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(54) CONTINUOUS CASTING OF MOLTEN METAL WITH VERTICALLY FLEXIBLE EDGE CONTAINMENT

(57) An approach for continuous casting of molten metals with vertically flexible edge containment is disclosed. A vertically flexible edge containment device can confine molten metal in a moving mold cavity of a continuous metal casting apparatus. In operation, the vertically flexible edge containment device is configured to flex in a vertical direction relative to a flow of the molten metal in the moving mold cavity. The flex in the vertical direction of the vertically flexible edge containment device corresponds with changes in one of a thickness and height of the molten metal in the moving mold cavity as the molten metal travels from an upstream mold region to a downstream mold region before leaving an exit end of the moving mold cavity.

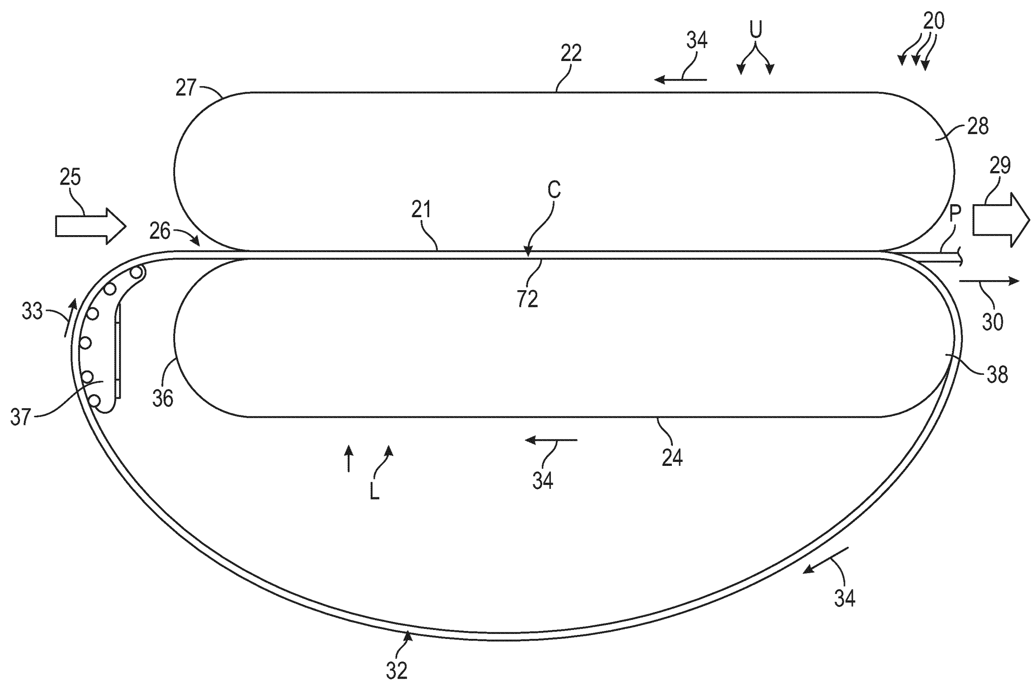

FIG. 1

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 63/539,851 filed on September 22, 2023, which is hereby incorporated by reference herein in its entirety.

BACKGROUND TECHNICAL FIELD

[0002] Embodiments of this disclosure relate generally to casting machines, and more specifically, to providing vertically flexible edge containment to a moving mold casting region in a continuous moving belt metal casting machine.

DISCUSSION OF ART

[0003] An endless edge dam of dam blocks in a casting machine such as a continuous moving belt metal casting machine is an example of one type of edge containment device that has been used to provide a side boundary to a moving mold casting region. A conventional edge dam of dam blocks is typically rigid in order to support the side of the casted slab of metal as it solidifies. The rigidity of edge containment provided by these dam blocks does not allow the belts of the casting machine to maintain contact with the slab near the edge as it travels downstream. The edge dam blocks, which are typically steel or copper, continue to support the belts through the length of the casting machine.

[0004] The solidifying metal shrinks as it as it cools and travels downstream, while the edge dam blocks expand as they absorb heat from the solidifying metal. Over most of the cast width, gravity and/or pressure on the non-cast side of the belts keeps the belts in contact with the shrinking slab. The shrinkage/expansion at the interface of the slab and edge dam blocks prevents belt-to-slab contact at the very edges. This can result in localized areas of increased slab temperature along the edges of the slab as it exits the casting machine. These localized areas of increased temperature along the edges of the slab are an indication of uneven heat extraction rates which can result in longitudinal cracks through the thickness of the slab.

BRIEF DESCRIPTION

[0005] The following presents a simplified summary of the disclosed subject matter in order to provide a basic understanding of some aspects of the various embodiments described herein. This summary is not an extensive overview of the various embodiments. It is not intended to exclusively identify key features or essential features of the claimed subj ect matter set forth in the Claims, nor is it intended as an aid in determining the scope of the claimed subj ect matter. Its sole purpose is to present some concepts of the disclosure in a streamlined form as a prelude to the more detailed description that is presented later.

[0006] Embodiments described herein provide a solution that obviates the issues that arise in a casting machine such as a continuous moving belt metal casting machine that deploys an edge dam with rigid edge containment. The solution provided by the embodiments includes a vertically flexible edge containment device for a casting machine that is rigid enough to support continuous casting and edge formation, yet vertically flexible to closely correspond or better match with changes in one of the thickness and height of a shrinking solidified slab as it travels together through the moving mold casting region of the casting machine that can include an upstream mold region and a downstream mold region. In one embodiment, the vertical flexing of the vertically flexible edge containment device can vary as a function of a length that the molten metal in the moving mold casting region is from the molten metal injector. This vertical flexibility provided by the vertically flexible edge containment device of the various embodiments allows the downstream section of the top belt to maintain uniform contact with the top of the solidified slab, providing an improved and more uniform transverse temperature profile. Moreover, this uniform contact of the slab that is provided by the top belt ensures uniform heat extraction.

[0007] In one aspect, a continuous metal casting apparatus includes opposing rotating casting surfaces forming a moving mold casting region therebetween that defines a moving mold cavity, the moving mold casting region having an upstream mold region and a downstream mold region and a molten metal injector to introduce molten metal into an entrance end of the moving mold cavity. The apparatus further includes a vertically flexible edge containment device to confine the molten metal in the moving mold cavity as the molten metal solidifies, wherein the vertically flexible edge containment device is configured to flex in a vertical direction relative to a flow of the molten metal in the moving mold cavity, wherein the flex in the vertical direction of the vertically flexible edge containment device varies as a function of a length that the molten metal in the moving mold cavity is from the molten metal injector.

[0008] In an embodiment, the vertically flexible edge containment device includes a web of material extending between the upstream mold region and the downstream mold region that is configured to vary in height as the molten metal travels from the upstream mold region to the downstream mold region.

[0009] In an embodiment, vertically flexible edge containment device comprises an endless loop of material that moves along with the opposing rotating casting surfaces, wherein the endless loop of material is configured to vary in height between the upstream mold region and the downstream mold region, the height variation in the endless loop of material corresponding with the length that the molten metal in the moving mold cavity is from the molten metal injector.

[0010] In an embodiment, the vertically flexible edge containment device includes an endless edge dam formed of edge dam blocks that revolve in a preselected path with the opposing rotating casting surfaces about the moving mold cavity.

[0011] In an embodiment, each edge dam block includes a lower dam block portion, an upper dam block portion seated on the lower dam block portion, and a mechanism for imparting a default force between the lower dam block portion and the upper dam block portion that pushes the lower dam block portion and the upper dam block portion apart from each other.

[0012] In an embodiment, the lower dam block portion comprises a lower main body that extends from a cast side to a non-cast side and an upward protruding region that extends upward from the lower main body at the cast side, the upward protruding region and the lower main body each having a surface that slopes downward from the cast side towards the non-cast side.

[0013] In an embodiment, the upper dam block portion comprises an upper main body that extends from the non-cast side to the cast side and a shelf region that expands out from the upper main body towards the cast side, the upper main body and the shelf region each having a lower surface that slopes upward from the non- cast side to the cast side, wherein the upward sloping lower surface of the shelf region sits on the downward sloping surface of the upward protruding region and the upward sloping lower surface of the upper main body sits on the downward sloping surface of the lower main body.

[0014] In an embodiment, the apparatus further includes an edge dam block compressor that is configured to impart a compressive load into the edge dam blocks at the non-cast side while the edge dam blocks are moving through the upstream mold region, the compressive load counteracting the default force between the lower dam block portion and the upper dam block of each of the edge dam blocks in the upstream mold region.

[0015] In an embodiment, the compressive load compresses the edge dam blocks in the upstream mold region towards the cast side of the edge dam blocks, leading to an increase in height of the of the edge dam blocks to full height.

[0016] In an embodiment, the imparting mechanism of each of the edge dam blocks in the upstream mold region is further configured to impart a decreasing force in response to the edge dam blocks being at full height, the decreasing force causing a decrease in height from full height to a compressed height as the edge dam blocks travel to the downstream mold region.

[0017] According to another aspect, a continuous metal casting apparatus includes opposing rotating casting surfaces forming a moving mold casting region therebetween that defines a moving mold cavity, the moving mold casting region having an upstream mold region and a downstream mold region. The apparatus further includes a molten metal injector to introduce molten metal into an entrance end of the moving mold cavity and an endless edge dam formed of edge dam blocks that revolve in a preselected path with the opposing rotating casting surfaces about the moving mold casting region to provide a side boundary to the molten metal in the moving mold cavity as the molten metal travels from the upstream mold to the downstream mold region before leaving an exit end of the of the moving mold cavity as a slab of metal. Wherein each edge dam block includes a lower dam block portion, an upper dam block portion seated on the lower dam block portion, and at least one spring situated to impart a force into the upper dam block portion while the edge dam block is moving through the upstream mold region, the imparted force pushing the upper dam block portion laterally towards a non-cast side opposing a cast side, reducing full height of the edge dam block to a compressed height as the edge dam block travels through the downstream mold region.

