauf, und eine Vielzahl von Längswasserströmungskanälen (126) aufweist, die sich durch das zylindrische Rohr (120) erstrecken;
b. Positionieren von zumindest zwei Dehnungsringen (210) innerhalb und in Nachbarschaft des zylindrischen Rohrs (120) und beabstandet innerhalb von 450 mm von Kantenabschnitten des

gegossenen Bandes, die während eines Gießvorgangs an gegenüberliegenden Endabschnitten der Gießwalzen (12) ausgebildet sind, und/oder Positionieren zumindest eines Dehnungsrings (210) innerhalb des zylindrischen Rohrs (120) entsprechend den Mittelabschnitten des gegossenen Bandes, die während des Gießens auf den Gießwalzen (12) gebildet werden, wobei jeder Dehnungsring (210) zumindest ein Heizelement (370) und eine isolierende Beschichtung (350) von zumindest 0,25 mm (0,010 Zoll) aufweist, wobei die isolierende Beschichtung (350) derart ist, dass, wenn das zylindrische Rohr (120) mit den Längswasserströmungskanälen (126) gekühlt wird und das Heizelement (370) betrieben wird, ein Dehnungsring (210) mit einer isolierenden Beschichtung von 0,64 mm (0,025 Zoll) in der Lage ist, eine Temperaturdifferenz in Bezug auf das zylindrische Rohr (120) zu erreichen, die zumindest 67 % größer ist als eine Temperaturdifferenz, die ein ähnlicher, aber unbeschichteter Dehnungsring unter ähnlichen Betriebsbedingungen erreichen könnte;

c. Zusammenbauen eines Metallzufuhrsystems, das in der Lage ist, ein Gießbecken (19) zu bilden, das auf den Gießflächen (12A) der Gießwalzen (12) oberhalb des Walzenspaltes (18) mit Seitendämmen (20) in Nachbarschaft der Enden des Walzenspaltes (18), um das Gießbecken (19) zu begrenzen, getragen wird; und

d. Steuern der radialen Abmessung der Dehnungsringe (210), die auf zumindest eines von einem digitalen oder analogen Signal ansprechen, das von zumindest einem Sensor (71) empfangen wird, um die Walzenkrone der Gießflächen (12A) der Gießwalzen (12) während des Gießvorgangs zu steuern.

2. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach Anspruch 1, ferner umfassend den folgenden Schritt:

e. Bereitstellen von Wasserkanälen in jedem Dehnungsring, wobei Wasser durch die Wasserkanäle fließen kann, und Steuern der Wasserströmung und Regulieren der Ausdehnung der Dehnungsringe (210).

3. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach Anspruch 1 oder 2, ferner umfassend den folgenden Schritt:

f. Positionieren zumindest eines Sensors, der in der Lage ist, zumindest eine der folgenden Eigenschaften zu erfassen:

- Temperatur der Dehnungsringe (210);
- Dickenprofil des gegossenen Bandes stromabwärts;
- lokale Dicke des gegossenen Bandes an einer definierten Stelle nahe den gegossenen Bandkanten;
- Gießen der Walzenflächenkrone während des Gießvorgangs;
- radiale Ausdehnung der Gießwalze an einer definierten Stelle nahe den gegossenen Bandkanten;

und Erzeugen von einem digitalen oder analogen Signal oder Signalen, das/die zumindest eine der oben genannten Eigenschaften des gegossenen Bandes angibt/angeben.

4. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der vorhergehenden Ansprüche, ferner umfassend den folgenden Schritt:

g. Steuern des Gießwalzenantriebs, um die Drehgeschwindigkeit der Gießwalzen (12) zu variieren, während die radiale Abmessung der Dehnungsringe (210) mit der darauf befindlichen isolierenden Beschichtung (350) in Reaktion auf zumindest eines von digitalen oder analogen Signalen, die von dem zumindest einen Sensor (71) zum Steuern der Walzenkrone der Gießflächen (12A) der Gießwalzen (12) während des Gießvorgangs empfangen werden.

5. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der vorhergehenden Ansprüche, wobei jeder Dehnungsring (210) mit einer isolierenden Beschichtung (350) darauf eine ringförmige Abmessung zwischen 50 und 150 mm aufweist.

6. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der vorhergehenden Ansprüche, wobei jeder Dehnungsring (210) mit einer isolierenden Beschichtung (350) darauf eine Heizleistung von bis zu 30 kW bereitstellt.

7. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der vorhergehenden Ansprüche, wobei die radiale Abmessung jedes Dehnungsrings (210) mit der darauf befindlichen isolierenden Beschichtung (350) unabhängig gesteuert werden kann, indem die Wasserströmung durch die Wasserkanäle in jedem Dehnungsring unabhängig gesteuert wird, um die Walzenkrone der Gießflächen (12A) der Gießwalzen (12) zu steuern.

8. Verfahren zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der vorhergehenden Ansprüche, ferner umfassend den fol-

genden Schritt:
h. Steuern der Position der Gießwalze (12), um den horizontalen Abstand zwischen den axialen Mittellinien der Gießwalze zu variieren, während die radiale Abmessung der Dehnungsringe (210) variiert wird, wobei jeder Dehnungsring (210) mit einer darauf befindlichen isolierenden Beschichtung (350) zumindest einer Eigenschaft in einem Mittelabschnitt oder Kantenabschnitt des gegossenen Bandes entspricht, die auf zumindest eines von digitalen oder analogen Signalen anspricht, die von dem zumindest einen Sensor (71) empfangen werden, um die Walzenkrone der Gießflächen (12A) der Gießwalzen (12) während des Gießvorgangs zu steuern.

9. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone, umfassend:

a. ein Paar gegenläufig rotierender Gießwalzen (12) mit einem Walzenspalt (18) dazwischen, die in der Lage sind, das gegossene Band von dem Walzenspalt (18) nach unten abzugeben, wobei jede Gießwalze (12) eine Gießfläche (12A) aufweist, die durch ein zylindrisches Rohr (120) mit einer Dicke von nicht mehr als 80 mm eines Materials gebildet ist, das aus der Gruppe ausgewählt ist, die aus Kupfer und Kupferlegierung besteht, gegebenenfalls mit einer Metall- oder Metalllegierungsbeschichtung darauf, und eine Vielzahl von Längswasserströmungskanälen (126) aufweist, die sich durch das zylindrische Rohr (120) erstrecken;
b. zumindest zwei Dehnungsringe (210) innerhalb und in Nachbarschaft des zylindrischen Rohrs (120) und beabstandet innerhalb von 450 mm von Kantenabschnitten des gegossenen Bandes, die während eines Gießvorgangs an gegenüberliegenden Endabschnitten der Gießwalzen (12) ausgebildet sind, und/oder zumindest ein Dehnungsring (210) innerhalb des zylindrischen Rohrs (120) in einer Position entsprechend den Mittelabschnitten des gegossenen Bandes, die während eines Gießvorgangs auf den Gießwalzen (12) gebildet werden, wobei jeder Dehnungsring (210) zumindest ein Heizelement (370) und eine isolierende Beschichtung (350) von zumindest 0,25 mm (0,010 Zoll) aufweist, wobei die isolierende Beschichtung (350) derart ist, dass, wenn das zylindrische Rohr (120) mit den Längswasserströmungskanälen (126) gekühlt wird und das Heizelement (370) betrieben wird, ein Dehnungsring mit einer isolierenden Beschichtung von 0,64 mm (0,025 Zoll) in der Lage ist, eine Temperaturdifferenz in Bezug auf das zylindrische Rohr (120) zu erreichen, die zumindest 67 % größer ist als eine Temperaturdifferenz, die ein ähnlicher, aber unbeschichteter Dehnungsring unter ähnlichen Betriebsbedingungen erreichen könnte;
c. ein Metallzufuhrsystem, das über dem Walzenspalt (18) positioniert und in der Lage ist, ein Gießbecken (19) zu bilden, das auf den Gießflächen (12A) der Gießwalzen (12) mit Seitendämmen (20) in Nachbarschaft der Enden des Walzenspaltes (18), um das Gießbecken (19) zu begrenzen, getragen wird; und
d. zumindest ein Sensor, der in der Lage ist, das Dickenprofil des gegossenen Bandes zu erfassen und elektrische Signale zu erzeugen, die das Dickenprofil des gegossenen Bandes angeben, kann stromabwärts positioniert sein.

10. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach Anspruch 9, ferner umfassend: jeden Dehnungsring (210) mit Wasserkanälen, wobei Wasser durch die Wasserkanäle (126) fließen und die Ausdehnung des Dehnungsrings (210) regulieren kann,

11. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach Anspruch 9 oder Anspruch 10, ferner umfassend:
e. zumindest einen Sensor, der zumindest eine der folgenden Eigenschaften erfassen kann:

- Temperatur der Dehnungsringe (210);
- Dickenprofil des gegossenen Bands, das stromabwärts des Walzenspaltes (18) positioniert ist;
- lokale Dicke des gegossenen Bandes an einer definierten Stelle nahe den gegossenen Bandkanten;
- Gießen der Walzenflächenkrone während des Gießvorgangs;
- radiale Ausdehnung der Gießwalze an einer definierten Stelle nahe den gegossenen Bandkanten;

und in der Lage ist, ein digitales oder analoges Signal oder Signale zu erzeugen, das/die zumindest eine der obigen Eigenschaften angibt/angeben, um die radiale Abmessung der Dehnungsringe (210) in Reaktion auf die Signale zu steuern, die von dem zumindest einen Sensor empfangen werden, um die Walzenkrone der Gießflächen der Gießwalzen während des Gießvorgangs zu steuern.

12. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der Ansprüche 9 bis 11, ferner umfassend:
e. ein Steuersystem, das in der Lage ist, den Gießwalzenantrieb zu steuern und die Drehgeschwindigkeit der Gießwalzen (12) zu variieren, während die radiale Abmessung der Dehnungsringe (210) mit einer darauf befindlichen isolierenden Beschichtung (350) in Reaktion auf elektrische Signale,

die von dem zumindest einen Sensor (71) empfangen werden, variiert wird, um die Walzenkrone der Gießflächen (12A) der Gießwalzen (12) während des Gießvorgangs zu steuern.

13. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der Ansprüche 9 bis 12, wobei jeder Dehnungsring (210) mit einer isolierenden Beschichtung (350) darauf eine ringförmige Abmessung zwischen 50 und 150 mm aufweist.

14. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der Ansprüche 9 bis 13, wobei jeder Dehnungsring (210) mit einer isolierenden Beschichtung (350) darauf und beabstandet von den Kantenabschnitten des gegossenen Bandes eine Breite von bis zu 200 mm aufweist.

15. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der Ansprüche 9 bis 14, wobei jeder Dehnungsring (210) mit einer isolierenden Beschichtung (350) darauf und beabstandet von den Kantenabschnitten des gegossenen Bandes eine Heizleistung von bis zu 30 kW bereitstellt.

16. Vorrichtung zum Stranggießen von dünnem Band durch Steuern der Walzenkrone nach einem der Ansprüche 9 bis 15, wobei die radiale Abmessung jedes Dehnungsrings (210) mit einer darauf befindlichen isolierenden Beschichtung (350) und beabstandet von den Kantenabschnitten des gegossenen Bandes unabhängig gesteuert werden kann, um die Walzenkrone der Gießflächen (12A) der Gießwalzen (12) zu steuern.

Revendications

1. Procédé de coulée en continu de fines bandes par commande de bombage de rouleau comprenant les étapes consistant à :

a. assembler une machine de coulée ayant une paire de rouleaux de coulée contrarotatifs (12) avec une ligne de contact (18) entre eux capable de délivrer la bande coulée vers le bas depuis la ligne de contact (18), chaque rouleau de coulée (12) ayant une surface de coulée (12A) formée par un tube cylindrique (120) ayant une épaisseur de pas plus de 80 millimètres d'un matériau choisi dans le groupe constitué du cuivre et d'un alliage de cuivre, facultativement avec un revêtement métallique ou d'alliage métallique sur celui-ci, et ayant une pluralité de passages d'écoulement d'eau longitudinaux (126) s'étendant à travers le tube cylindrique (120) ;

b. le positionnement d'au moins deux bagues de dilatation (210) au sein du tube cylindrique (120) et adjacentes à celui-ci et espacées de 450 mm des portions de bord de la bande coulée formée sur les portions d'extrémité opposées des rouleaux de coulée (12) pendant une campagne de coulée, et/ou le positionnement d'au moins une bague de dilatation (210) au sein du tube cylindrique (120) correspondant aux portions centrales de la bande coulée formée sur les rouleaux de coulée (12) pendant la coulée, chaque bague de dilatation (210) ayant au moins un élément chauffant (370) et un revêtement isolant (350) d'au moins 0,25 mm (0,010 pouce), avec le revêtement isolant (350) étant tel que lorsque le tube cylindrique (120) est refroidi avec les passages d'écoulement d'eau longitudinaux (126) et l'élément chauffant (370) mis en fonctionnement, une dite bague de dilatation (210) avec un revêtement isolant de 0,64 mm (0,025 pouce) est capable d'obtenir une différence de température par rapport au tube cylindrique (120) supérieure d'au moins 67 % à une différence de température qu'une bague de dilatation similaire mais non revêtue pourrait obtenir dans des conditions de fonctionnement similaires ;

c. l'assemblage d'un système de distribution de métal capable de former un bain de coulée (19) soutenu sur les surfaces de coulée (12A) des rouleaux de coulée (12) au-dessus de la ligne de contact (18) avec des faces latérales (20) adjacentes aux extrémités de la ligne de contact (18) pour confiner le bain de coulée (19) ; et

d. la commande de la dimension radiale des bagues de dilatation (210) en réponse à au moins un signal numérique ou analogique reçu depuis au moins un capteur (71) pour commander le bombage de rouleau des surfaces de coulée (12A) des rouleaux de coulée (12) pendant la campagne de coulée.

2. Procédé de coulée en continu de fines bandes par commande de bombage de rouleau selon la revendication 1, comprenant en outre l'étape consistant à :
e. fournir des passages d'eau dans chaque bague de dilatation, dans lequel l'eau peut s'écouler à travers lesdits passages d'eau, et commander ledit écoulement d'eau et réguler la dilatation des bagues de dilatation (210).

3. Procédé de coulée en continu de fines bandes par commande de bombage de rouleau selon la revendication 1 ou la revendication 2, comprenant en outre l'étape consistant à :
f. positionner au moins un capteur capable de capter au moins l'une des propriétés suivantes :

- température des bagues de dilatation (210) ;
- profil d'épaisseur de la bande coulée en aval ;
- épaisseur locale de la bande coulée à un endroit défini proche des bords de la bande coulée ;
- bombé de surface de rouleau de coulée pendant la campagne de coulée ;
- dilatation radiale du rouleau de coulée à un endroit défini proche des bords de bande coulée ;

et générer un signal ou des signaux numériques ou analogiques indicatifs d'au moins l'une des propriétés susmentionnées de la bande coulée.

4. Procédé de coulée en continu de fines bandes par commande de bombage de rouleau selon l'une quelconque des revendications précédentes, comprenant en outre l'étape consistant à :
g. commander l'entraînement des rouleaux de coulée pour faire varier la vitesse de rotation des rouleaux de coulée (12) tout en faisant varier la dimension radiale des bagues de dilatation (210) avec un revêtement isolant (350) sur celles-ci en réponse à au moins l'un des signaux numériques ou analogiques reçus depuis
l'au moins un capteur (71) pour commander le bombage de rouleau des surfaces de coulée (12A) des rouleaux de coulée (12) pendant la campagne de coulée.

5. Procédé de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications précédentes, dans lequel chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci a une dimension annulaire entre 50 et 150 mm.

6. Procédé de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications précédentes, dans lequel chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci fournit une puissance de chauffage allant jusqu'à 30 kW.

7. Procédé de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications précédentes, dans lequel la dimension radiale de chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci peut être commandée indépendamment par commande indépendante de l'écoulement d'eau à travers les passages d'eau dans chaque bague de dilatation pour commander le bombage de rouleau des surfaces de coulée (12A) des rouleaux de coulée (12).

