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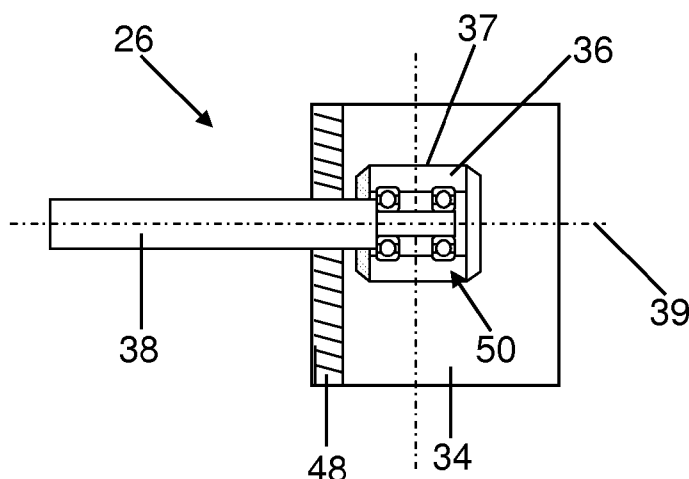
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(54) Title: LOW RUN-OUT EDGE ROLLERS FOR USE WITH GLASS RIBBONS



(57) Abstract: Edge rollers (26) for glass ribbons (20) are disclosed in which the run-out generating portion of the roller's bearing assembly (50) is located inboard of the ribbon's edge, e.g., over the ribbon's edge portion (34). Such a location reduces the amplification of run-out which occurs with conventional edge roller constructions. By eliminating the amplification, run-out at the surface of the ribbon can, for example, be reduced from 1-3 mm to 0.05-0.15 mm. To withstand the elevated temperatures which exist inboard of the ribbon's edge, the edge roller assemblies can employ gas or ceramic bearings.

FIG. 4

LOW RUN-OUT EDGE ROLLERS FOR USE
WITH GLASS RIBBONS

[0001] This application claims the benefit of priority of U.S. Provisional Application Serial No. 61/304,890 filed on February 16, 2010. .

Field

[0002] This disclosure relates to edge rollers used with glass ribbons and, in particular, to methods and apparatus for reducing the run-out exhibited by such rollers.

BACKGROUND

[0003] One method of forming a thin sheet of glass is by a drawing process where a ribbon of glass is drawn from a reservoir of molten glass. This may be accomplished, for example, via an up-draw process, where the ribbon is drawn upward from the reservoir (e.g. Foucault or Colburn), or by a down-draw process (e.g., slot or fusion), where the ribbon is drawn downward, typically from a forming body. Once the ribbon is formed, individual sheets of glass are cut from the ribbon.

[0004] In a conventional downdraw process, the molten glass is formed into a glass ribbon contained within a draw chamber defined by a shroud that surrounds the ribbon. Among other things the shroud serves to maintain a consistent thermal environment in the region defined by the shroud and surrounding the ribbon. Roller pairs penetrate the shroud and contact the ribbon near its edges. These edge rollers may be used to apply a pulling force to the ribbon, to apply a transverse tension to the ribbon, or merely to guide the ribbon. Accordingly, a rotational force may be applied to the rollers by a motor, or the rollers may be free-wheeling and the rotational force applied to the rollers by the descending ribbon. In either case, the rollers rotate.

[0005] Production roller mechanisms typically allow for the rollers to move horizontally and/or vertically from the glass contact area. The roller axles move to accommodate the geometric tolerances of the rollers, their run-out, and tolerance changes in operation, along with normal variability in glass thickness. Further, production roller mechanisms typically allow the rollers to be moved far away from the glass for maintenance access, process restart, and other practical considerations.

[0006] Frictional forces that resist the free motion of the edge rollers in production roller support mechanisms often change the forces the rolls impart on the glass ribbon,

which manifests as undesirable perturbations or stress changes in the ribbon that can become frozen into the glass as the glass transitions from a viscous material to an elastic material. In particular, the kinematics of the edge rollers can affect geometrical and stress uniformity of the ribbon, as well as sheets cut from the ribbon. Any roller rotation defect will also result in movement of the glass ribbon. The ribbon movement can, for example, have an amplitude in the 1 to 3 mm range which may disturb the sheet formation process and affect its geometry in the transition zone, where the glass under drawing progressively passes from viscous to elastic. The importance of minimizing ribbon motion for low stress and high precision flatness is understood from LCD glass experience and modelling.

[0007] Although high quality materials, including high quality bearing assemblies, are routinely used in the manufacture of edge rollers, and in practice the run-out from production systems is not abnormally high, the process impact from run-out is detectable and becomes more important to thinner, taller, and wider forming performance. As discussed below, the present disclosure addresses the run-out levels exhibited by existing edge rollers by: (1) identifying the source of run-out and (2) providing edge roller constructions which eliminate that source and thus are able to achieve reduced levels of run-out compared to rollers that have comparable intrinsic run-out but do not use the disclosed constructions.

[0008] Although such reduced run-out rollers can be used with glass ribbons of any size or thickness, they are particularly beneficial when ribbon stiffness is low. Process directions which reduce stiffness include thinner product, wider product, and taller processes. All these directions are being pursued to meet market needs for thinner and wider glass sheets, e.g., market needs associated with the glass sheets that are used as substrates in the production of display products, such as liquid crystal displays (LCDs). Accordingly, the advantages associated with the edge roller constructions disclosed herein are expected to become ever more valuable as glass manufacturing processes continue to respond to market needs.

SUMMARY

[0009] In accordance with a first aspect, an edge roller assembly (26) for use with a glass ribbon (20) is disclosed which includes:

- (A) a support (38) which defines a longitudinal axis (39);

(B) a bearing assembly (50) which includes a portion that generates run-out; and

(C) a head (36) having an outer surface which includes a glass-engaging portion (37);

wherein:

(i) the head (36) is rotatably mounted to the support (38) by the bearing assembly (50), the rotation being about the longitudinal axis (39); and

(ii) the glass-engaging portion (37) of the head (36) and the run-out generating portion of the bearing assembly (50) are located at positions along the longitudinal axis (39) so that, during use of the edge roller assembly (26), they are both inboard of an edge of the glass ribbon (20).