[0018] In an embodiment, the apparatus further includes an edge dam block compressor that is configured to impart a compressive load into the edge dam blocks at the non-cast side while the edge dam blocks are moving the upstream mold region.

[0019] In an embodiment, the compressive load leads to an increase in height of the of the edge dam block to full height.

[0020] In an embodiment, the at least one spring of each edge dam block comprises a first spring and a second spring spaced apart from the first spring in the lower dam block portion about the cast side.

[0021] According to another aspect, a method for providing vertically flexible edge containment to molten metal in a moving mold casting region having an upstream mold region and a downstream mold region that defines a moving mold cavity in a continuous moving belt metal casting machine includes introducing the molten metal into an entrance end of the moving mold cavity with a molten metal injector. The method further includes confining the molten metal in the moving mold cavity with a vertically flexible edge containment device as the molten metal travels from the upstream mold region to the downstream mold region before leaving an exit end of the of the moving mold cavity as a slab of metal and flexing the vertically flexible edge containment device in a vertical direction relative to a flow of the molten metal in the moving mold cavity, wherein the flex in the vertical direction of the vertically flexible edge containment device corresponds with changes in one of a thickness and height of the molten metal in the moving mold cavity as the molten metal travels from the upstream mold region to the downstream mold region before leaving the exit end of the of the moving mold cavity.

[0022] In an embodiment, the flexing comprises varying a height of the vertically flexible edge containment device as a function of a length that the molten metal in the moving mold casting region is from the molten metal injector.

[0023] In an embodiment, the vertically flexible edge containment device comprises one of a web of material extending between the upstream mold region and the downstream mold region, and an endless loop of material that moves along with opposing rotating casting surfaces in the continuous moving belt metal casting machine.

[0024] In an embodiment, the vertically flexible edge containment device comprises an endless edge dam formed of edge dam blocks that revolves in a preselected path with opposing rotating casting surfaces about the moving mold casting region.

[0025] In an embodiment, the method further includes applying a compressive load at a non-cast side of the edge dam blocks that are passing through the upstream mold region, the compressive load compressing the edge dam blocks in the upstream mold region towards the cast side of the edge dam blocks, leading to an increase in height of the of the edge dam blocks to full height, and reducing the full height of the edge dam blocks to a compressed height as the edge dam blocks move from the upstream mold region into the downstream mold region.

[0026] In an embodiment, the vertically flexible edge containment device enables opposing rotating casting surfaces in the casting machine that form the moving mold casting region to maintain uniform contact with the molten metal in the mold casting region, the uniform contact ensuring uniform heat extraction throughout the casting machine such that the metal at the exit end of the of the moving mold cavity has a uniform transverse temperature profile.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The present invention will be better understood from reading the following description of non-limiting embodiments, with reference to the attached drawings, wherein below:

FIG. 1 shows a schematic side elevational view of a twin-belt continuous casting machine that can be deployed with a vertically flexible edge containment device according to an embodiment of the invention;

FIG. 2 shows a perspective view of an edge dam block that can be used in an endless edge dam of compressible edge dam blocks to form a vertically flexible edge containment device according to an embodiment of the invention;

FIGS. 3A and 3B show perspective views of an upper dam block portion of an edge dam block from a top view and a bottom view, respectively, according to an embodiment of the invention;

FIGS. 4A-4C show various perspective views of a lower dam block portion of an edge dam block according to an embodiment of the invention;

FIG. 5A shows a perspective view from a cast side of an edge dam block;

FIG. 5B shows a cross-section of the edge dam block, both of which show the edge dam block with a reduced or compressed height according to an embodiment of the invention;

FIG. 6A shows a perspective view from a cast side of an edge dam block;

FIG. 6B shows a cross-section of the edge dam block, both of which show the edge dam block with a full height according to an embodiment of the invention;

FIG. 7 shows a perspective view of an edge dam block coupled to a flexible member that is configured to receive a plurality of edge dam blocks to form an endless edge dam that can provide vertically flexible edge containment with a casting machine like that depicted in FIG. 1 according to an embodiment of the invention;

FIG. 8 shows a top view of an edge dam block compressor system for providing flexible edge containment to a moving mold casting region in a casting machine such as a continuous moving belt metal casting machine with a vertically flexible edge containment device utilizing an endless edge dam of compressible edge dam blocks according to an embodiment of the invention; and

FIG. 9 shows an alternative to the system depicted in FIG. 8 in which an angled edge dam block compressor is utilized to compress the edge dam blocks according to an embodiment of the invention.

DETAILED DESCRIPTION

[0028] Example embodiments of the present invention will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments are shown. Indeed, the present invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. For like numbers may refer to like elements throughout.

[0029] This disclosure relates generally to casting machines such as continuous moving belt metal casting machines that employ one or more endless, flexible, moving heat-conducting casting belts (e.g., metallic casting belts). Such a belt or belts define a moving mold casting region having a mold cavity or mold space along which the belt or belts are continuously moving therethrough. In this manner, successive areas of each belt enter the mold casting region, move along the mold casting region and subsequently leave the mold casting region. The product of such continuous casting is normally a continuous slab, plate, sheet or strip, or a generally rectangular continuous bar of a metallic material that can include, but is not limited to, aluminum, copper, lead, and zinc. The vertically flexible edge containment device (which confines molten metal in the moving mold cavity as the molten metal solidifies) can have utility with a continuous moving belt metal casting machine that produces a continuous slab, plate, sheet or strip, or a generally rectangular continuous bar of any of these metallic materials. Although the description that follows is directed to a continuous moving belt metal casting machine, it is understood that the vertically flexible edge containment device of the various embodiments is suitable for use with any continuous casting machine that has a need to provide a side boundary to support solidifying metal, while preventing any metal from escaping laterally from between the casting surfaces.

[0030] FIG. 1 shows a schematic side elevational view of a twin-belt continuous casting machine 20 as seen from the outboard side. The upper carriage is indicated at U and the lower carriage at L. Through molten-metal-feeding equipment that can include a molten metal injector with a nozzle (not shown), both which are known in the art of continuous casting machines, molten metal is introduced into the entrance end 26 of the mold cavity or mold space C of the moving mold casting region 21. This introduction of molten metal is schematically indicated by the large open arrow 25 shown at the left in FIG. 1, and open arrow 29 at the right shows product flow. A continuously cast product P shown at the right in FIG. 1 emerges (arrow 30) from an exit end of moving mold cavity C of the moving mold casting region 21. In one embodiment, the continuously cast product P can include a continuous slab of metallic material. The description of the various embodiments that follows may refer to the cast product as a slab, and this designation is not meant to be limiting as the product could include a plate, sheet or strip, or a generally rectangular continuous bar.

[0031] The upper and lower sides of the moving mold cavity C are bounded by endless revolving upper (top) and lower (bottom), flexible, thin-gauge, heat-conducting casting belts 22 and 24, respectively. These casting belts are normally fabricated from thin flexible sheet metal. The front or working surfaces of the casting belts may be suitably treated with any a number of protective coatings that are known in the art. For example, the reverse surfaces can be cooled by liquid coolant.

[0032] The two lateral sides of the moving mold cavity C are bounded by two revolving edge dams 32 as known in the art. Only one edge dam 32 is shown in FIG. 1 with the lower belt 24 for clarity. Lower belt 24 and edge dams 32 revolve around a downstream pulley drum 38 after passing by the mold casting region 21 (as shown by motion arrows 34) and travel back towards the entrance (upstream) end 26 of the moving mold cavity via upstream dam block rollers 37. Upper belt 22 is shown revolving around an upstream upper pulley drum 27 and around a downstream upper pulley drum 28. The structure and operation of such a twin-belt casting machines is well known in the art of continuous moving belt metal casting machines.

[0033] Edge dam guide 72, also known as side guides can be employed to guide the path of the edge dams 32 despite the pressure of the metallostatic head of molten metal in the mold casting region 21. To this end, these edge-dam guides keep the edge-dams in contact with the product while it is solidifying before it becomes solid enough to retain its own shape without remelting the edge.

[0034] It is understood that the continuous casting machine 20 of FIG. 1 can include other components as known in the art. These components are not necessary to provide an understanding of the various embodiments and are not detailed in this disclosure for purposes of clarity. Further, it is understood that the continuous casting machine 20 is not meant to be limiting to the various embodiments. Those skilled in the art will appreciate that the various embodiments can have applicability with other types of continuous casting machines.

[0035] A conventional edge dam of edge dam blocks is typically rigid in order to support the metallostatic head of the non-solidified cast slab. Because the rigidity of edge containment that is provided by these conventional edge dam blocks continues through the length of the casting machine, belt-to-slab contacts at the very edges is prevented. As a result, heat extraction can be lower near the edge of the cast product as it travels through the casting machine. This can be seen as increased temperature measurements in the local area as the cast product exits the casting machine and could be an indication of less homogeneous material properties caused by slower solidification rates near the edge.

[0036] The various embodiments obviate the issues that arise from rigid edge containment by providing a vertically flexible edge containment device that is rigid enough to support continuous casting and edge formation, yet vertically flexible to closely correspond or better match with changes in the thickness or the height of a shrinking solidified slab as it travels through the casting cavity defined by the moving mold casting region of the casting machine that can include at least an upstream mold region and a downstream mold region. In one embodiment, the vertical flexing of the vertically flexible edge containment device can vary as a function of a length that the molten metal in the moving mold casting region is from the molten metal injector.