8. Procédé de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications précédentes, comprenant en outre l'étape consistant à :
h. commander la position du rouleau de coulée (12) pour faire varier la distance horizontale entre les lignes centrales axiales de rouleau de coulée tout en faisant varier la dimension radiale des bagues de dilatation (210), chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci correspondant à au moins une propriété dans une portion centrale ou une portion de bord de la bande coulée en réponse à au moins l'un des signaux numériques ou analogiques reçus depuis l'au moins un capteur (71) pour commander le bombage de rouleau des surfaces de coulée (12A) des rouleaux de coulée (12) pendant la campagne de coulée.

9. Appareil de coulée en continu de fines bandes par commande de bombage de rouleau comprenant :

a. une paire de rouleaux de coulée contrarotatifs (12) avec une ligne de contact (18) entre eux capable de délivrer la bande coulée vers le bas depuis la ligne de contact (18), chaque rouleau de coulée (12) ayant une surface de coulée (12A) formée par un tube cylindrique (120) ayant une épaisseur de pas plus de 80 millimètres d'un matériau choisi dans le groupe constitué du cuivre et d'un alliage de cuivre, facultativement avec un revêtement métallique ou d'alliage métallique sur celui-ci, et ayant une pluralité de passages d'écoulement d'eau longitudinaux (126) s'étendant à travers le tube cylindrique (120) ;
b. au moins deux bagues de dilatation (210) positionnées au sein du tube cylindrique (120) et adjacentes à celui-ci et espacées de 450 mm des portions de bord de la bande coulée formée sur les portions d'extrémité opposées des rouleaux de coulée (12) pendant une campagne de coulée, et/ou au moins une bague de dilatation (210) au sein du tube cylindrique (120) à une position correspondant aux portions centrales de la bande coulée formée sur les rouleaux de coulée (12) pendant une campagne de coulée, chaque bague de dilatation (210) ayant au moins un élément chauffant (370) et un revêtement isolant (350) d'au moins 0,25 mm (0,010 pouce), avec le revêtement isolant (350) de telle sorte que lorsque le tube cylindrique (120) est refroidi avec les passages d'écoulement d'eau longitudinaux (126) et l'élément chauffant (370) mis en fonctionnement, une dite bague de dilatation avec un revêtement isolant de 0,64 mm (0,025 pouce) est capable d'obtenir une différence de température par rapport au tube cylindrique (120) supérieure d'au moins 67 % à une différence de température qu'une bague de dilatation similaire mais non revêtue pourrait ob-

tenir dans des conditions de fonctionnement similaires ;
c. un système de distribution de métal positionné au-dessus de la ligne de contact (18) et capable de former un bain de coulée (19) soutenu sur les surfaces de coulée (12A) des rouleaux de coulée (12) avec des faces latérales (20) adjacentes aux extrémités de la ligne de contact (18) pour confiner le bain de coulée (19) ; et
d. au moins un capteur capable de capter le profil d'épaisseur de la bande coulée et capable de générer des signaux électriques indicatifs du profil d'épaisseur de la bande coulée peut être positionné en aval.

10. Appareil de coulée en continu de fines bandes par commande de bombage de rouleau selon la revendication 9, comprenant en outre : chaque bague de dilatation (210) ayant des passages d'eau dans lequel l'eau peut s'écouler à travers lesdits passages d'eau (126) et réguler la dilatation de la bague de dilatation (210),

11. Appareil de coulée en continu de fines bandes par commande de bombage de rouleau selon la revendication 9 ou la revendication 10, comprenant en outre :
e. au moins un capteur capable de capter au moins l'une des propriétés suivantes :

- température des bagues de dilatation (210) ;
- profil d'épaisseur de la bande coulée positionnée en aval de la ligne de contact (18) ;
- épaisseur locale de la bande coulée à un endroit défini proche des bords de la bande coulée ;
- bombé de surface de rouleau de coulée pendant la campagne de coulée ;
- dilatation radiale du rouleau de coulée à un endroit défini proche des bords de bande coulée ;

et capable de générer un signal ou des signaux numériques ou analogiques indicatifs d'au moins une des propriétés ci-dessus pour commander la dimension radiale des bagues de dilatation (210) en réponse aux signaux reçus depuis l'au moins un capteur pour commander le bombage de rouleau des surfaces de coulée des rouleaux de coulée pendant la campagne de coulée.

12. Appareil de coulée en continu de fines bandes par commande de bombage de rouleau selon l'une quelconque des revendications 9 à 11, comprenant en outre :
e. un système de commande capable de commander l'entraînement des rouleaux de coulée et de faire varier la vitesse de rotation des rouleaux de coulée (12) tout en faisant varier la dimension radiale des bagues de dilatation (210) avec un revêtement isolant (350) sur celles-ci en réponse aux signaux électriques reçus depuis l'au moins un capteur (71) pour commander le bombage de rouleau des surfaces de coulée (12A) des rouleaux de coulée (12) pendant la campagne de coulée.

13. Appareil de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications 9 à 12, dans lequel chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci a une dimension annulaire entre 50 et 150 mm.

14. Appareil de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications 9 à 13, dans lequel chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci et espacée des portions de bord de la bande coulée a une largeur allant jusqu'à 200 mm.

15. Appareil de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications 9 à 14, dans lequel chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci et espacée des portions de bord de la bande coulée fournit une puissance de chauffage allant jusqu'à 30 kW.

16. Appareil de coulée en continu d'une fine bande par commande de bombage de rouleau selon l'une quelconque des revendications 9 à 15, dans lequel la dimension radiale de chaque bague de dilatation (210) avec un revêtement isolant (350) sur celle-ci et espacée des portions de bord de la bande coulée peut être commandée indépendamment pour commander le bombage de rouleau des surfaces de coulée (12A) des rouleaux de coulée (12).

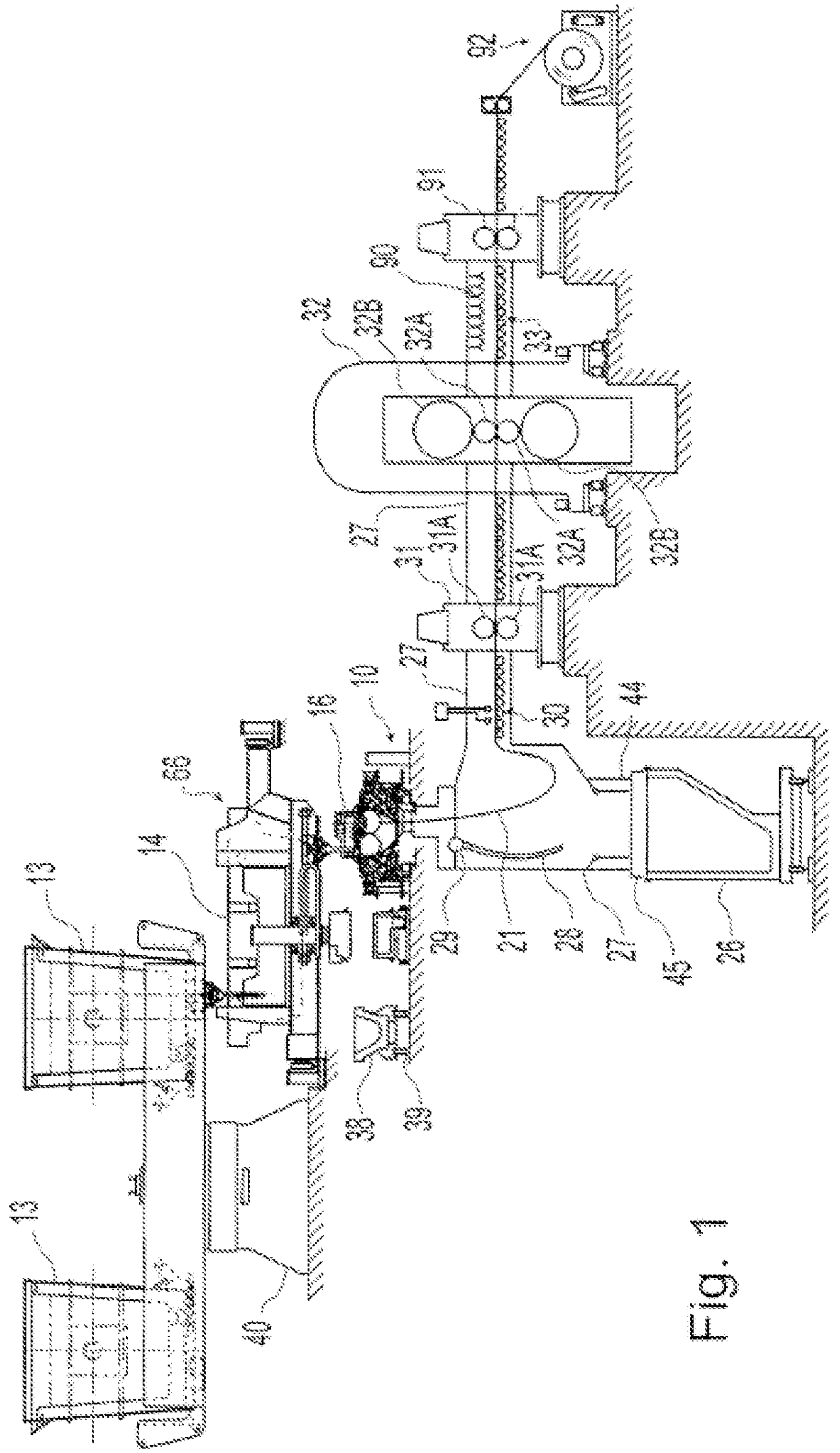
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Fig. 1