[0010] In accordance with a second aspect, a method is disclosed for fabricating sheets of glass which includes:

(A) producing a glass ribbon (20) using a drawing process; and

(B) cutting sheets from the glass ribbon (20);

wherein:

(i) the glass ribbon (20) has an edge portion (34);

(ii) step (A) includes contacting the ribbon's edge portion (34) with a glass-engaging surface (37) of an edge roller assembly (26);

(iii) the edge roller assembly (26) includes a bearing assembly (50); and

(iv) at least the portion of the bearing assembly (50) that generates run-out has an across-the-ribbon location which lies within the ribbon's edge portion (34).

[0011] The reference numbers used in the above summaries of the various aspects of the disclosure are only for the convenience of the reader and are not intended to and should not be interpreted as limiting the scope of the invention. More generally, it is to be understood that both the foregoing general description and the following detailed description are merely exemplary of the invention and are intended to provide an overview or framework for understanding the nature and character of the invention.

[0012] Additional features and advantages of the invention are set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the invention as exemplified by the

description herein. The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. It is to be understood that the various features of the invention disclosed in this specification and in the drawings can be used in any and all combinations. By way of non-limiting example, the various features of the invention may be combined as the following additional aspects.

[0013] According to a third aspect, there is provided the edge roller assembly of aspect 1 wherein the ribbon has an edge portion and the glass-engaging portion of the head and the run-out generating portion of the bearing assembly are located at positions along the longitudinal axis so that, during use of the edge roller assembly, they have across-the-ribbon locations which lie within the edge portion.

[0014] According to a fourth aspect, there is provided the edge roller assembly of aspect 1 or aspect 3 wherein:

- (a) the assembly comprises a second head which comprises a glass-engaging portion and a second bearing assembly which comprises a portion that generates run-out;
- (b) the second head is rotatably mounted to the support by the second bearing assembly, the rotation being about the longitudinal axis; and
- (c) the glass-engaging portion of the second head and the run-out generating portion of the second bearing assembly are located at positions along the longitudinal axis so that, during use of the edge roller assembly, they are both inboard of an edge of the glass ribbon.

[0015] According to a fifth aspect, there is provided the edge roller assembly of aspect 4 wherein the ribbon has two edge portions and each of the glass-engaging portions and each of the run-out generating portions is located at a position along the longitudinal axis so that it has an across-the-ribbon location which lies within an edge portion during use of the edge roller assembly.

[0016] According to a sixth aspect, there is provided the edge roller assembly of any one of aspects 1, or 3-5 wherein the bearing assembly employs a gas cushion.

[0017] According to a seventh aspect, there is provided the edge roller assembly of aspect 6 wherein the gas of the gas cushion is air.

[0018] According to an eighth aspect, there is provided the edge roller assembly of aspect 6 or aspect 7 wherein the bearing assembly comprises a sub-assembly which resists motion of the head along the longitudinal axis.

[0019] According to a ninth aspect, there is provided the edge roller assembly of aspect 8 wherein the sub-assembly employs a gas cushion.

[0020] According to a tenth aspect, there is provided the edge roller assembly of any one of aspects 1 or 3-9 wherein the head is insulated to reduce heat transfer from the glass ribbon during use of the assembly.

[0021] According to an eleventh aspect, there is provided the edge roller assembly of any one of aspects 1 or 3-10 wherein the distal end of the head comprises a ceramic cap.

[0022] According to a twelfth aspect, there is provided an apparatus for producing glass sheets by a drawing process which produces a glass ribbon comprising an edge roller assembly according to any one of aspects 1 or 3-11.

[0023] According to a thirteenth aspect, there is provided the apparatus of aspect 12 comprising a second edge roller assembly according to any one of aspects 1 or 3-11 wherein the two edge roller assemblies engage opposite sides of the glass ribbon during use of the apparatus.

[0024] According to a fourteenth aspect, there is provided the method of aspect 2 wherein the bearing assembly employs a gas cushion and the method comprises passing gas through the edge roller assembly to form the gas cushion.

[0025] According to a fifteenth aspect, there is provided the method of aspect 14 wherein the bearing assembly comprises a sub-assembly which resists across-the-ribbon motion of the glass engaging surface of the edge roller assembly.

[0026] According to a sixteenth aspect, there is provided the method of aspect 15 wherein the sub-assembly employs a gas cushion and the method comprises passing gas through the edge roller assembly to form the gas cushion.

[0027] According to a seventeenth aspect, there is provided the method of any one of aspects 2 or 14-16 wherein the edge roller assembly comprises a ceramic end cap which reduces heat transfer to the assembly from the glass ribbon.

[0028] According to an eighteenth aspect, there is provided the method of any one of aspects 2 or 14-17 wherein the drawing process is a fusion downdraw process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] FIG. 1 is a schematic side elevation view of an exemplary fusion downdraw process according to an embodiment of the present disclosure.

[0030] FIG. 2 is a schematic edge view of a portion of a glass ribbon formed via a downdraw process, where an edge of the ribbon is engaged between a pair of opposing edge rollers.

[0031] FIG. 3 is a schematic diagram illustrating the origin of the excessive run-out of conventional edge rollers.

[0032] FIG. 4 is a schematic side elevation view of an exemplary embodiment of an edge roll assembly of the present disclosure.

[0033] FIG. 5 is a schematic side elevation view, partially in section, of an exemplary embodiment of an edge roll assembly of the present disclosure which employs a gas bearing.

[0034] FIG. 6 is a schematic side elevation view of the embodiment of FIG. 5 in full cross-section.