[0037] These mold regions can be looked upon as a function of the changing height of the edge dams 32 while in the moving mold casting region 21. In one embodiment, in which the edge dams 32 include an endless edge dam of compressible edge dam blocks, the upstream mold region is from where the metal enters the moving mold casting region 21 at the entrance end 26 at a full height to where the edge dam blocks end at having a full height, and the downstream mold region is where the edge dam blocks start to have a compressed or reduced height to the end of the moving mold casting region 21. In general, as used herein, "upstream" and "downstream" are terms that indicate a direction relative to the flow of the molten metal and the slab of metal formed in and passing through the moving mold casting region 21 towards the exit end.

[0038] It is understood that this representation is only an example of one characterization of the moving mold casting region and is not meant to have a limiting effect on the various embodiments. For example, the moving mold casting region 21 can have a transitional mold region between the upstream mold region and the downstream mold region.

[0039] As discussed below in more detail, the vertically flexible edge containment device that is provided with the various embodiments can be configured to alter its' height at any given point along the length of the casting machine. This capability to have control over height of the edge dams at any point along the length of the casting machine is in contrast to the rigid edge containment approaches that do not have any control over the height of the dams. With this control over the height of the edge dams that is provided by the various embodiments, one can have the capability to configure the height change of the dams to optimally result in a slab that has more even heat extraction across the width. As a result, there will be more homogenous material properties and temperature of the slab as it exits the casting machine.

[0040] In addition, this vertical flexibility of the vertically flexible edge containment device of the various embodiments allows the downstream section of the upper belt 22 to maintain uniform contact with the solidified slab providing an improved transverse temperature profile. As used herein, an improved transverse temperature profile means less variation of temperature will be measured across the width of the slab as it exits the casting machine. Moreover, allowing vertical flexibility in the edge containment will enable the upper belt 22 to fully contact the top of the solidified slab ensuring uniform heat extraction throughout the machine.

[0041] FIG. 2 shows a perspective view of an edge dam block 40 that can be used in an endless edge dam of compressible edge dam blocks like that depicted in FIG. 1 to form a vertically flexible edge containment device according to an embodiment of the invention. In this embodiment, the edge dam block 40 is configured to be compressible to provide vertical flexibility in the height of the dam block while traveling through the moving mold casting region of the casting machine. As shown in FIG. 2, the edge dam block 40 can include a lower dam block portion 42 having a lower main body 44 that extends from a cast side 46 to an opposing non-cast side 48 and an upward protruding region 50 that extends upward from the lower main body 44 at the cast side. In one embodiment, the upward protruding region 50 and the lower main body 44 can each have a surface that slopes downward from the cast side 46 towards the non-cast side 48. As used herein, the cast side is the side of the edge dam block 40 that faces the moving mold casting region where a slab of metal is formed from the molten metal, and the non-cast side is the side of the edge dam block that faces away from the mold casting region and the slab of metal.

[0042] FIG. 2 further shows that the edge dam block 40 can include an upper dam block portion 52 seated on the lower dam block portion 42. In one embodiment, the upper dam block portion 52 can have an upper main body 54 that extends from the non-cast side 48 to the cast side 46 and a shelf region 56 that expands out from the upper main body towards the cast side. The upper main body 54 and the shelf region 56 can each have a lower surface that slopes upward from the non-cast 48 side to the cast side 46. As shown in FIG. 2, the upward sloping lower surface of the shelf region 56 can sit on the downward sloping surface of the upward protruding region 50, and the upward sloping lower surface of the upper main body 54 can sit on the downward sloping surface of the lower main body 44.

[0043] As shown in FIGS. 4C and 7, at least one spring 58 can be situated in the lower dam block portion 42 about the cast side 46 of the lower main body 44 that is operative to impart a force into the upper main body 54 while the edge dam block 40 travels through the downstream mold region of the moving mold casting region. In this manner, the imparted force can push the upper main body 54 laterally towards the non-cast side 48. This reduces the total height of the edge dam block 40 as the edge dam block travels through the downstream mold region. As noted above, in certain embodiments, the moving mold casting region can include a transitional mold region between the upstream mold region and the downstream mold region. In these embodiments, the at least one spring 58 in some of the edge dam blocks in the transitional mold region can be configured to begin to impart a force into the upper main body 54 of the dam blocks, reducing the total height of those blocks in the transitional mold region and maintaining the reduced height while entering and passing through the downstream mold region.

[0044] In one embodiment, as shown in FIGS. 4C and 7, the at least one spring 58 of each edge dam block 40 can include a first spring and a second spring spaced apart from the first spring in the lower dam block portion 42 about the cast side 46 of the lower main body 44. FIG. 7 shows that the springs 58 can be placed in corresponding grooves 60 formed in the cast side 46 of the upper main body 54 of the upper dam block portion 52 that are operative to receive the springs. Although FIG. 7 depicts grooves to receive the springs 58, it is understood that other mechanical shapes can be formed in the upper main body 54 of the upper dam block portion 52 and are not meant to be limiting. For example, a slot, a slit, a passage, opening, and the like can be formed in the upper main body 54 of the upper dam block portion 52 to receive the springs 58.

[0045] Also, it is understood that the embodiment depicted in FIGS. 4C and 7 represents only one configuration of how the lower dam block portion 42 can impart a into the upper main body 54 via the springs 58 for purposes of reducing the total height of the blocks and maintaining the reduced or compressed height. For example, instead of having the springs 58 contact the upper main body 54 via the grooves, the springs can be configured to contact the face on the upper main body without grooves.

[0046] In one embodiment, as shown in FIG. 2, FIG. 3A, FIG. 3B, FIG. 5A, and FIGS. 6A and 7, the upper main body 54 of upper dam block portion 52 can have at least one counterbore slot 68 formed therethrough. In one embodiment, as shown in FIG. 3A, the slot 68 defines an opening with an inward facing shelf feature 70 that extends around an inner region. The slot 68 can receive at least one fastener 74 to facilitate a coupling of the lower dam block portion 42 of the edge dam block 40 with the upper dam block portion 52. To this extent, upon insertion, the at least one fastener 74 can sit on the inward facing shelf feature 70 of the slot 68 and be fastened to the lower dam block portion 42 to facilitate the coupling of the lower dam block portion 42 of edge dam block 40 with the upper dam block portion 52.

[0047] The at least one fastener 74 can include any of a number of well-known fasteners that can facilitate the coupling of the lower dam block portion 42 of edge dam block 40 with the upper dam block portion 52. For example, the at least one fastener 74 can include a screw, a bolt, a pin, an insert, a rivet, and the like. In addition to these examples of fasteners, other approaches can be used to secure the lower dam block portion 42 with the upper dam block portion 52.

[0048] In operation, by default, the springs 58 are loaded between the lower dam block portion 42 and the upper dam block portion 52 such that these halve portions are pushing apart from one another. The lower main body 44 of the lower dam block portion 42 can receive a force from the springs 58 that is imparted into the upper main body 54 of the upper dam block portion 52 below the shelf region 56 that sits atop the upward protruding region 50 of the lower dam block portion 42. This force imparted into the upper main body 54 of the upper dam block portion 52 causes the upper main body 54 to push laterally towards the non-cast side 48 away from the lower main body 44 of the lower dam block portion 42.

[0049] This imparted force that pushes the upper main body 54 of the upper dam block portion 52 laterally towards the non-cast side 48 away from the lower main body 44 of the lower dam block portion 42 results in the edge dam block 40 having a reduced or compressed total height. FIGS. 5A and 5B provide various views showing the reduced total height of the edge dam block 40 that can occur when the upper dam block portion 52 is pushed laterally towards the non-cast side 48 away from the lower main body 44 of the lower dam block portion 42 by the springs. As used herein, an edge dam block with a "reduced or compressed total height" means that that there is a deviation from the actual full height of the edge dam block, while an edge dam block with its actual "full height" corresponds to the actual height of the edge dam block when subject to an external horizontal force between the lower dam block portion and the upper dam block portion that brings the halves together increasing the height to its actual full height. FIGS. 6A and 6B provide various views of an edge dam block with its actual full height that is in contrast to the edge dam block of FIGS. 5A and 5B that has a reduced total height. In particular, in order to be "full height," the upper dam block portion 52 needs to move closer to the lower dam block portion 42 which compresses the springs more. When the edge dam block is at full height there is more spring force than when it is at compressed height, and when it is at compressed height there is still a spring force greater than zero to keep the springs from being loose.

[0050] The ability to have the edge dam blocks change from a full height to a reduced or compressed height and vice a versa enables the edge dam blocks of the various embodiments to provide vertically flexible edge containment. In this manner, a continuous loop of edge containment of edge dam blocks can be provided for a casting machine that is rigid enough to support continuous casting and edge formation, yet vertically flexible to closely correspond or better match with changes in the thickness or the height of a shrinking solidified slab as it travels through the moving mold casting region of the casting machine. FIGS. 8 and 9 provide further details describing how to effectuate a change in the height of the edge dam blocks during the casting of the slab, such as from a full height to a reduced height and vice versa to provide such vertically flexible edge containment to confine molten metal.