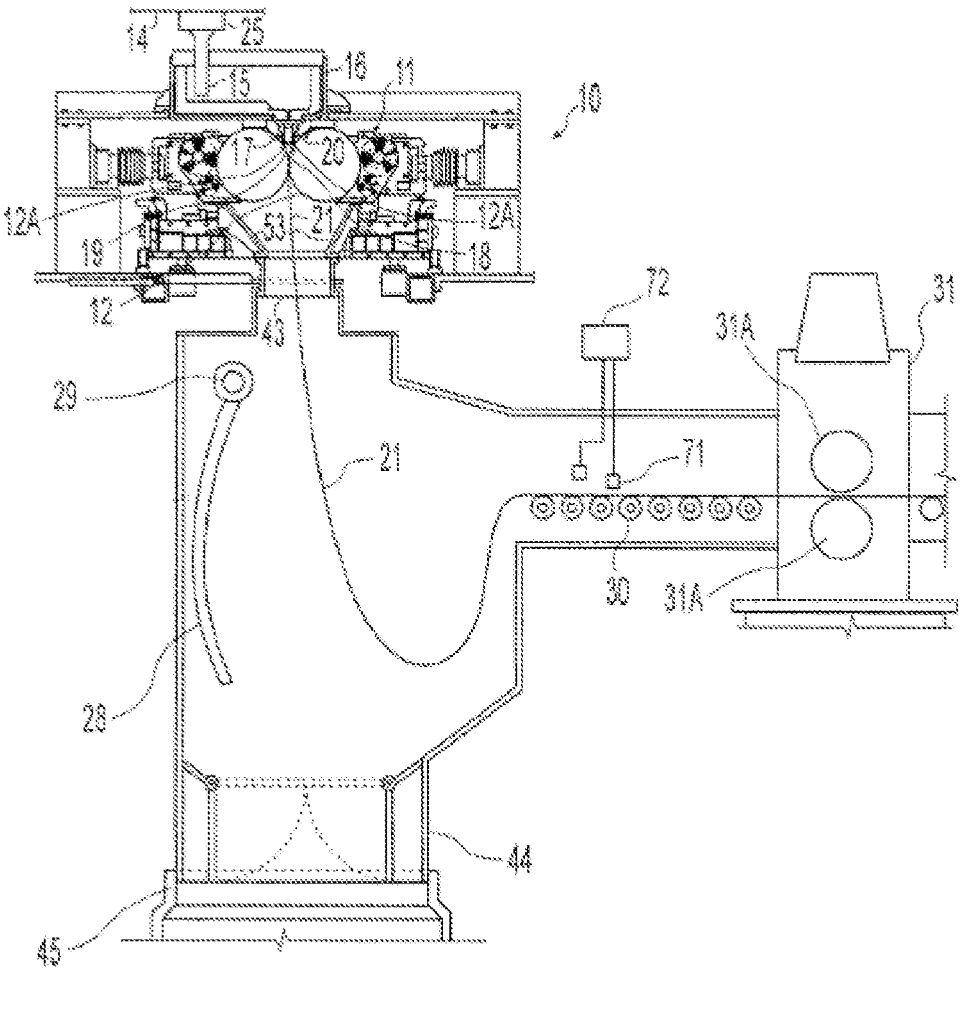
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Fig. 2