[0035] FIG. 7 is a schematic side elevation view, partially in section, of a variation of the embodiment of FIG. 5 where the roller is an idler roll, rather than a driven roll.

[0036] FIG. 8 is a schematic side elevation view, partially in section, of an exemplary embodiment of an edge roll assembly of the present disclosure which employs a ceramic bearing.

DETAILED DESCRIPTION

[0037] Drawing a thin ribbon of material to form a glass sheet having a thickness less than about two millimeters to the exacting standards of flatness required for modern display applications, such as televisions and computer monitors, requires careful control of all aspects of the manufacturing process. However, particular attention must be paid to the period of time during which the glass ribbon is transitioning from a viscous state to an elastic state. Even small force variations on the ribbon, especially from forces imparted at the roll contact surfaces nearest the glass transition temperatures, can manifest themselves as perturbations in what should be a pristine, flat surface.

[0038] In an exemplary fusion-type downdraw process, molten glass is supplied to a forming body comprising a channel open at its top in an upper surface of the body. The molten glass overflows the walls of the channel and flows down converging outside

surfaces of the forming body until the separate flows meet at the line along which the converging surfaces meet (i.e. the “root”). There, the separate flows join, or fuse, to become a single ribbon of glass that flows downward from the forming body. Various rollers (or “rolls”) positioned along the edges of the ribbon serve to draw (or pull) the ribbon downward and/or apply a tensioning force to the ribbon that helps maintain the width of the ribbon and/or simply fully or partly constrain the ribbon position within the process. That is, some rollers may be rotated by motors, whereas other rollers are free-wheeling.

[0039] As the ribbon descends from the forming body, the molten material transitions from a viscous state at the bottom of the forming body, to a visco-elastic state, and finally to an elastic state. When the ribbon has cooled to an elastic state, the ribbon is scored across its width, and separated along the score line to produce a separate glass sheet.

[0040] During the time the ribbon is in a fluid, viscous state, stresses imposed on the molten material are immediately relieved. However, as the ribbon cools and the viscosity increases, induced stresses are not so quickly relieved, until a temperature range is reached where (1) induced stresses will be retained by the glass and (2) ribbon shape can be retained in the glass. Both are sources of undesirable retained stresses and warping of the final product. It is desirable, therefore, that during this period when stress and shape can be frozen into the glass that forces imposed onto the glass ribbon and the ribbon shape be as consistent as possible. One source of such variation comes from the edge rollers. (Note that force variation from the edge rollers could also result in variability to the glass thickness, and other product attributes.) Experience has been that force and position consistency is important to achieving ultra low stress and high flatness requirements, for example, of LCD substrate sheets.

[0041] Although edge rollers may take different forms, in each case a pair of rollers pinches or grips the ribbon. Pairs of rollers are positioned at opposite edges of the ribbon so that for a particular vertical location (i.e., distance from the root) along the length of the ribbon, two pairs of edge rollers are typically used. Edge rollers may be driven, such as by electric or hydraulic motors, or edge rollers may be free-wheeling. Edge rollers at opposing edges may share a common support structure (e.g., a common axle) that extends across the width of the ribbon, or each edge roller may have its own, separate support structure (own axle) that extends only so far as necessary to position the roller's head and

associated contact surface at the desired lateral location on the glass ribbon, i.e., in edge portion 34 between the ribbon's quality area and the ribbon's edge. This contact surface is designed to withstand prolonged high temperatures, sometimes in excess of 900°C, arising from contact with the glass ribbon, and preferably utilizes a ceramic material, e.g., the contact surface is commonly composed of discs of a ceramic fiber material. Moreover, the longitudinal axis of an edge roller assembly need not be horizontal (transverse to the direction of draw), but can be tilted with respect to horizontal to increase tension across the width of the ribbon.

[0042] The positioning and support mechanism for each pair of edge rollers is designed to accommodate a varying gap between the contact surfaces of the rollers. For example, the rollers accommodate fluctuations in the glass thickness of the ribbon edges. The roll axle shafts are not perfectly straight and will sometimes warp in the heat. The roll face is often not perfectly round or centered. Roll material properties can vary over the roll rotation. Also, the roll materials wear with age and the diameter decreases, and sometimes the roll material's properties change as the roll ages. A function of the roll support mechanism is to allow the roller pairs to separate horizontally, and then draw closer together again as the rollers operate.

[0043] Production edge roller mechanisms are designed to allow for this motion during roller operation, while attempting to keep a consistent pinch force applied to the glass. Thus, the rollers are normally pressured inward, toward the plane of the glass ribbon, by a biasing force. This pinch force between roller pairs serves to minimize roll slippage and is a key contributor to the horizontal and vertical tensions imparted by the rollers to the glass ribbon. The mechanism which applies this biasing force should accommodate inward and outward movement (widening of the gap between the edge roll pair) from the sources described above. For example, the edge rollers may include a lever and fulcrum arrangement that translates the edge roller support laterally. Counterweights may be used to apply sufficient force to the lever so the edge roller contact surfaces can grip the glass ribbon, yet still allow the rollers to move transversely to the ribbon plane in response to a varying contact surface eccentricity for example. However, other methods of applying a biasing force can be used, such as springs arranged to either pull or push the roller assembly along a predetermined line of movement.

[0044] Shown in FIG. 1 is an exemplary fusion downdraw apparatus 10 comprising forming body 12 including channel or trough 14 and converging forming surfaces 16. Converging forming surfaces 16 meet at root 18. Trough 14 is supplied from a source (not shown) with molten glass that overflows the walls of the trough and descends over the outer surfaces of the forming body as separate streams. The separate streams of molten glass flowing over converging forming surfaces 16 meet at root 18 and form glass ribbon 20.

[0045] When glass ribbon 20 has reached a final thickness and viscosity, the ribbon is separated across its width to provide an independent glass sheet or pane. As molten glass is continuously supplied to the forming body, and the ribbon lengthens, additional glass sheets are separated from the ribbon.