[0051] To form the endless edge dam 32 like that depicted in FIG. 1, the edge dam blocks 40 can be coupled to a looped endless tension member 62 such as a ribbon or a strap shown in FIG. 7. Although FIG. 7 shows the tension member 62 with only one edge dam block 40, it is understood that a typical tension member used in a continuous moving casting machine would have more dam blocks to attain the endless edge dam. In one embodiment as shown in FIGS. 2, 4A-4C, and 7, the lower main body 44 of the lower dam block portion 42 of each edge dam block 40 can include a notch 64 that extends therethrough transverse to the cast side 46 and the non-cast side 48. To this extent, the tension member 62 can extend through the notch allowing the edge dam block to sit on the tension member. It is understood that the notch 64 and the screw fastener design of FIGS. 4B and 7 represent only an example of one configuration that can be used to couple the edge dam blocks 40 to the tension member 62 and is not meant to be limiting as other designs are possible. For example, a T-slot and roll pin design, can be used to secure the edge dam blocks to a dam strap such as the tension member 62.

[0052] As noted above, the endless edge dam 32 of the edge dam blocks 40 can be operatively coupled to the belts of the casting machine so that the dam blocks revolve in a preselected path to provide a side boundary to the moving mold casting region 21. FIG. 8 shows a top view of a system 76 for providing flexible edge containment to confine the molten metal introduced into the mold cavity of a moving mold casting region 21 in a casting machine such as a continuous moving belt metal casting machine with a vertically flexible edge containment device utilizing an endless edge dam of compressible edge dam blocks according to an embodiment of the invention. In this embodiment depicted in FIG. 8, a molten metal injector 77 can introduce the molten metal into the moving mold casting region 21 via a channel 79 that feeds into the upstream mold region 21A.

[0053] As noted above, the moving mold casting region can be characterized into various regions in order to convey points where the edge dams change height. These mold regions illustrate this concept, and in particular, convey points in the moving mold casting region where the edge dam blocks deliberately have a change to their height. The deliberate changes to the height of the blocks in the edge dams will depend on how the overall system of the casting machine is configured.

[0054] As shown in the system 76 depicted in FIG. 8, the moving mold casting region 21 can include an upstream mold region 21A and a downstream mold region 21B. This representation is meant to be only an example of one characterization of a moving mold casting region. Those skilled in the art will appreciate that the moving mold casting region can include more or less regions. For example, the mold casting region 21 can include a transitional mold region between the upstream mold region and the downstream mold region. Further, it is understood that the size of each mold region depicted in FIG. 8 is representative of one size and is not meant to be limiting as the sizes of the upstream mold region 21A and the downstream mold region 21B can vary.

[0055] The vertically flexible edge containment that is provided by the system 76 is achieved in part by utilizing the compressible quality of the edge dam blocks 40 to have the vertical flexibility to change from a full height to a reduced or compressed height and vice versa. The system 76 provides other elements that can facilitate the vertically flexible edge containment that is achieved in this embodiment. For example, as shown in FIG. 8, the system 76 can include the edge dam block guide 72 to maintain alignment of the plurality of edge dam blocks 40 as the edge dam blocks travel adjacent to the upstream mold region 21A.

[0056] In one embodiment, edge dam block guide 72 can include an edge dam block compressor 80. As shown in FIG. 8, the edge dam block compressor 80 can define the length of the upstream mold region 21A. The edge dam block compressor 80 is operative to impart a compressive load at the non- cast side of the edge dam blocks 40 that can counteract the spring force in each of the edge dam blocks that by default pushes the top and bottom halves apart from one another. In this manner, the compressive load imparts a compressive force into the upper dam block of portion and the lower dam block portion of the edge dam blocks 40 that are passing through the upstream mold region 21A to counteract the default bias of the springs in the blocks. This compressive force compresses the edge dam blocks 40 laterally towards the cast side of the edge dam blocks, obtaining a full height of the edge dam blocks and maintaining it as the blocks pass through the upstream mold region 21A.

[0057] In one embodiment, the edge dam block compressor 80 can be integrated with the edge dam block guide 72. The edge dam block compressor 80 can operate by applying an external force to the edge dam blocks (e.g., via the endless loop strap that receives the edge dam blocks). A compression spring 82 can be compressed between the edge dam guide 72 and a fixed block 84 attached to the casting machine. A threaded rod 86 can be used with a nut or knob 88 to adjust the compression spring force of the compression spring. To this extent, the edge dam guide 72 can pivot around a main pivot 90. Other pivots can be used to allow non-binding rotation around the main pivot 90.

[0058] As the edge dam blocks 40 move downstream from the edge dam block compressor 80 into the downstream mold region 21B from the upstream mold region 21A, a total height of the blocks is reduced. In particular, the height of the edge dam blocks transitions from full height to reduced or compressed height. The reduced total height of the edge dam blocks 40 downstream from the edge dam block compressor 80 is due to the at least one spring situated in the lower dam block portion about the cast side of each edge dam block imparting a force into the upper dam block portion while the edge dam block travels to the downstream mold region 21B. As noted above, the imparted force pushes the upper main body laterally towards the non-cast side, reducing the total height of the edge dam block in this area.

[0059] In operating the system 76 in this manner, the reduced total height of the edge dam blocks 40 in the downstream mold region 21B of the moving mold casting region 21 can closely correspond or better match with changes in the thickness of the solidified slab of metal 30 produced in the casting machine that shrinks while traveling from the upstream mold region 21A through the downstream mold region 21B. As a result, the dam block guide 72 and the edge dam block compressor 80 enable the rotating casting surfaces of the belts 22 and 24 (FIG. 1) to provide more uniform contact with the slab of metal 30 produced in the casting machine that travels through the mold casting region 21. Instead of having the reduced total height of the edge dam blocks 40 closely correspond or better match with changes in the thickness of the slab of metal, this reduced total height of the blocks can be configured to match the height of the slab or be less than the height of slab at any point. In one embodiment, the reduction in the total height of the edge dam blocks can vary as a function of the length that the molten metal in the moving mold casting region is from the molten metal injector.

[0060] Another benefit of the method implemented by the system 76 is that the uniform contact with the solidified slab of metal produces a slab with a more uniform transverse temperature profile. In general, as used herein, a slab with a more uniform transverse temperature profile means that the deviation of temperature measurements measured across the slab cross section will be less than that of conventional methods of non-flexible edge dam containment. It is understood that typical measurements can be taken by direct surface contact measurement of the slab via a hand held probe, or other methods (e.g., infrared laser scanning, pyrometers etc.) to ascertain whether a more uniform transverse temperature profile as defined herein is attained.

[0061] It is understood that the configuration shown in FIG. 8 represents only one approach that can be utilized to apply a force to the edge dam blocks described herein passing through the upstream mold region 21A to effectuate vertically, flexible edge containment of the molten metal in the moving mold casting region 21. Those skilled in the art will appreciate that other elements can be used with the system 76, as can other configurations be deployed in place of this system depicted in FIG. 8. For example, a one-piece fixture could be used to apply the force to the edge dam blocks. To this extent, this one-piece fixture can define a path that produces a height profile of any manner between full height and compressed height as a function of the length into the moving mold region 21 . In another variation, the edge dam block compressor 80 can be configured to pivot in a manner that allows it to apply the force to the edge dam blocks. Another option can include configuring the edge dam block compressor 80 to slide upstream/downstream to change the size of the upstream mold region 21A and the downstream mold region 21B during casting based on a number of variables that can include, but are not limited to cast speed, alloy type, tundish temperature, etc.

[0062] FIG. 9 shows a system 92 that is an alternative to the one depicted in FIG. 8 in that the edge dam block compressor 80 extends into a transitional mold region 21C placed between the upstream mold region 21A and the downstream mold region 21B, with the part of the compressor that is in the transitional mold region being angled. Although not shown in FIG. 9, it is understood that the system 92 can include elements from FIG. 8 that facilitate the application of a force to the edge dam blocks passing about the upstream mold region 21A and the transitional mold region 21C. For example, the system 92 can include the use of the edge dam block guide 72, the compression spring 82, the fixed block 84 the threaded rod 86, the nut or knob 88 and the main pivot 90. Similarly, the variations mentioned with respect to FIG. 8 are also applicable to FIG. 9.

[0063] As shown in FIG. 9, the edge dam block compressor 80 includes a portion that extends into the transitional mold region 21C from the upstream mold region 21A. In this manner, the edge dam block compressor 80 can apply the force to some of the edge dam blocks that enter the transitional mold region 21C after passing out from the upstream mold region 21A. The portion of the edge dam block compressor 80 that extends into the transitional mold region 21C has a section closer to the downstream mold region 21B that is angled outward from the moving mold casting region 21. At this section where the edge dam block compressor 80 is angled outward from the moving mold casting region 21 is where the at least one spring situated in the lower dam block portion about the cast side of each edge dam block in this area can impart the force into the upper dam block portion of the dam blocks, reducing the total height of the blocks as those blocks continue by the remaining portion of the transitional mold region 21C into and through the downstream mold region 21B.

[0064] It is understood that the configuration shown in FIG. 9 represents only one approach that can be utilized to apply a force to the edge dam blocks passing by the transitional mold region 21C with an edge dam block compressor 80. Those skilled in the art will appreciate that variations are possible, and thus the configuration of FIG. 9 is not meant to be limiting. For example, the angled portion of the edge dam block compressor 80 in the transitional mold region 21C may be angled more in comparison to the amount depicted in FIG. 9. Further, the angled edge dam block compressor 80 can be radiused or otherwise configured with a type of a non-linear path. Another variation to the design depicted in FIG. 9 can include having a chamfer on the corner of each of the edge dam blocks to better mesh with the transition defined by the angled edge dam block compressor 80 as the blocks pass by the upstream mold region 21A into the transitional mold region 21C.

