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(54) Title: FUSION DRAW METHOD RIBBON POSITION CONTROL SCHEME

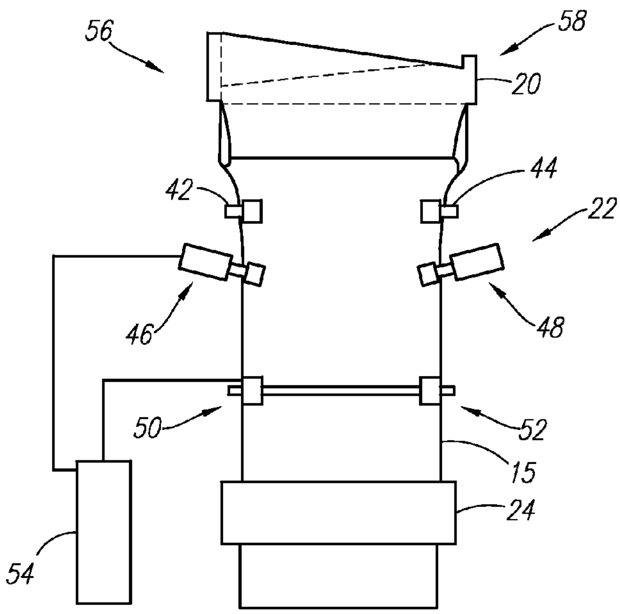

FIG. 2

(57) Abstract: A glass manufacturing system for forming a continuously moving ribbon of glass comprising a fixed roll, a floating roll, a first sensor, a second sensor, a controller and a mechanism operably connected to the controller. The fixed and floating rolls include a fixed axis of rotation with an initial fixed location and a floating axis of rotation with an initial floating location, respectively. The fixed and floating rolls are oriented parallel to one another so as to be a predetermined distance apart with the continuously moving ribbon of molten glass disposed therebetween. The first sensor is configured to monitor a location of the fixed axis. The second sensor is configured to monitor a location of the floating axis. The controller is in communication with the first sensor and the second sensor. The mechanism is operably configured to move the fixed roll when a difference between an initial location of the floating axis and a subsequent location of the floating axis exceeds a predetermined value.

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FUSION DRAW METHOD RIBBON POSITION CONTROL SCHEME

CLAIMING BENEFIT OF PRIOR FILED U.S. APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 61/346,537, filed on May 20, 2010. The content of this document and the entire disclosure of publications, patents, and patent documents mentioned herein are incorporated by reference.

FIELD

[0002] The present disclosure relates to a fusion draw machine and, more specifically, apparatus and methods of controlling a ribbon position in a fusion draw machine.

BACKGROUND

[0003] Fusion draw machines utilize rolls that guide a ribbon of molten glass. Because even slight variations in the location of the rolls can affect the attributes of the manufactured glass sheets, there is a need for a method or an apparatus that can reduce, correct or prevent such variations.

SUMMARY

[0004] The following present a simplified summary of the disclosure in order to provide a basic understanding of some example aspects described in the detailed description.

[0005] In one example aspect, a method of making a glass sheet is provided and includes the steps of forming a ribbon of molten glass with a glass manufacturing system comprising a fixed roll with a fixed axis of rotation and a floating roll with a floating axis of rotation, the fixed roll and the floating roll arranged parallel to one another such that the fixed and floating rolls are a predetermined distance apart, the fixed and floating rolls adapted to draw the ribbon of molten glass between the rolls, the fixed axis of rotation including an initial fixed location and the floating axis of rotation including an initial floating location; detecting a second location of the floating axis; and executing a position control scheme if a difference between the second location of the floating axis and the initial floating location of the floating axis exceeds a predetermined value. The position control scheme includes the steps of determining a final target location of the fixed axis based on a first set of one or more factors

including the second location of the floating axis; determining a correction amount by which the fixed axis is to be moved to reach the final target location; and moving the fixed axis by the correction amount to the final target location of the fixed axis.