[0046] Shroud 22 surrounds the upper reaches of ribbon 20 below root 18 and connects with an upper enclosure 24 that houses forming body 12. Shroud 22 serves as a platform on which various heating and/or cooling equipment may be positioned to regulate the temperature of the ribbon. Due to the buoyancy of the hotter air in the interior 30 of the shroud, along with the hottest temperatures being in the uppermost extent of the shroud, the interior pressure rises over the height of the shroud. Openings and leaks in the walls of shroud 22 result in upward internal air flow from the shroud's base and typically have significant impact on thermal conditions within the shroud. Accordingly, it is desirable that openings and leaks be minimized and stay consistent over time.

[0047] Edge roller assemblies 26 are positioned at predetermined vertical locations below root 18, and may include driven edge rollers used to apply a pulling force to the ribbon so that it moves in the direction of arrow 21 in FIG. 1 and/or non-driven idler rollers that guide the ribbon and limit its motion and/or help maintain a tension across the ribbon width. As described above, rollers may share a common support structure which spans the ribbon width, or each roller may have its own support structure. As noted above, edge rollers are typically arranged in pairs, each roller of a roller pair positioned on opposite sides of an edge of the ribbon (see FIG. 2). Additionally, as also noted above, edge roller pairs are themselves often arranged in pairs, one pair of rollers per ribbon edge at a given vertical position.

[0048] As discussed above, one aspect of the present disclosure relates to the discovery of the source of the high levels of run-out observed with conventional edge rollers. FIG. 3

illustrates the discovery. In this figure, 42 is the conventional roller's bearing assembly, 44 is its rotating shaft, and 46 its head which contacts the ribbon's edge portion 34 inboard of the ribbon's bulbous edge 48. As shown in this figure, bearing assembly 42 is separated from the contact patch between the roller's head and the glass ribbon by the distance 40. In practice, this distance is typically a third or a half a meter. As a result of this distance, the intrinsic run-out of the edge roller assembly is highly amplified at the glass ribbon. This amplification, in turn, results in variations in contact location of the type shown in the four drawings which form the right hand portion of FIG. 3. In particular, the first and last of these drawings show the nominal contact location of the roller's head with the glass ribbon 20, while the middle two drawings show the periodic changes in the contact location which result from the amplified run-out. These changes in contact location impart motion directly to the glass ribbon. Also, friction in the seals, pivots and slide mechanisms of production roll systems lead to variability in the actual delivered pinch force on the roll face. This, in turn, results in changes in the horizontal and vertical tensions applied to the glass ribbon. Both force variation and motion disturbs the ribbon drawing processing and affects the final sheet stress and warp.

[0049] FIG. 4 illustrates an edge roller construction in accordance with the present disclosure which reduces run-out compared to that for the conventional edge roller of FIG. 3. As shown in FIG. 4, edge roller assembly 26 includes a support 38 which defines a longitudinal axis 39, a bearing assembly 50, and a head 36 whose outer surface includes a glass-engaging portion 37. As shown in FIGS. 4-8, support 38 is in the form of an axle, although other configurations can be used for the support if desired. Support 38 will typically be stationary, but, if desired, it can rotate to minimize shaft sag or warp in the case where it is operated at high process temperatures. Head 36 is rotatably connected to support 38 by bearing assembly 50, the rotation being about longitudinal axis 39. The glass-engaging portion 37 of the head's outer surface and the bearing assembly are located in the vicinity of the same end of the edge roller assembly. In this way, as illustrated in FIG. 4, during use, they are both located inboard of the ribbon's bulbous edge 48, specifically, they are both located within the ribbon's edge portion 34.

[0050] Although in some embodiments, the entire bearing assembly is inboard of the ribbon's bulbous edge, in practice, only the run-out generating portion of the bearing assembly (i.e., the bearing surfaces at which rotation takes place) needs to be inboard of

the edge of the ribbon. For example, in the embodiments of FIGS. 5-7 discussed below, only the bearing surfaces and gas cushion need to be inboard of the edge of the ribbon, while the remainder of the bearing assembly, e.g., the gas port, proximal portion of the gas passages, radial bearing, etc., can be located at substantial distances outside the ribbon's edge portion without creating excessive levels of run-out. By placing the run-out generating portion of the bearing assembly inboard of the ribbon's edge, the amplification effect caused by distance 40 of FIG. 3 is substantially reduced or, depending on the construction of the roller assembly, completely eliminated. The reduction in run-out is dramatic. For example, a typical run-out for the system of FIG. 3 can be on the order of 1-3 millimeters. With the systems of FIGS. 4-8, on the other hand, this value can, for example, be in the range of 0.05-0.15 millimeters.

[0051] The portion of the bearing assembly that is located inboard of the edge of the ribbon needs to withstand the higher operating temperatures associated with such a location. FIGS. 5 and 6 show an edge roller assembly which employs a gas cushion bearing system capable of withstanding these temperatures. The gas used in this bearing will typically be air, although other gases like nitrogen may be used to avoid oils and containments common in compressed air systems.

[0052] The overall arrangement of the components of the system is shown in FIG. 5. As shown therein, shell 60 whose outer surface includes glass contact material 61 for engaging the edge portion of the glass ribbon is mounted to support 38 by gas bearing 62, one surface of which is formed as part of the distal end of the support. Glass contact material 61 is typically a ceramic and can be in the form of ceramic fiber discs or a ceramic monolith. To prevent axial motion, the system includes radial gas bearing 63. This bearing resists axial forces from tension in the ribbon, especially in the case of down-tilted edge roller assemblies.