[0065] Although the edge dam block configuration described to this point with regard to the vertically flexible edge containment device that deploys such blocks utilizes a spring to impart the force into the upper dam block portion of the dam blocks to reduce the total height of the blocks, it is understood that these embodiments are not limited to the spring design described herein. Moreover, it is understood that other means for imparting a force can be utilized to attain a vertically, flexible edge containment device. For example, one or more springs can be oriented vertically within the multi part edge dam block. In another embodiment, the edge dam blocks can be cut in a manner to use the material as a spring.

[0066] As mentioned above, other means for imparting a force into the edge dam blocks can be utilized in place of a spring. For example, in one embodiment, a magnet can be used to pull the upper dam block portion away from the moving mold casting region 21 from the non-cast side. In another embodiment, a T-track or similar product can be used at the non-cast side positioned about the upper dam block portions so that these portions can ride on the T-track or the like. In this manner, the T- track or similar product can be used to control the relative distance between the two edge dam block halves.

[0067] The use of an endless dam of edge dam blocks to act as a vertically flexible edge containment device in a continuous metal casting apparatus represents only one type of vertically, flexible edge containment device and is not meant to be limiting to the various embodiments of the invention. Those skilled in the art will appreciate that the vertically flexible edge containment device can be configured to other implementations. For example, other endless loop (or possibly non- endless loop) configurations that provide vertically, flexible edge containment are possible. In one embodiment, the vertically flexible edge containment device can include a web of material that extends between the upstream mold region and the downstream mold region that is configured to vary in height as a function of the changes in the thickness or height of the molten metal in the moving mold cavity. Examples of such a web of material can include, but are not limited to, a ceramic rope with spring back, a type of inflated high temp fabric tube loop or material(s) in an endless loop or non-endless loop configuration that can be flexibly compressed, bent, shrunk, articulated or otherwise changed in height as it travels through the various mold regions that make up the moving mold casting region.

[0068] In one embodiment, this web of material can be configured with various elements that facilitate the flexibly compressing, bending, shrinking, articulating or otherwise changing of its height while traveling through the various mold regions. For example, a support bar or suitable structure can be used to support the web of material as it travels through the various mold regions. Pulleys and a belt system can be used to pass the web of material in and out of the mold regions for those embodiments in which the web of material is configured as an endless loop.

[0069] From the description of the embodiments presented herein, it should be evident that the subject disclosure sets forth an effective solution that obviates the issues that arise in a continuous moving belt metal casting machine that deploys an edge dam with rigid edge containment. The solution provided by the embodiments includes a vertically, flexible edge containment device that is rigid enough to support continuous casting edge formation, yet vertically flexible to closely correspond or better match with changes in the thickness or the height of a shrinking solidified slab as it travels through the casting cavity defined by the moving mold casting region of the casting machine. In one embodiment, the vertical flexing of the vertically flexible edge containment device can vary as a function of a length that the molten metal in the moving mold casting region is from the molten metal injector. This vertical flexibility allows the downstream section of the top belt to maintain uniform contact with the solidified slab providing an improved uniform transverse temperature profile. Moreover, allowing vertical flexibility in the edge containment will enable the top belt to better contact the top of the solidified slab ensuring uniform heat extraction throughout the machine. A more even heat extraction across the width of the slab will result in more homogenous material properties and temperature as the slab exits the casting machine.

[0070] While specific embodiments and examples are described herein for illustrative purposes, various modifications and methods are possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize. For example, parts, components, steps and aspects from different embodiments may be combined or suitable for use in other embodiments even though not described in the disclosure or depicted in the figures. Therefore, since certain changes may be made in the above-described invention, without departing from the spirit and scope of the invention herein involved, it is intended that all of the subject matter of the above description shown in the accompanying drawings shall be interpreted merely as examples illustrating the inventive concept herein and shall not be construed as limiting the invention.

[0071] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below. For example, references to "one embodiment" of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0072] In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, in the following claims, terms such as "first," "second," "third," "upper," "lower," "bottom," "top," etc. are used merely as labels, and are not intended to impose numerical or positional requirements on their objects. The terms "substantially," "generally," and "about" indicate conditions within reasonably achievable manufacturing and assembly tolerances, relative to ideal desired conditions suitable for achieving the functional purpose of a component or assembly. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted as such, unless and until such claim limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

[0073] What has been described above includes examples of systems and methods illustrative of the disclosed subject matter. It is, of course, not possible to describe every combination of components or methodologies here. One of ordinary skill in the art may recognize that many further combinations and permutations of the claimed subject matter are possible. Furthermore, to the extent that the terms "includes," "has," "possesses," and the like are used in the detailed description, claims, appendices and drawings, such terms are intended to be inclusive in a manner similar to the term "comprising" as "comprising" is interpreted when employed as a transitional word in a claim. That is, unless explicitly stated to the contrary, embodiments "comprising," "including," or "having" an element or a plurality of elements having a particular property may include additional such elements not having that property. Moreover, articles "a" and "an" as used in the subject specification and annexed drawings should generally be construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form.

[0074] This written description uses examples to disclose several embodiments of the invention, including the best mode, and also to enable ordinary skill in the art to practice the embodiments of invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to one of ordinary skill in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. A continuous metal casting apparatus, comprising:

opposing rotating casting surfaces forming a moving mold casting region therebetween that defines a moving mold cavity, the moving mold casting region having an upstream mold region and a downstream mold region; and
a molten metal injector to introduce molten metal into an entrance end of the moving mold cavity;
a vertically flexible edge containment device to confine the molten metal in the moving mold cavity as the molten metal solidifies, wherein the vertically flexible edge containment device is configured to flex in a vertical direction relative to a flow of the molten metal in the moving mold cavity, wherein the flex in the vertical direction of the vertically flexible edge containment device varies as a function of a length that the molten metal in the moving mold cavity is from the molten metal injector.

2. The continuous metal casting apparatus of claim 1, wherein the vertically flexible edge containment device comprises a web of material extending between the upstream mold region and the downstream mold region that is configured to vary in height as the molten metal travels from the upstream mold region to the downstream mold region.

3. The continuous metal casting apparatus of claim 1, wherein the vertically flexible edge containment device comprises an endless loop of material that moves along with the opposing rotating casting surfaces, wherein the endless loop of material is configured to vary in height between the upstream mold region and the downstream mold region, the height variation in the endless loop of material corresponding with the length that the molten metal in the moving mold cavity is from the molten metal injector.

4. The continuous metal casting apparatus of claim 1, wherein the vertically flexible edge containment device comprises an endless edge dam formed of edge dam blocks that revolve in a preselected path with the opposing rotating casting surfaces about the moving mold cavity.

5. The continuous metal casting apparatus of claim 4, wherein each edge dam block comprises:

a lower dam block portion;
an upper dam block portion seated on the lower dam block portion; and
a mechanism for imparting a default force between the lower dam block portion and the upper dam block portion that pushes the lower dam block portion and the upper dam block portion apart from each other.

6. The continuous metal casting apparatus of claim 5, wherein the lower dam block portion comprises a lower main body that extends from a cast side to a non-cast side and an upward protruding region that extends upward from the lower main body at the cast side, the upward protruding region and the lower main body each having a surface that slopes downward from the cast side towards the non-cast side.

7. The continuous metal casting apparatus of claim 6, wherein the upper dam block portion comprises an upper main body that extends from the non-cast side to the cast side and a shelf region that expands out from the upper main body towards the cast side, the upper main body and the shelf region each having a lower surface that slopes upward from the non-cast side to the cast side, wherein the upward sloping lower surface of the shelf region sits on the downward sloping surface of the upward protruding region and the upward sloping lower surface of the upper main body sits on the downward sloping surface of the lower main body.

8. The continuous metal casting apparatus of claim 6, further comprising an edge dam block compressor that is configured to impart a compressive load into the edge dam blocks at the non-cast side while the edge dam blocks are moving through the upstream mold region, the compressive load counteracting the default force between the lower dam block portion and the upper dam block of each of the edge dam blocks in the upstream mold region.

9. The continuous metal casting apparatus of claim 8, wherein the compressive load compresses the edge dam blocks in the upstream mold region towards the cast side of the edge dam blocks, leading to an increase in height of the of the edge dam blocks to full height.

10. The continuous metal casting apparatus of claim 9, wherein the imparting mechanism of each of the edge dam blocks in the upstream mold region is further configured to impart a decreasing force in response to the edge dam blocks being at full height, the decreasing force causing a decrease in height from full height to a compressed height as the edge dam blocks travel to the downstream mold region.

11. A continuous metal casting apparatus, comprising:

opposing rotating casting surfaces forming a moving mold casting region therebetween that defines a moving mold cavity, the moving mold casting region having an upstream mold region and a downstream mold region;
a molten metal injector to introduce molten metal into an entrance end of the moving mold cavity;
an endless edge dam formed of edge dam blocks that revolve in a preselected path with the opposing rotating casting surfaces about the moving mold casting region to provide a side boundary to the molten metal in the moving mold cavity as the molten metal travels from the upstream mold to the downstream mold region before leaving an exit end of the of the moving mold cavity as a slab of metal, wherein each edge dam block comprises:

a lower dam block portion;
an upper dam block portion seated on the lower dam block portion; and
at least one spring situated to impart a force into the upper dam block portion while the edge dam block is moving through the upstream mold region, the imparted force pushing the upper dam block portion laterally towards a non-cast side opposing a cast side, reducing full height of the edge dam block to a compressed height as the edge dam block travels through the downstream mold region.

12. The continuous metal casting apparatus of claim 11, further comprising an edge dam block compressor that is configured to impart a compressive load into the edge dam blocks at the non-cast side while the edge dam blocks are moving the upstream mold region.

13. The continuous metal casting apparatus of claim 12, wherein the compressive load leads to an increase in height of the of the edge dam block to full height.