[0006] A glass manufacturing apparatus for producing a continuously moving ribbon of glass is provided and comprises a fixed roll, a floating roll, a first sensor, a second sensor, a controller and a mechanism. The fixed roll comprises a fixed axis of rotation with an initial fixed location. The floating roll comprises a floating axis of rotation with an initial floating location. The fixed and floating rolls oriented parallel to one another so as to be a predetermined distance apart. The first sensor is configured to monitor a location of the fixed axis. The second sensor is configured to monitor a location of the floating axis. The controller is in communication with the first sensor and the second sensor. The mechanism is operably connected to the controller and is configured to move the fixed roll when a difference between the location of the floating axis and the initial floating location exceeds a predetermined value.

Brief Description Of The Drawings

[0007] These and other features, aspects and advantages of the present disclosure are better understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0008] **FIG. 1** is a schematic representation of a glass manufacturing system with a pull roll assembly;

[0009] **FIG. 2** is a schematic representation of the pull roll assembly including a plurality of pairs of rolls to which an apparatus and a method discussed herein can be implemented;

[0010] **FIG. 3A** schematically shows a first embodiment of the apparatus for sensing and controlling locations of a fixed roll and a floating roll;

[0011] **FIG. 3B** schematically shows a second embodiment of the apparatus for sensing and controlling locations of the fixed roll and the floating roll;

[0012] **FIG. 4A** shows locations of the fixed roll and the floating roll prior to operation;

[0013] **FIG. 4B** shows locations of the fixed roll and the floating roll altered by roll wear;

[0014] **FIG. 4C** shows locations of the fixed roll and the floating roll realigned using the apparatus and the method discussed herein;

[0015] **FIG. 5A** is a flow chart showing a control logic by which the fixed roll and the floating roll are realigned based on estimated roll wear; and

[0016] **FIG. 5B** is a flow chart showing a control logic by which the fixed roll and the floating roll are realigned based on estimated roll wear and ribbon position.

DETAILED DESCRIPTION

[0017] High quality thin glass sheets for use in flat panel displays can be produced through a fusion process such as an overflow downdraw process. **FIG. 1** shows an example embodiment of a glass manufacturing system **10**, or a fusion draw machine, more specifically, that implements the fusion process for manufacturing a glass sheet **17**. The glass manufacturing system **10** may include a melting vessel **12**, a fining vessel **14**, a mixing vessel **16** (e.g., the illustrated stir chamber), a delivery vessel **18** (e.g., the illustrated bowl), a forming vessel **20** (e.g., the illustrated isopipe), a pull roll assembly **22** and a traveling anvil machine **24** (TAM).

[0018] The melting vessel **12** is where the glass batch materials are introduced as shown by arrow **26** and melted to form molten glass **13**. The fining vessel **14** has a high temperature processing area that receives the molten glass **13** from the melting vessel **12** and in which bubbles are removed from the molten glass **13**. The fining vessel **14** is connected to the mixing vessel **16** by a finer to stir chamber connecting tube **28**. Thereafter, the mixing vessel **16** is connected to the delivery vessel **18** by a stir chamber to bowl connecting tube **30**. The delivery vessel **18** delivers the molten glass **13** through a downcomer **32** to an inlet **34** and into the forming vessel **20**. The forming vessel **20** includes an opening **36** that receives the molten glass **13** which flows into a trough **38** and then overflows and runs down two sides of the forming vessel **20** before fusing together at what is known as a root **40**. The root **40** is where the two sides come together and where the two overflow walls of molten glass **13** rejoin before being drawn downward by the pull roll assembly **22** to form the glass ribbon **15**. Then, the TAM **24** scores the drawn glass ribbon **15** which is then separated into individual glass sheets **17**.