[0053] As shown in FIG. 6, support 38 includes gas passages 64, 65, 66, and 67 for introducing and removing gas from the assembly. In particular, as shown by arrow 68, pressurized gas enters the assembly at port 69 and is distributed by passage 64 to passages 65 and 66. As shown by arrows 70 and 71, passage 65 provides gas to radial bearing 63. As shown by arrows 72, passages 66 provide the main gas cushion of the bearing assembly at gap 73. As shown by arrows 74, after passing through gap 73, the gas is removed from the bearing assembly through passage 67 which may be connected to a

vacuum collector (not shown) so as to minimize the introduction of gas into the interior 30 of shroud 22 at the locations of the edge roller assemblies. Such gas could, for example, affect the cleanliness of the ribbon as well as the ribbon's temperature distribution which, in turn, could affect the ribbon's stress distribution and/or its shape.

[0054] To minimize the effects of the edge roller on the temperature distribution of the ribbon, the distal end 75 of the roller assembly, specifically, the distal end of the head in the embodiment of FIG. 6, can be composed of a ceramic material having a low thermal conductivity (see, for example, reference number 76 in FIG. 6). In this way, cooling of the distal end of the edge roller assembly by the gas passing through the assembly is less pronounced so that the edge roller assembly does not constitute a strong heat sink as seen from the ribbon. If desired, the ceramic end cap or a sub-assembly containing the end cap can be made replaceable. Since the end of the edge roller assembly can be damaged by falling glass in case of a fracture of the glass ribbon, such replaceability can reduce operating costs and facilitate maintenance operations. In addition or as an alternative to a ceramic end cap, thermal insulation 79 can be incorporated in the assembly to reduce the thermal effects of the roller assembly.

[0055] The embodiment of FIGS. 5-6 includes an elongated shell 60 suitable for attachment to an electric or hydraulic motor (not shown). In a typical fusion downdraw machine, many of the edge rollers are idler rollers which are not driven by a motor. In such cases, shell 60 can be made substantially shorter as illustrated in FIG. 7. Such a shorter configuration can reduce the cost of the assembly. Also, shell 60 can be made of graphite, but a non-oxygen containing protection gas would then be required.

[0056] Instead of an gas bearing, high temperature ceramic bearings, available from various manufacturers, can also be used, e.g., bearings having operative surfaces composed of, for example, zirconium or alumina. FIG. 8 illustrates an embodiment employing bearings of this type. For such an embodiment, both balls 77 and races 78 will be composed of a high temperature ceramic material, which may be the same or different for the balls and the races.

[0057] Although the edge roller assemblies shown in FIGS. 4-8 employ a single head 36, the run-out reducing technology disclosed herein is equally applicable to assemblies where more than one head is rotatably mounted on a support 38 as illustrated by the uppermost edge roller assembly of FIG. 1.

[0058] The low run-out edge rollers disclosed herein lead to a variety of benefits in the manufacture of glass sheets. As noted above, it has been observed that conventional rollers generate highly variable forces and also impart motion to the ribbon, which together can lead to warp, stress, and/or thickness variations. By reducing run-out at the surface of the ribbon, both force variation and the motion imparted to the glass by the rollers can be reduced. As indicated above, the run-out reduction achievable with the edge roller assemblies disclosed herein can be on the order of a factor of 20, e.g., from 1-3 mm to 0.05-0.15 mm. A similar reduction in force variability can be achieved from the run-out reduction. Importantly, the combination of reductions in both force variation and ribbon motion can result in process benefits in terms of reduced warp, reduced stress variability, and/or reduced thickness variations greater than those achievable from either alone.

[0059] In addition to their run-out benefits, the edge roller assemblies disclosed herein can have simpler and more robust constructions involving less components and resulting in smaller overall sizes than conventional edge rollers. Also the size of the glass-engaging portion of the head of the assembly can be smaller than that used with conventional rollers which can reduce thermal effects in the vicinity of the rolls which result in stress and polarization effects in the finished product.

[0060] Also, because in a typical embodiment, support 38 does not rotate, the insertion depth of the head of the edge roller assembly can be more easily changed by changing the support's length to accommodate the specific dimensions of a particular forming draw. This can be done by, for example, dividing the support into two or more sections. In this way, for manufacturing where different forming processes are used, a universal head section can be used with different length supports thus reducing the number of unique parts associated with the edge roller assemblies of a given glass making machine. Such constructions can also facilitate maintenance by making it easier to mount and disassemble the edge roller assemblies. Indeed, the construction can be used to allow a pair of edge roller assemblies to be removed and serviced while the glass ribbon continues to be driven by other assemblies.

[0061] A variety of modifications that do not depart from the scope and spirit of the invention will be evident to persons of ordinary skill in the art from the foregoing disclosure. The following claims are intended to cover the specific embodiments set forth herein as well as modifications, variations, and equivalents of those embodiments.

What is claimed is:

1. An edge roller assembly for use with a glass ribbon comprising:
 - (A) a support which defines a longitudinal axis;
 - (B) a bearing assembly which comprises a portion that generates run-out; and
 - (C) a head having an outer surface which comprises a glass-engaging portion;wherein:
 - (i) the head is rotatably mounted to the support by the bearing assembly, the rotation being about the longitudinal axis; and
 - (ii) the glass-engaging portion of the head and the run-out generating portion of the bearing assembly are located at positions along the longitudinal axis so that, during use of the edge roller assembly, they are both inboard of an edge of the glass ribbon.
2. The edge roller assembly of Claim 1 wherein the ribbon has an edge portion and the glass-engaging portion of the head and the run-out generating portion of the bearing assembly are located at positions along the longitudinal axis so that, during use of the edge roller assembly, they have across-the-ribbon locations which lie within the edge portion.
3. The edge roller assembly of Claim 1 or Claim 2 wherein:
 - (a) the assembly comprises a second head which comprises a glass-engaging portion and a second bearing assembly which comprises a portion that generates run-out;
 - (b) the second head is rotatably mounted to the support by the second bearing assembly, the rotation being about the longitudinal axis; and
 - (c) the glass-engaging portion of the second head and the run-out generating portion of the second bearing assembly are located at positions along the longitudinal axis so that, during use of the edge roller assembly, they are both inboard of an edge of the glass ribbon.
4. The edge roller assembly of Claim 3 wherein the ribbon has two edge portions and each of the glass-engaging portions and each of the run-out generating portions is located at a position along the longitudinal axis so that it has an across-the-ribbon location which lies within an edge portion during use of the edge roller assembly.
5. The edge roller assembly of any one of Claims 1-4 wherein the bearing assembly employs a gas cushion.