14. The continuous metal casting apparatus of claim 11, wherein the at least one spring of each edge dam block comprises a first spring and a second spring spaced apart from the first spring in the lower dam block portion about the cast side.

15. A method for providing vertically flexible edge containment to molten metal in a moving mold casting region having an upstream mold region and a downstream mold region that defines a moving mold cavity in a continuous moving belt metal casting machine, the method comprising:

introducing the molten metal into an entrance end of the moving mold cavity with a molten metal injector;
confining the molten metal in the moving mold cavity with a vertically flexible edge containment device as the molten metal travels from the upstream mold region to the downstream mold region before leaving an exit end of the of the moving mold cavity as a slab of metal; and
flexing the vertically flexible edge containment device in a vertical direction relative to a flow of the molten metal in the moving mold cavity, wherein the flex in the vertical direction of the vertically flexible edge containment device corresponds with changes in one of a thickness and height of the molten metal in the moving mold cavity as the molten metal travels from the upstream mold region to the downstream mold region before leaving the exit end of the of the moving mold cavity.

16. The method of claim 15, wherein the flexing comprises varying a height of the vertically flexible edge containment device as a function of a length that the molten metal in the moving mold casting region is from the molten metal injector.

17. The method of claim 15, wherein the vertically flexible edge containment device comprises one of a web of material extending between the upstream mold region and the downstream mold region, and an endless loop of material that moves along with opposing rotating casting surfaces in the continuous moving belt metal casting machine.

18. The method of claim 15, wherein the vertically flexible edge containment device comprises an endless edge dam formed of edge dam blocks that revolves in a preselected path with opposing rotating casting surfaces about the moving mold casting region.

19. The method of claim 18, comprising:

applying a compressive load at a non-cast side of the edge dam blocks that are passing through the upstream mold region, the compressive load compressing the edge dam blocks in the upstream mold region towards a cast side of the edge dam blocks, leading to an increase in height of the of the edge dam blocks to full height; and

reducing the full height of the edge dam blocks to a compressed height as the edge dam blocks move from the upstream mold region into the downstream mold region.

20. The method of claim 19, wherein the vertically flexible edge containment device enables opposing rotating casting surfaces in the casting machine that form the moving mold casting region to maintain uniform contact with the molten metal in the mold casting region, the uniform contact ensuring uniform heat extraction throughout the casting machine such that the metal at the exit end of the of the moving mold cavity has a uniform transverse temperature profile.