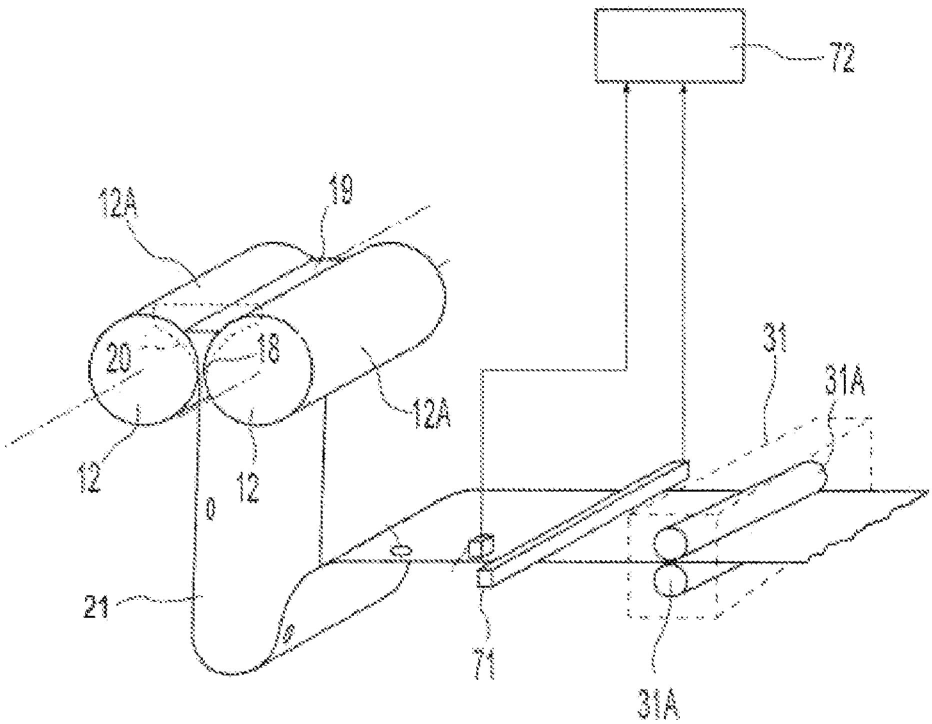

Fig. 2A

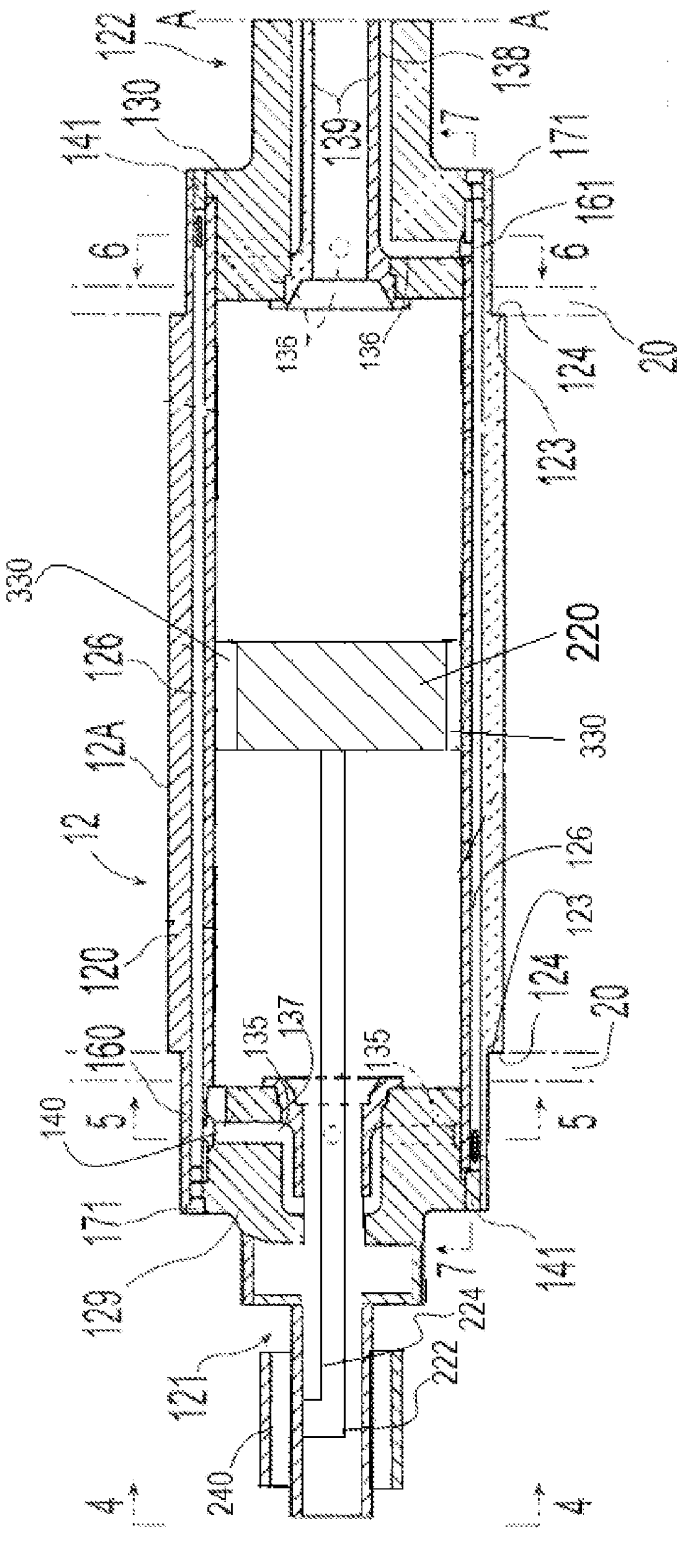
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Fig. 3A