6. The edge roller assembly of Claim 5 wherein the gas of the gas cushion is air.

7. The edge roller assembly of Claim 5 or Claim 6 wherein the bearing assembly comprises a sub-assembly which resists motion of the head along the longitudinal axis.

8. The edge roller assembly of Claim 7 wherein the sub-assembly employs a gas cushion.

9. The edge roller assembly of any one of Claims 5-8 wherein the head is insulated to reduce heat transfer from the glass ribbon during use of the assembly.

10. The edge roller assembly of any one of Claims 1-9 wherein the distal end of the head comprises a ceramic cap.

11. Apparatus for producing glass sheets by a drawing process which produces a glass ribbon comprising an edge roller assembly according to any one of Claims 1-10.

12. The apparatus of Claim 11 comprising a second edge roller assembly according to any one of Claims 1-10 wherein the two edge roller assemblies engage opposite sides of the glass ribbon during use of the apparatus.

13. A method for fabricating sheets of glass comprising:

- (A) producing a glass ribbon using a drawing process; and
- (B) cutting sheets from the glass ribbon;

wherein:

- (i) the glass ribbon has an edge portion;
- (ii) step (A) comprises contacting the ribbon's edge portion with a glass-engaging surface of an edge roller assembly;
- (iii) the edge roller assembly comprises a bearing assembly; and
- (iv) at least the portion of the bearing assembly that generates run-out has an across-the-ribbon location which lies within the ribbon's edge portion.

14. The method of Claim 13 wherein the bearing assembly employs a gas cushion and the method comprises passing gas through the edge roller assembly to form the gas cushion.

15. The method of Claim 14 wherein the bearing assembly comprises a sub-assembly which resists across-the-ribbon motion of the glass engaging surface of the edge roller assembly.

16. The method of Claim 15 wherein the sub-assembly employs a gas cushion and the method comprises passing gas through the edge roller assembly to form the gas cushion.

17. The method of any one of Claims 13-16 wherein the edge roller assembly comprises a ceramic end cap which reduces heat transfer to the assembly from the glass ribbon.

18. The method of any one of Claims 13-17 wherein the drawing process is a fusion downdraw process.

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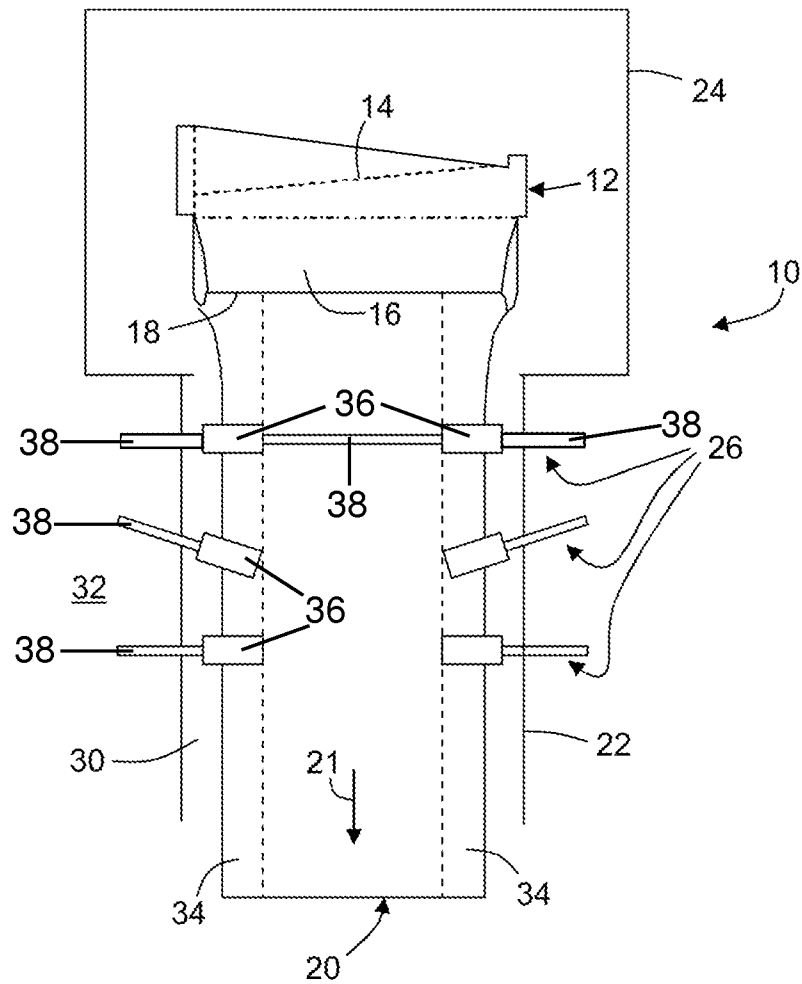