[0019] As shown in **FIG. 2**, the pull roll assembly **22** may include a plurality of sets of rolls that are provided along the edges of ribbon **15** of molten glass for guiding the ribbon **15** in a downward direction and a controller **54** that controls the operation of the rolls. One set of rolls provided at a predetermined location along the ribbon **15** of the molten glass includes a pair of rolls at a first end **56** and a pair of rolls located oppositely at a second end **58**. The pull roll assembly **22** may include sets of edge rolls (ER) **42, 44**, driven stub rolls (DSR) **46, 48** and/or idle stub rolls (ISR) **50, 52** that are disposed in a downstream direction along the ribbon **15** of molten glass. The sets of rolls generally may be arranged in the following order in a downstream direction: ER, DSR and ISR. The rolls may be embodied in a variety of manners. For example, each of the rolls may include a longitudinal axis that is horizontally oriented, as shown for the rolls **42**, **44** and the rolls **50, 52**. Additionally, the pair of rolls on first end **56** and the pair of rolls on a second end **58** may be in operative connection with one another so that the rolls on each side of the ribbon **15** rotate as one, as shown for the rolls **50, 52**. Alternatively, the longitudinal axis of each of the rolls may be downwardly tilted, for example, as shown for the rolls **46, 48**. While the ER, DSR and ISR are shown in **FIG. 2** as having a particular configuration, the horizontal, downwardly tilted or operatively connected configuration may be applicable to any set of rolls. Moreover, as discussed more fully below, the horizontal or downwardly tilted rolls can include a fixed roll and a floating roll that are arranged parallel to one another.

[0020] As shown in **FIG. 3A-3B**, two embodiments of a mechanism **21** are provided that moves the longitudinal axes of the rolls in the pull roll assembly **22** based on communication with the controller **54**. Each pair of rolls includes a fixed roll **60** with a fixed axis **62** of rotation and a floating roll **64** with a floating axis **66** of rotation and the rolls **60**, **64** are arranged parallel to one another a predetermined distance apart. The ribbon **15** is drawn between the fixed roll **60** and the floating roll **64**, and the rotational directions of the fixed roll **60** and the floating roll **64** are such that the rolls **60**, **64** direct the ribbon **15** of glass in a downward direction. As shown in **FIG. 4A**, prior to the start of rotation, the fixed roll **60** and the floating roll **64** are at an initial fixed location **68** and an initial floating location **70**. For example, the initial fixed location **68** and the initial floating location **70** can be points X_1 and X_2 respectively on an axis.

[0021] During operation of the glass manufacturing system **10**, the floating roll **64** can float in that the floating axis **66** can move in response to forces applied to the floating roll **64**. This can be enabled, for example, by a mechanism **23**, shown to the right of the ribbon **15** in **FIGS. 3A-3B**, where the floating roll **64** applies a constant amount of force against the ribbon **15** of glass while the fixed roll **60** applies an equal amount of reactive force in the opposite direction against the ribbon **15**. In this mechanism **23**, an L-shaped member **72** is configured to pivot about a fixed point **74** and includes, on a first end **76**, a weight **78** and, on a second end **80**, a second link **82** that is pivotably coupled thereto and is configured to move in a substantially linear fashion or horizontally in **FIGS. 3A-3B**. The weight **78** thus biases the L-shaped member **72** to rotate clockwise and the second link **82** to move toward the ribbon **19** so as to apply a constant amount of force against the ribbon **15**. The amount of force applied to the ribbon **15** may be altered by changing the weight **78**. In comparison, the location of the fixed roll **60** is fixed unless a mechanism **25**, such as a motor **84**, a gear box and a belt drive (**FIG. 3A**) or a servo-mechanism such as linear actuator **86** (**FIG. 3B**), is operated to change the location. In **FIG. 3A**, the motor **84** can rotate an arm **88** in either clockwise or counterclockwise direction thus moving a first link **90**, which is pivotably connected to the arm **88** and is configured to move in a substantially linear fashion, toward and away from the ribbon **19**. In **FIG. 3B**, the movement of the first link **90** is controlled by the linear actuator **86** which can be powered electrically, hydraulically, pneumatically or the like. The substantially linear movement of the fixed roll **60** is partly illustrated in phantom in **FIGS. 3A-3B** and the floating roll **64** can also move in a similar fashion.