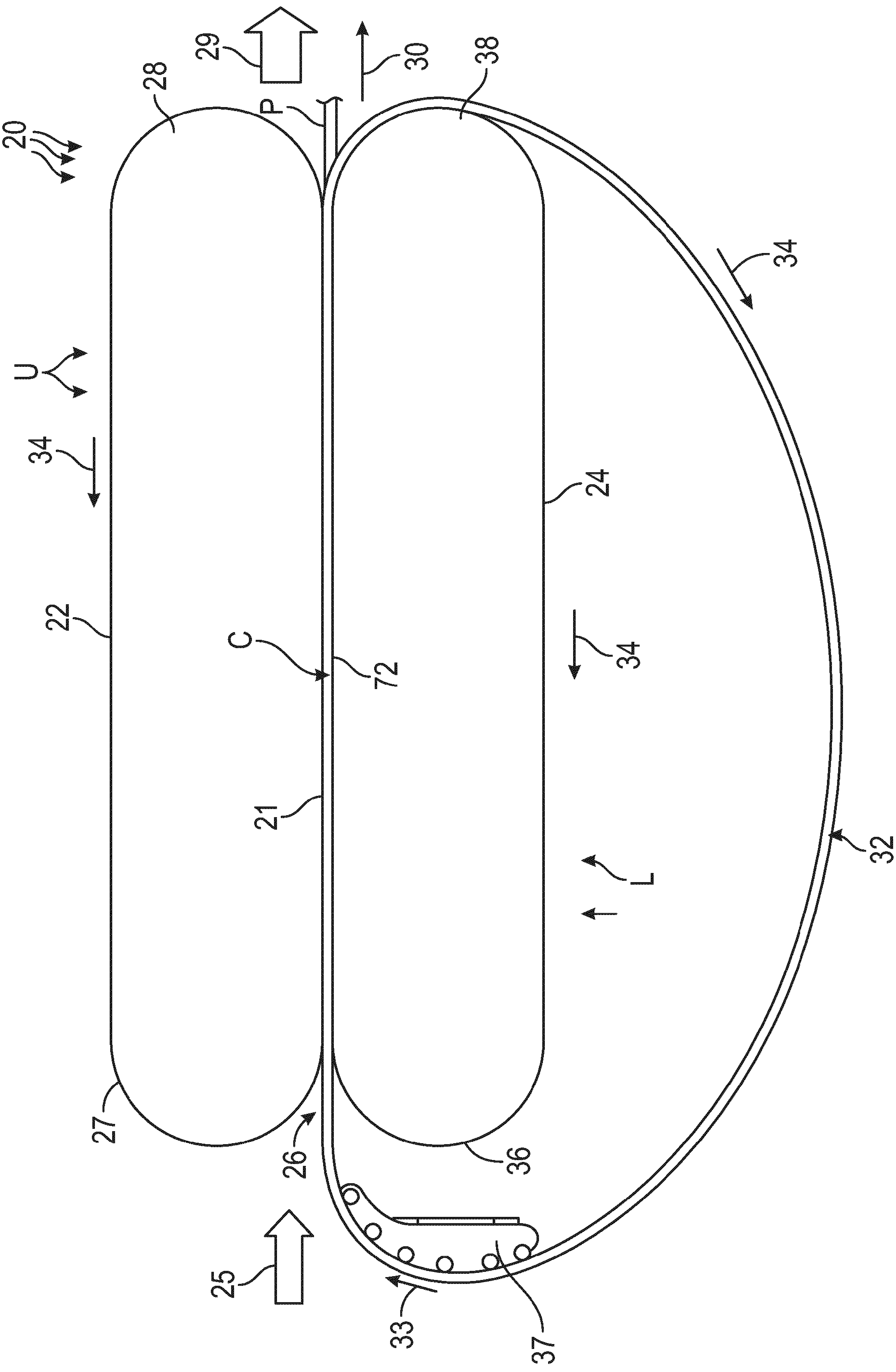

FIG. 1

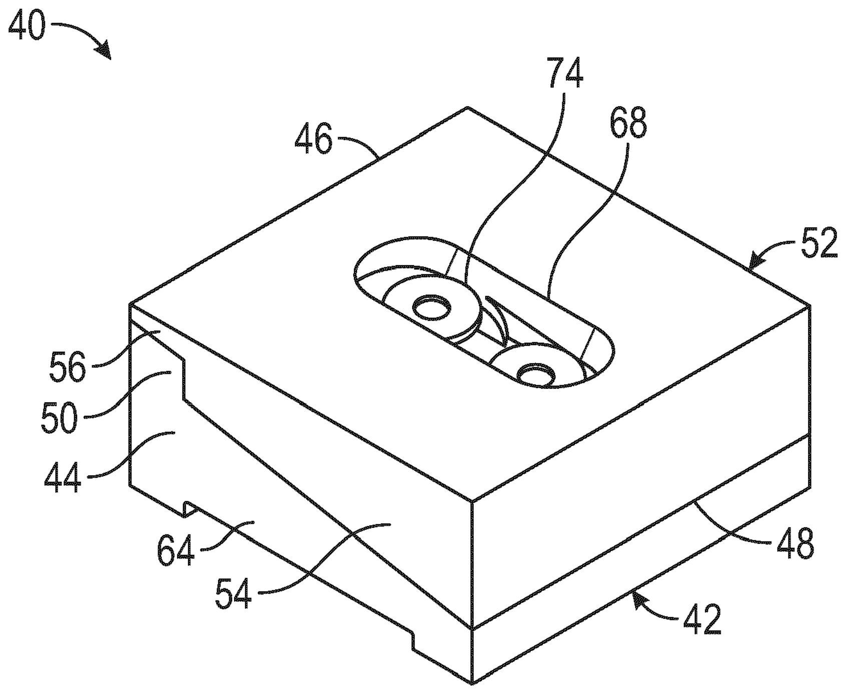

FIG. 2

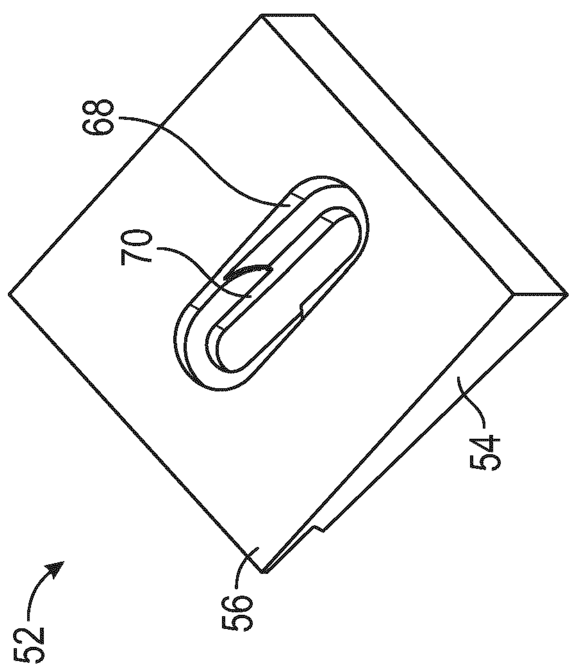

FIG. 3A

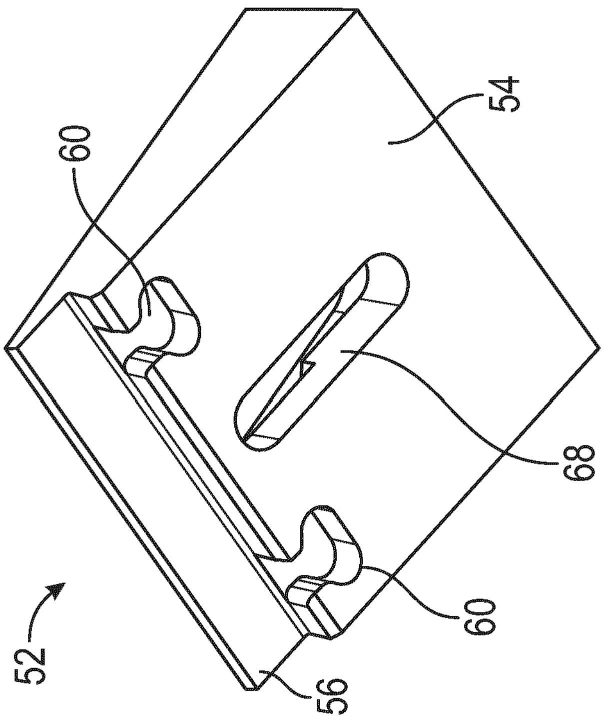

FIG. 3B

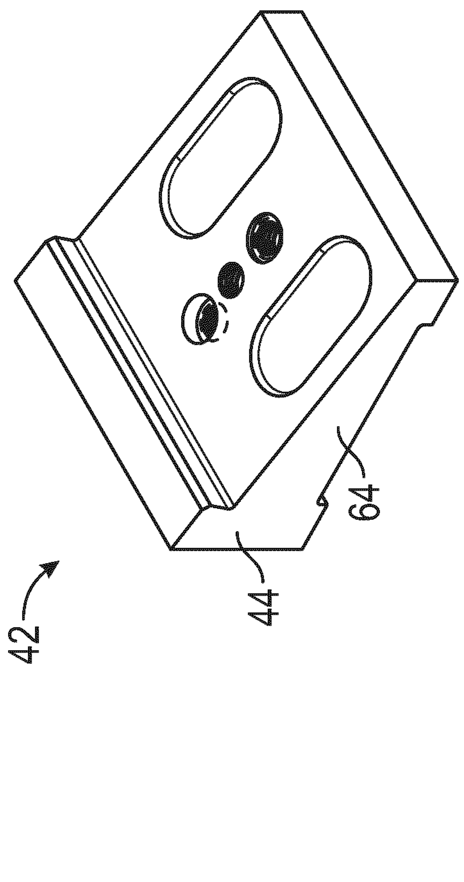

FIG. 4A

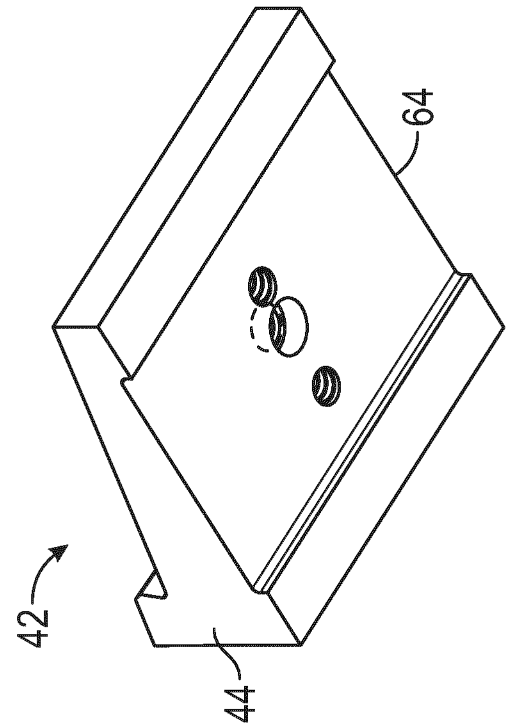

FIG. 4B

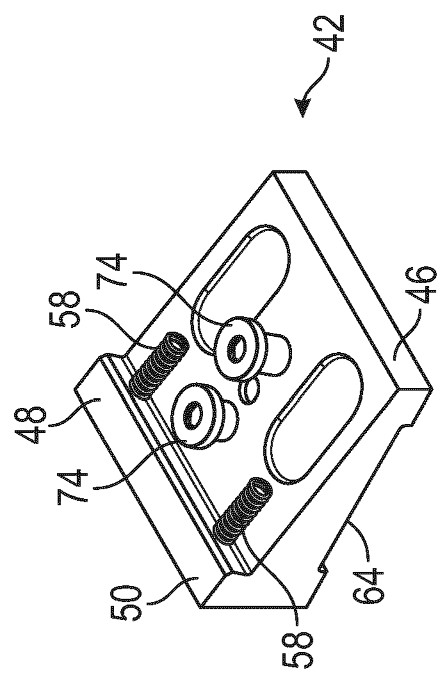

FIG. 4C

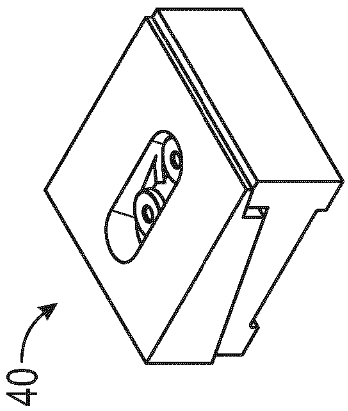

FIG. 5A

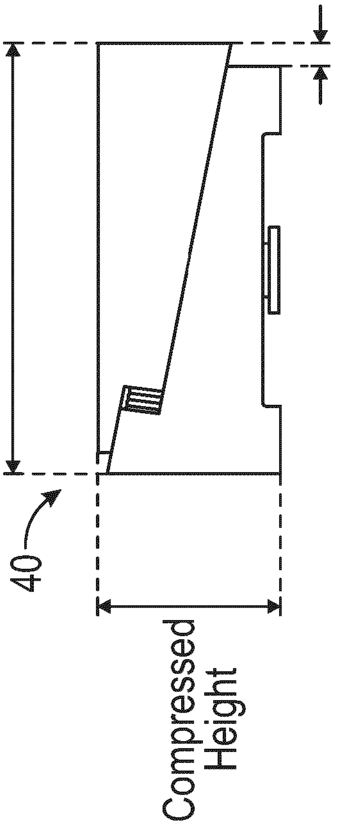

FIG. 5B

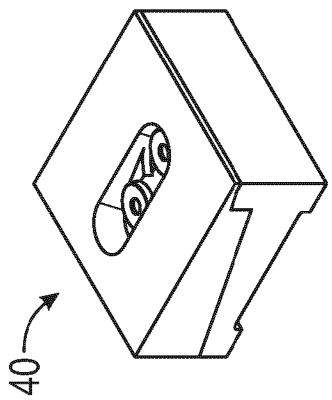

FIG. 6A

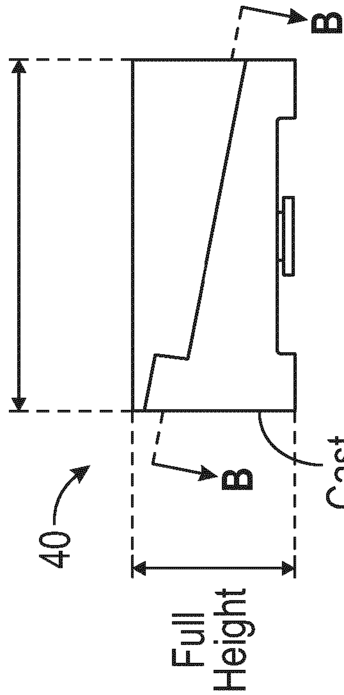

FIG. 6B

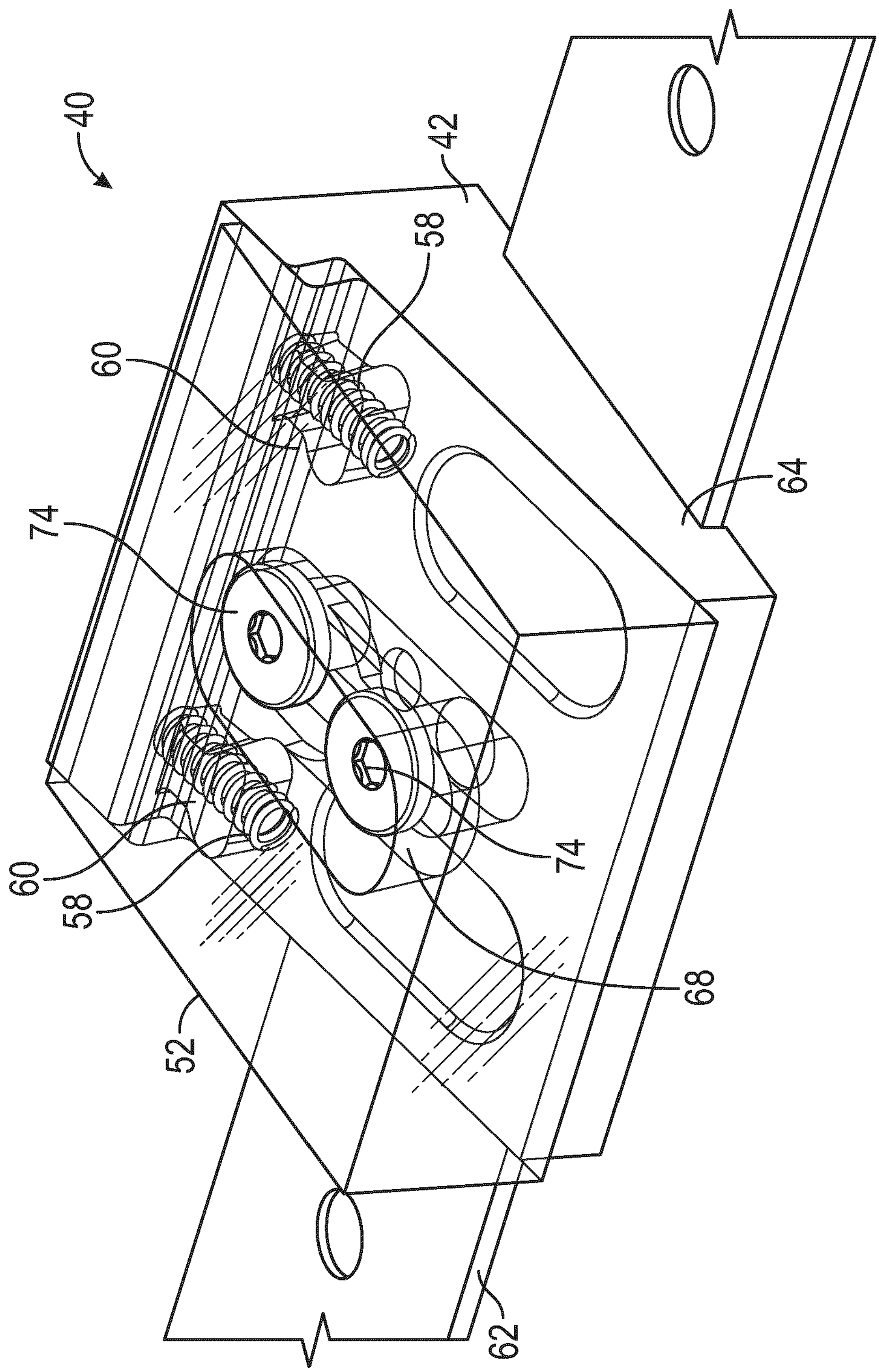

FIG. 7

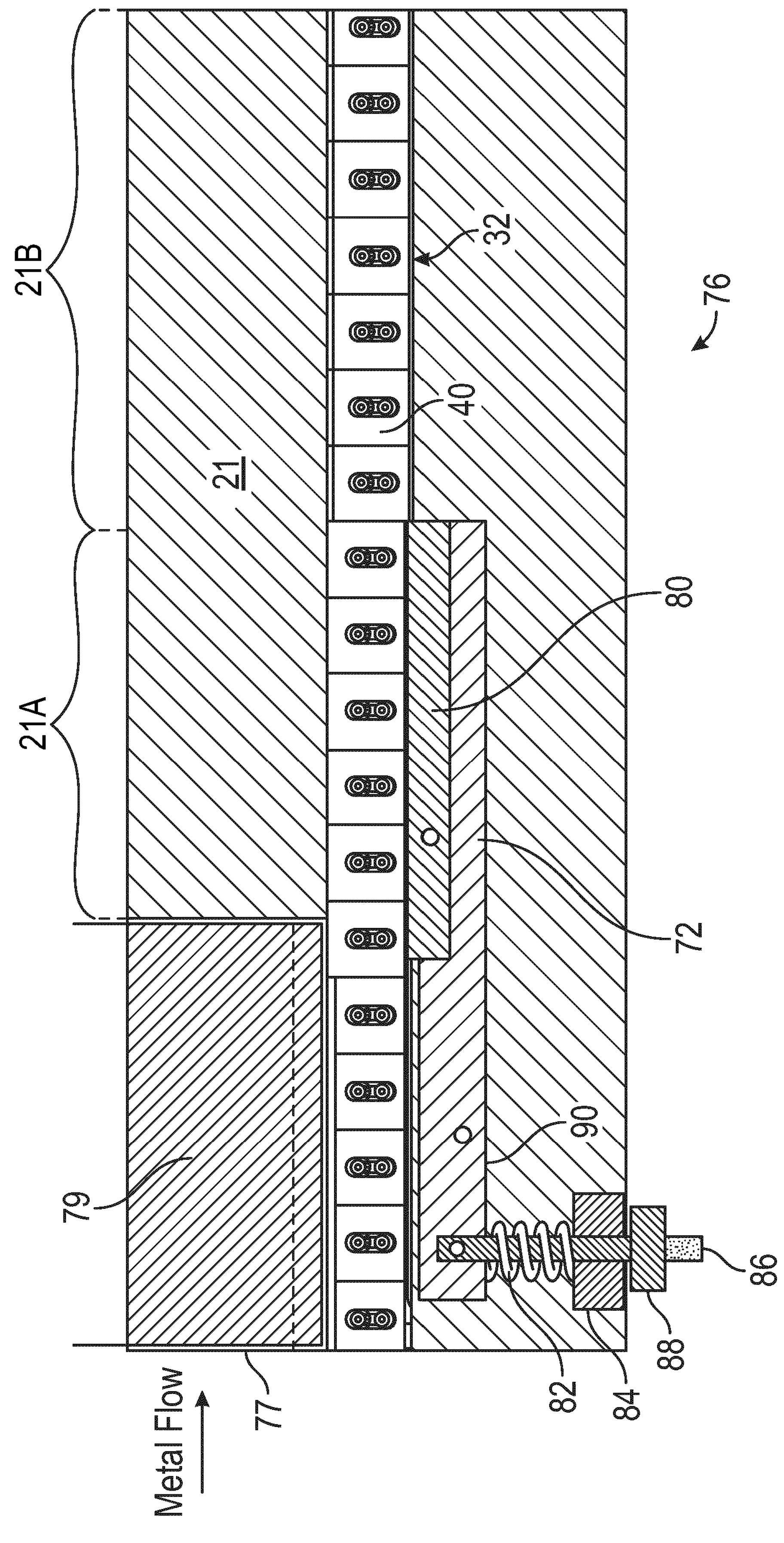

FIG. 8

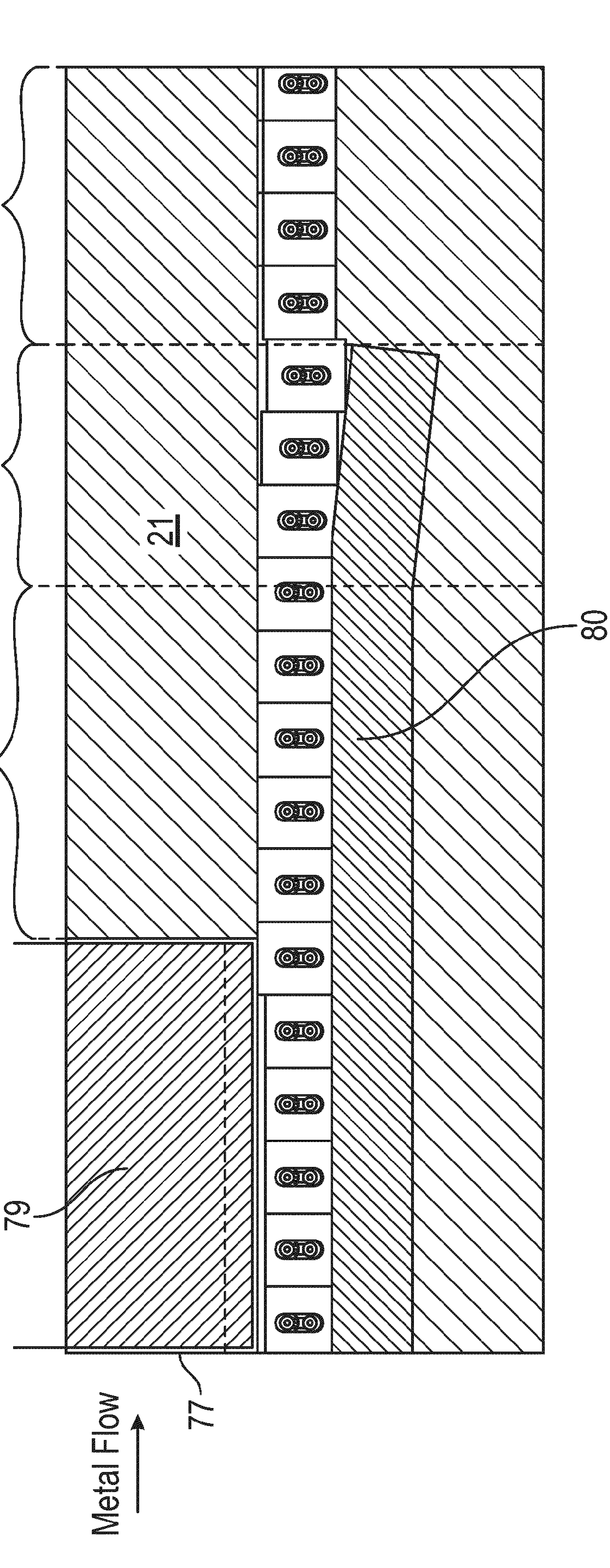

FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 24 20 1617

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	US 4 510 990 A (ARTZ GERD [DE] ET AL) 16 April 1985 (1985-04-16) * paragraph [DESCRIPTIONOFTHEPREFERREDEMBODIMENTS]; claims 1-15; figures 1-5c * -----	1-5, 15-18 6-14,19, 20	INV. B22D11/06
A	US R E38 555 E (BRAUN CURT [US] ET AL) 13 July 2004 (2004-07-13) * paragraph [DETAILEDDESCRIPTION]; figures 1-6 * -----	1-20	

TECHNICAL FIELDS SEARCHED (IPC)

B22D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	16 January 2025	Desvignes, Rémi

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 24 20 1617

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16-01-2025

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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