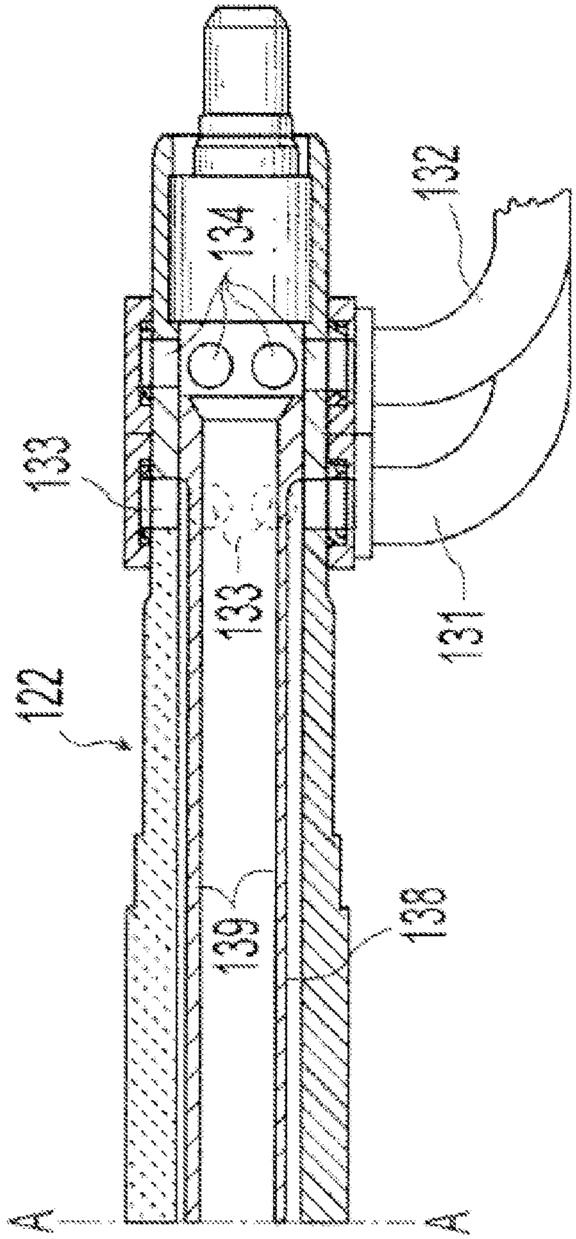

Fig. 3B

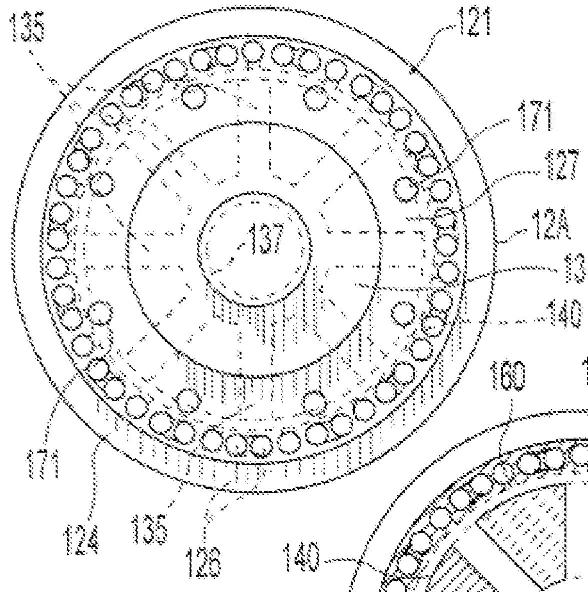

Fig. 4

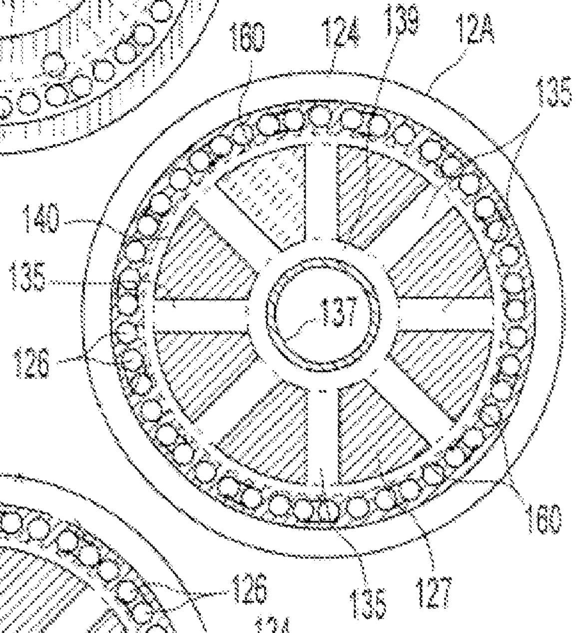

Fig. 5

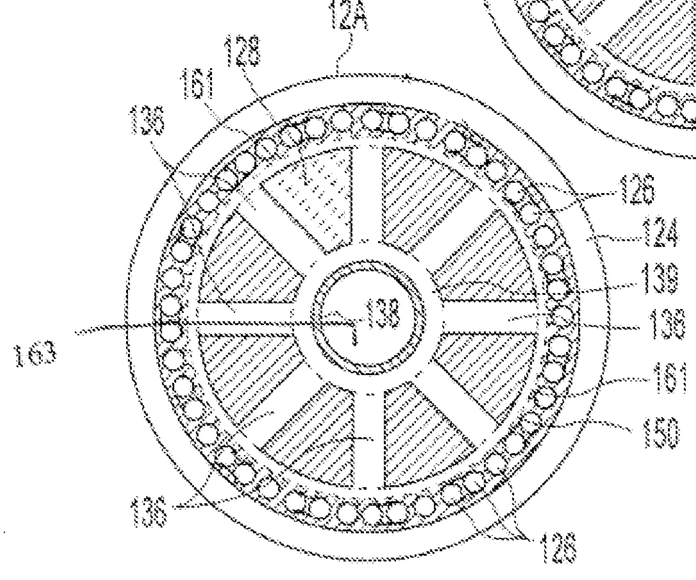

Fig. 6

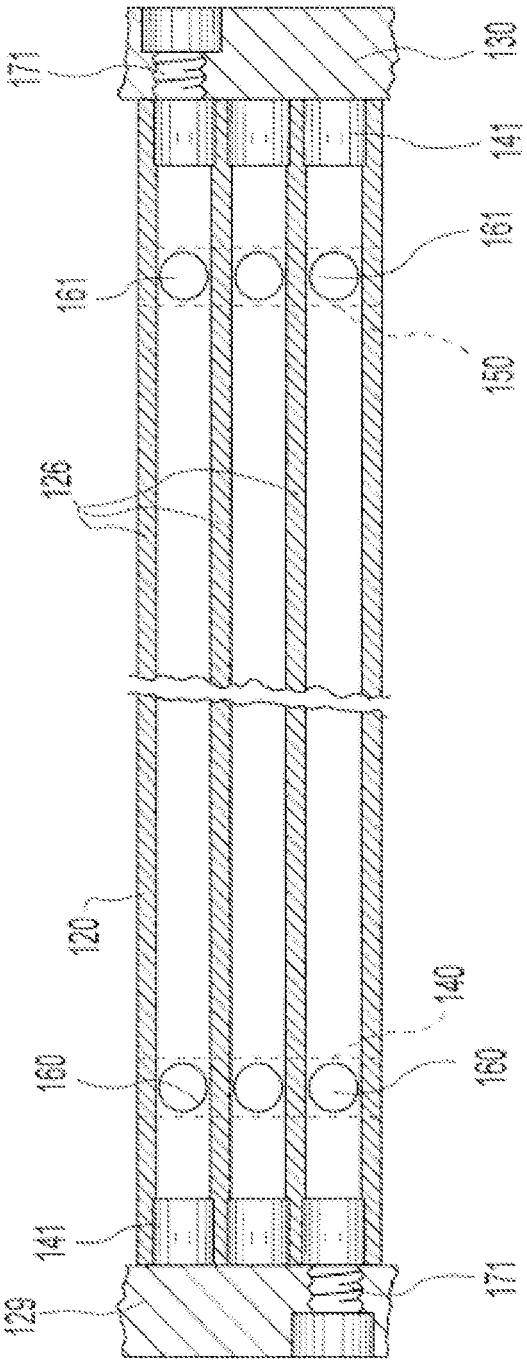

Fig. 7

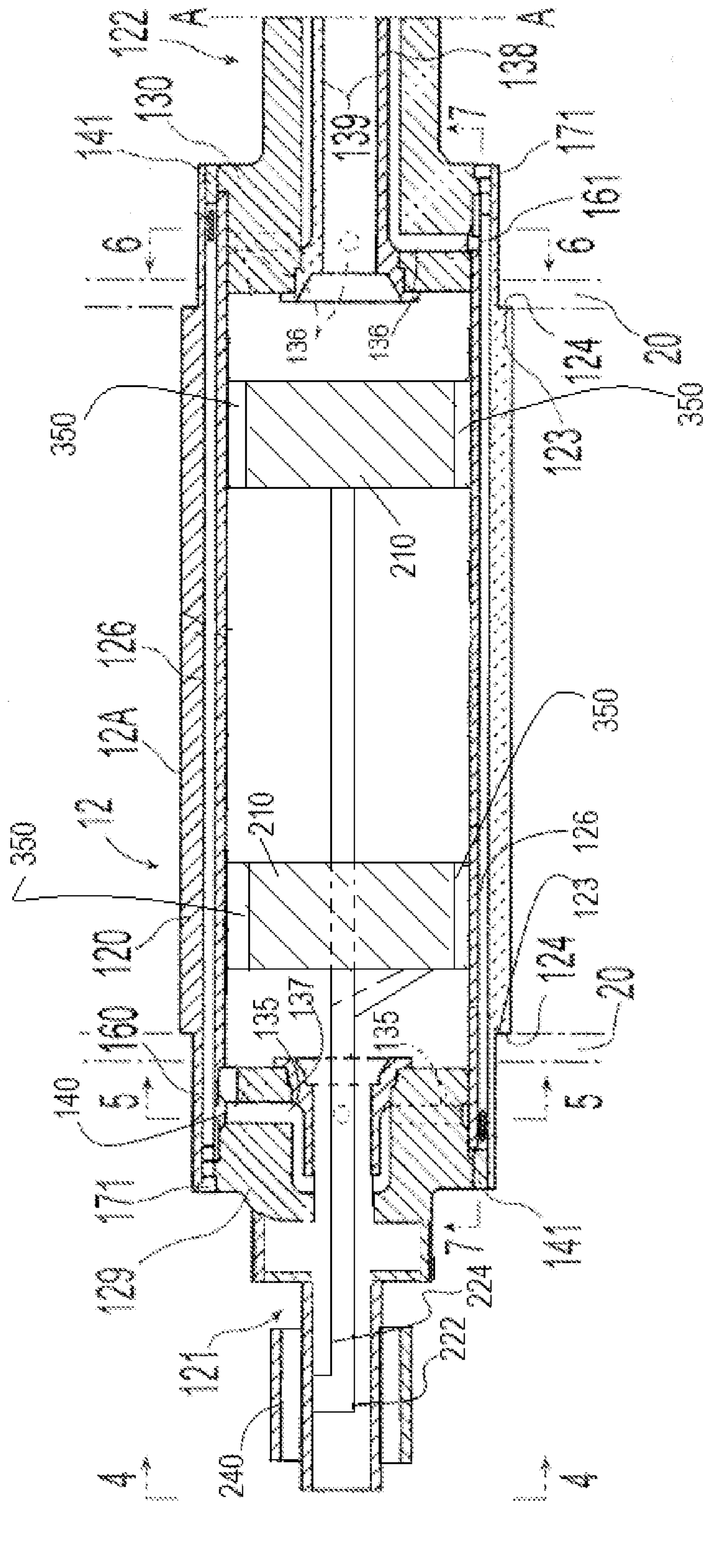
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Fig. 8