FIG. 1

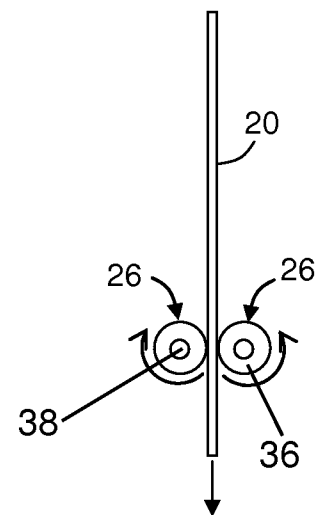


FIG. 2

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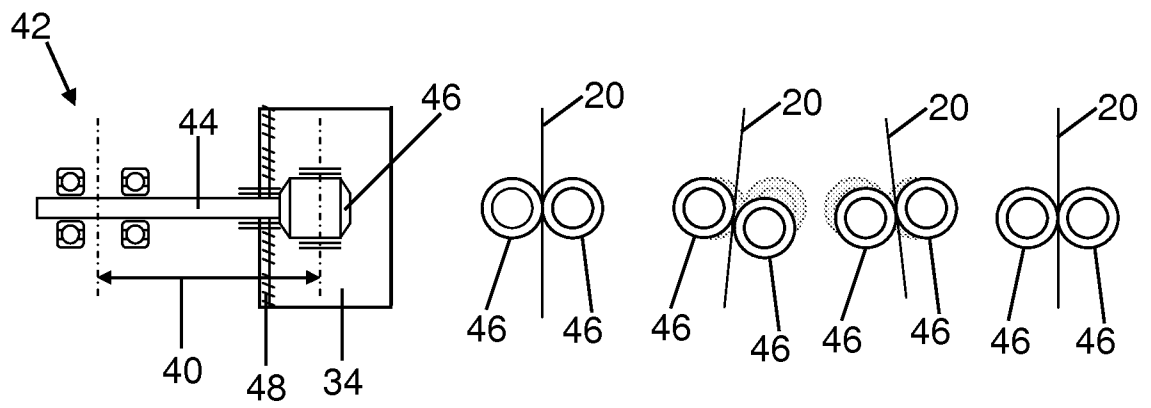


FIG. 3

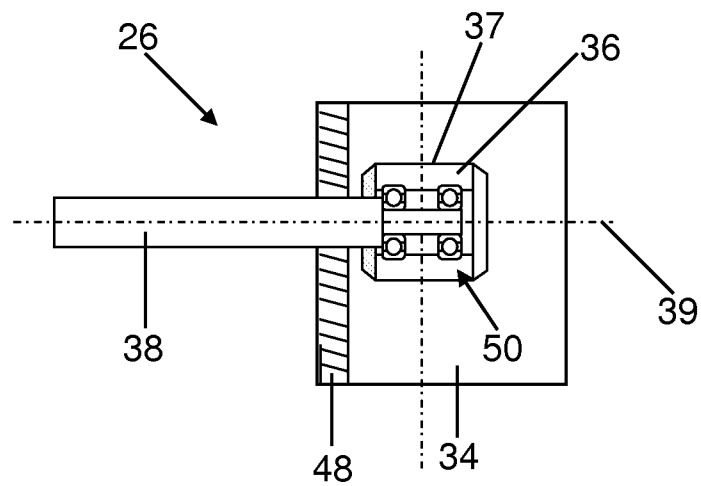


FIG. 4

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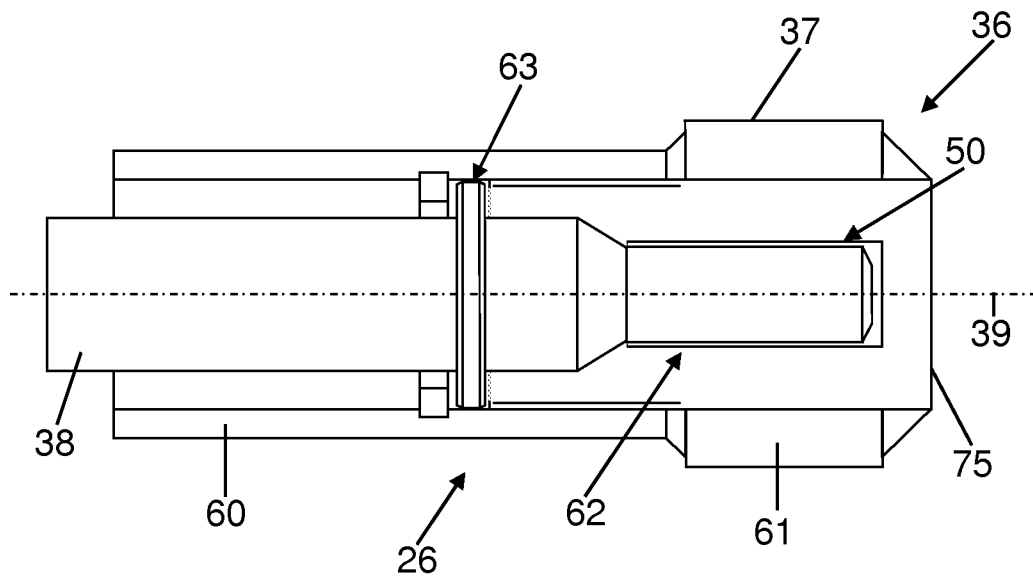