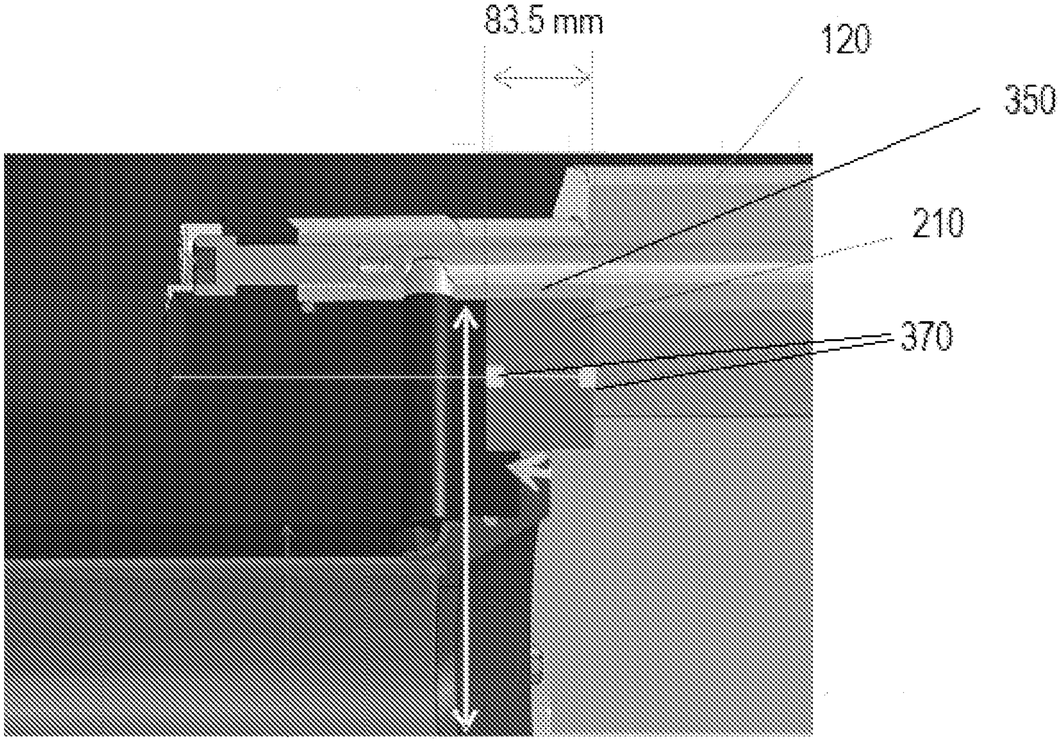

Fig. 9

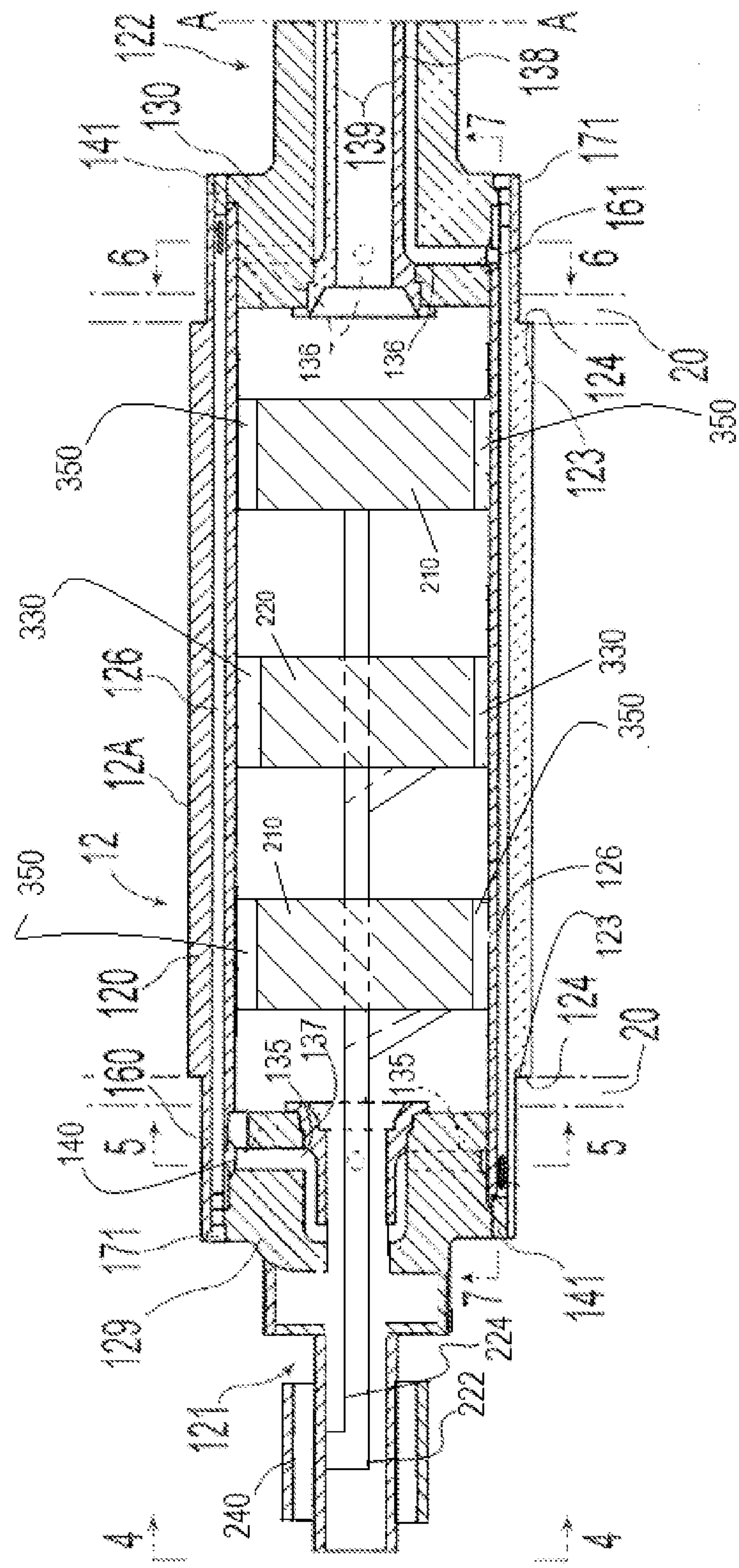
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Fig. 10

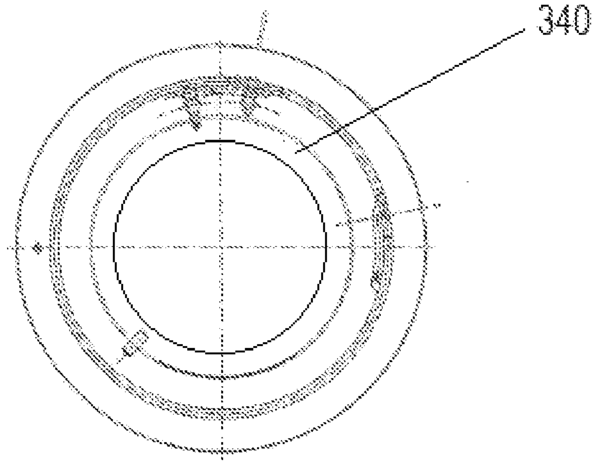

Fig. 11

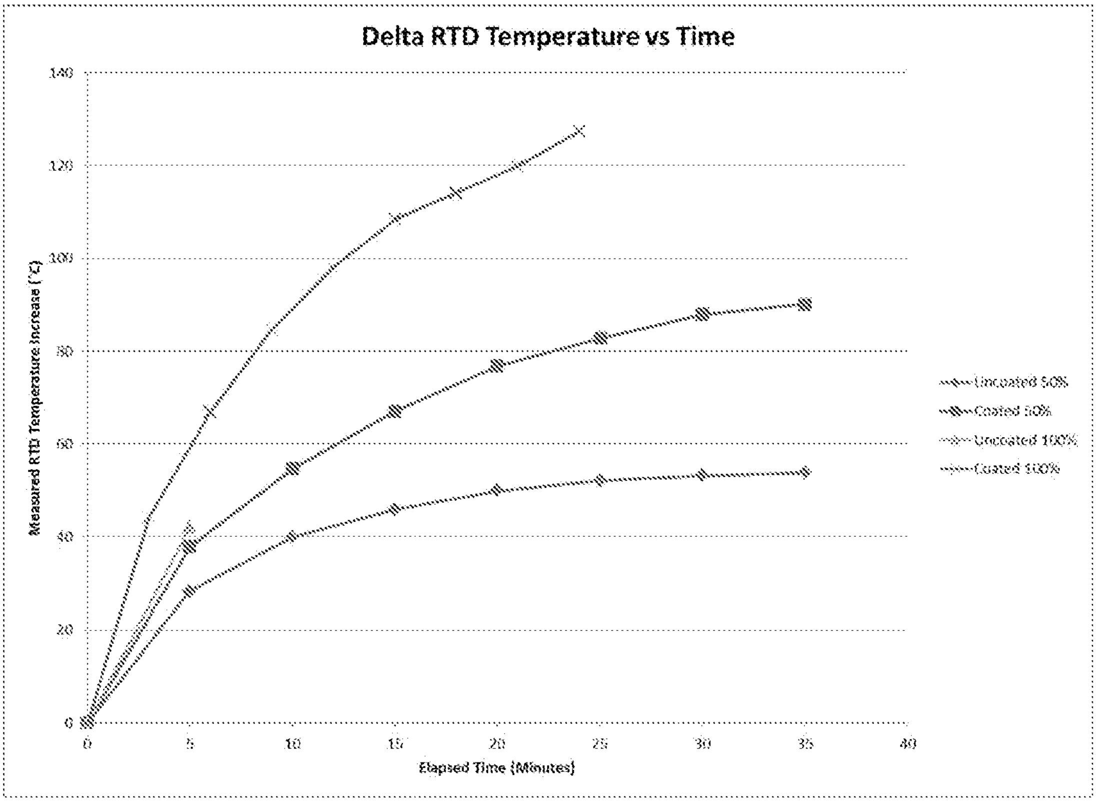
Delta RTD Temperature vs Time
Measured RTD Temperature Increase (°C)
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
Elapsed Time (Minutes)
Uncoated 50%
Coated 50%
Uncoated 100%
Coated 100%

Fig. 12

Average Ring Temperature vs. Edge Drop

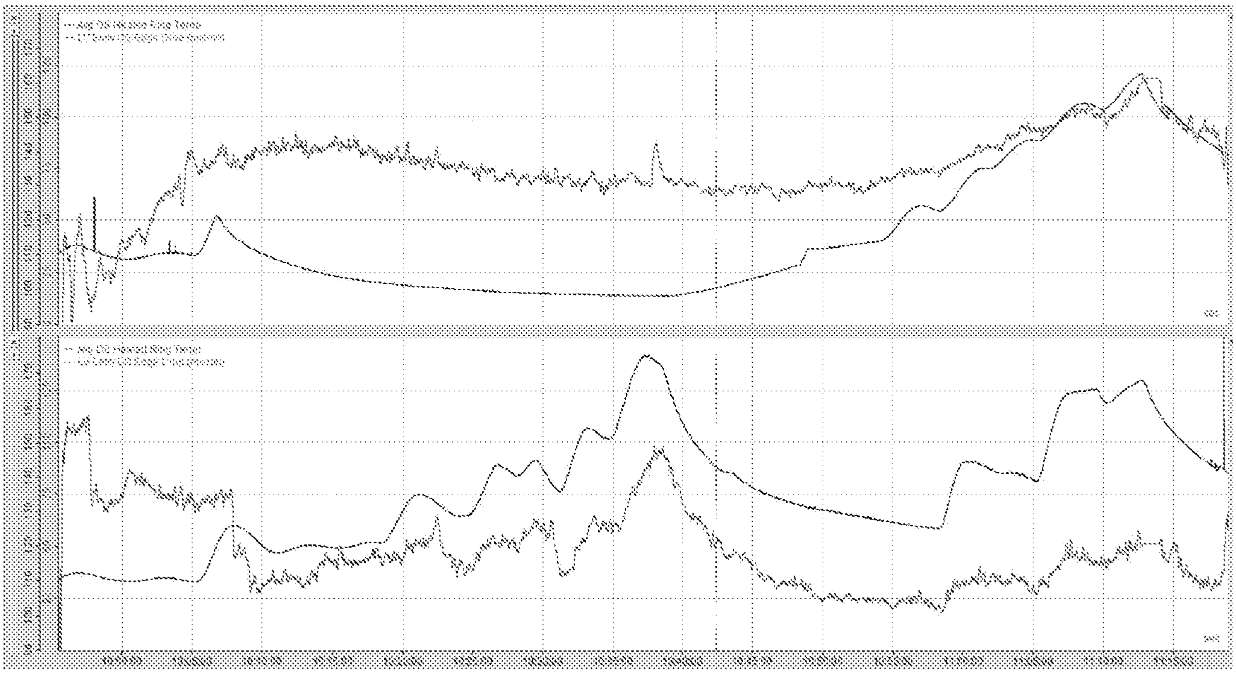

Fig. 13

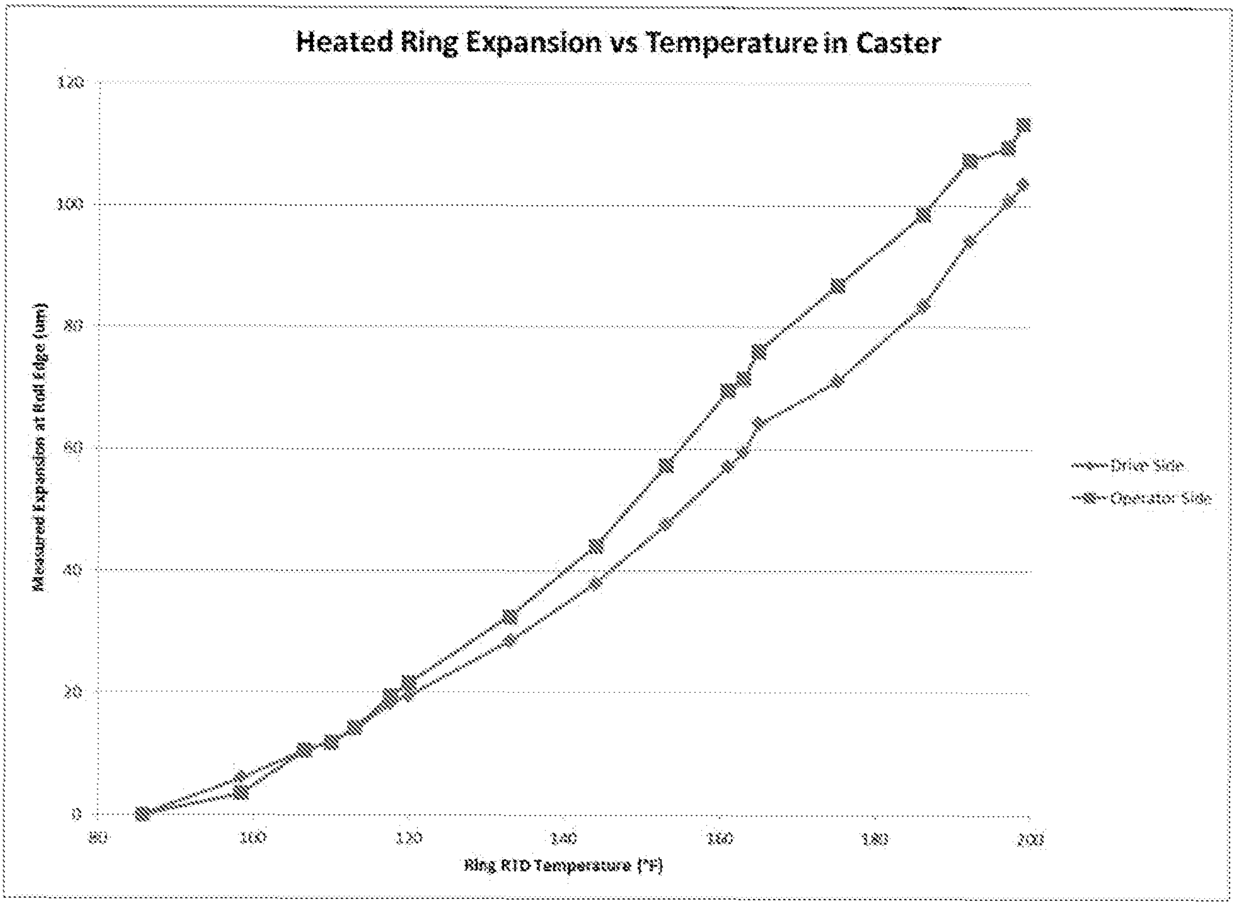
Heated Ring Expansion vs Temperature in Caster
Measured Expansion at Roll Edge (um)
Ring RTD Temperature (°F)
Drive Side
Operator Side

Fig. 14

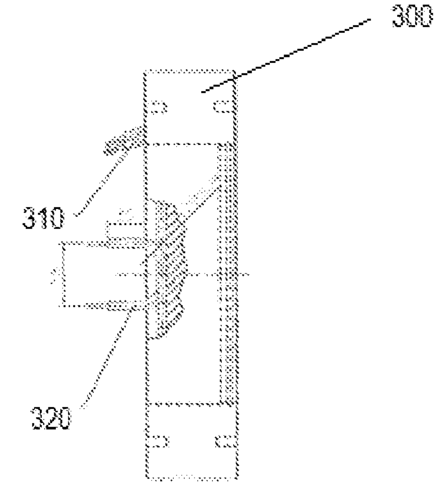

Fig. 15

REFERENCES CITED IN THE DESCRIPTION

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- US 5560421 A **[0006]**
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- US 2004256077 A **[0007]**