FIG. 5

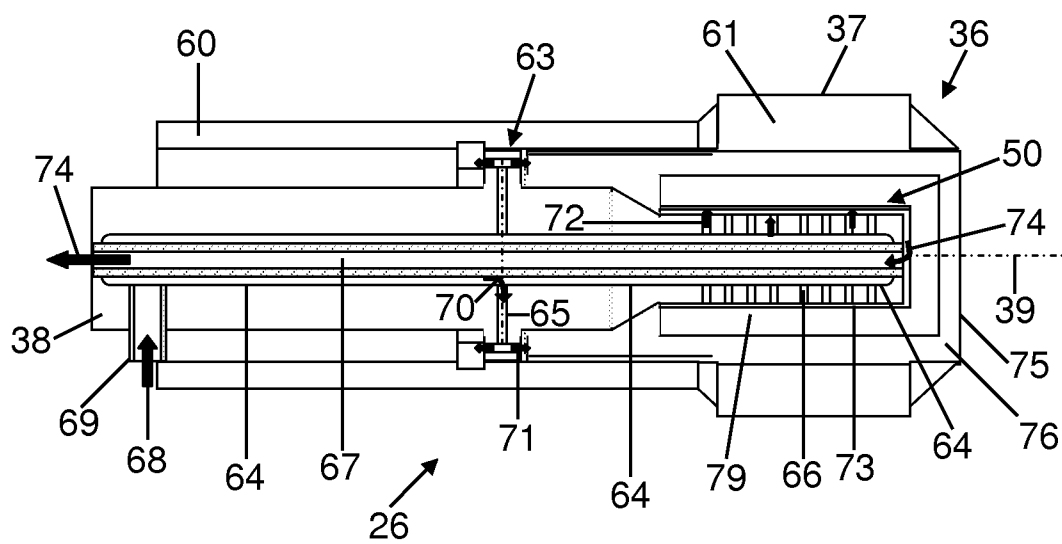


FIG. 6

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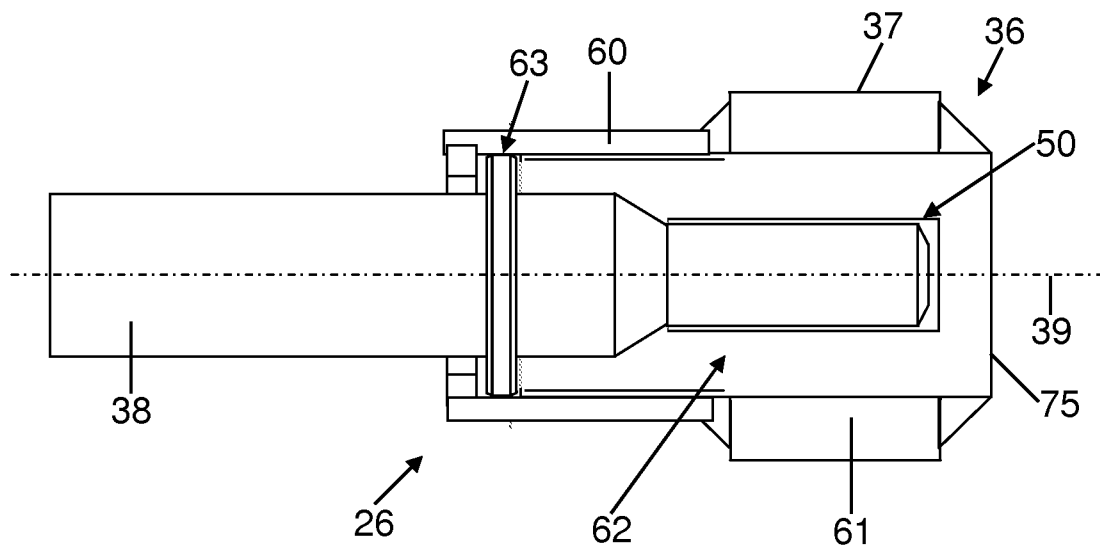


FIG. 7

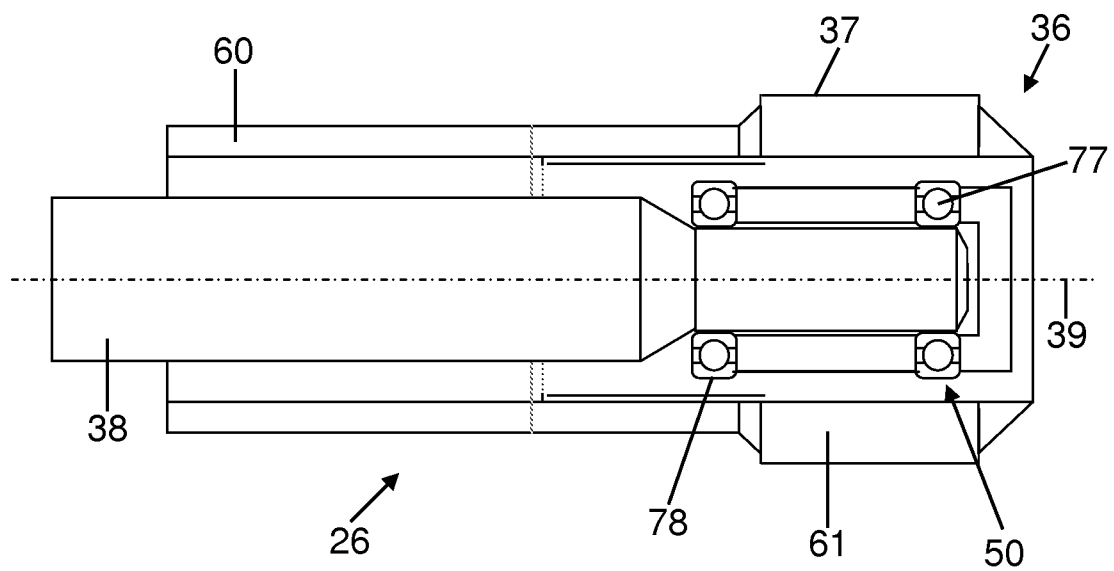


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/023861

A. CLASSIFICATION OF SUBJECT MATTER
INV. C03B17/06 C03B35/16 C03B35/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BE 334 007 A (W.L. DUPOURQUE) 30 June 1926 (1926-06-30) page 2, line 30 - page 3, line 2 page 3, line 18 - page 4; claims 1-3; figures 1,4,5	1-4,11
A	JP 5 124826 A (HOYA CORP; NIPPON SHEET GLASS CO LTD) 21 May 1993 (1993-05-21) abstract	1,13
A	US 3 709 673 A (BISHOP H) 9 January 1973 (1973-01-09) column 3, lines 13-24; figures 1,5 column 3, lines 55-68 column 4, line 65 - column 5, line 6	1
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

1 April 2011

Date of mailing of the international search report

07/04/2011

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/023861

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 195 44 995 C1 (KRAMER CARL [DE]; GERHARDT HANS JOACHIM PROF M S [DE]) 3 April 1997 (1997-04-03) figure 2 -----	11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/023861

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
BE 334007	A	NONE	
JP 5124826	A	21-05-1993 JP 3093000 B2	25-09-2000
US 3709673	A	09-01-1973 BE 790546 A1	25-04-1973
DE 19544995	C1	03-04-1997 EP 0776866 A1	04-06-1997