[0022] As further shown in **FIGS. 3A-3B**, the locations of the fixed axis **62** and the floating axis **66** may be detected by a first sensor **92** and a second sensor **94** respectively. The first and second sensors **92**, **94** can detect or monitor the locations of the fixed axis **62** and the floating axis **66** respectively along a line and may be embodied as cable transducers or string potentiometers. Moreover, the locations of the fixed axis **62** and the floating axis **66** may be altered by way of translation such that orientations of the axes **62**, **66** are unchanged. Additionally, the glass manufacturing system **10** may be equipped with a measurement device **96** adjacent the area where the pull roll assembly **22** is located as shown in **FIGS. 3A-3B**. The measurement device **96** may be configured to measure the ribbon position at various points across a draw of the ribbon **19** and may utilize ultraviolet rays for the measurements. The measurement device **96** may be located near a setting zone of the ribbon **19** where the product stress and flatness of the glass sheet are determined.

[0023] As shown in **FIGS. 4A-4B**, the method and apparatus discussed herein are provided to allow realignment of the fixed roll **60** and the floating roll **64** in circumstances where the floating roll **64** has diverted from a properly aligned location due to changes in operating conditions, arising from, for example, roll wear, which may lead to inconsistencies in the shape of the ribbon **15**. **FIG. 4A** shows the ribbon **15** drawn downward through the upstream edge rolls **42**, **44** and the driven stub rolls **46**, **48** (or the idle stub rolls **50**, **52**) in a vertically straight configuration. **FIG. 4A** thus shows properly aligned locations for the fixed roll **60** and the floating roll **64** (i.e., the initial fixed location **68** and the initial floating location **70**). The fixed roll **60** and the floating roll **64** may be part of either the driven stub rolls **46**, **48** or the idle stub rolls **50**, **52**. In **FIG. 4B**, the fixed roll **60** and the floating roll **64** are in misaligned locations because the diameters of the rolls **60**, **64** have decreased through usage or wear. As described above, while the location of the fixed axis **62** is unchanged by roll wear, the location of the floating axis **66** has shifted toward the left in **FIG. 4B** because the floating roll **64** is configured to maintain a constant force against the ribbon **15**. This causes the ribbon **15** to deviate from the vertical and straight configuration, indicated by a dotted line in **FIG. 4B**, and it becomes necessary to realign the rolls **60**, **64** such that ribbon **19** will be drawn in the desired vertical and straight manner, as shown in **FIG. 4C**.

[0024] **FIG. 5A** shows a first embodiment of a position control scheme **100** (i.e., “a feed-forward control scheme”) for adjusting the locations of the rolls **60**, **64** such that a vertical and straight ribbon draw is achieved. The position control scheme **100** represents a looped method or control logic by which the controller **54** adjusts the locations of the axes **62**, **66** of the rolls **60**, **64**. It must also be noted that the controller **54** can be a single processing apparatus or multiple discrete apparatuses operating in conjunction with the pull roll assembly **22**. The controller **54** is in electrical communication with the sensors **92**, **94** and the measurement device **96**. The position control scheme **100** may be configured to be executed whenever the location of the floating axis **66** is offset from the initial floating location **70** by an amount exceeding a predetermined value thereby controlling the frequency of adjustment. In the first embodiment of the position control scheme **100**, the location of the floating axis **66** is measured by the second sensor **94** at step **114** and is relayed to adder-subtractor **106** and estimator **102**. The estimator **102** may include an algorithm for estimating roll wear rw_e based on the detected location y_r of the floating axis **66** that was measured by the second sensor **94**. The estimated roll wear rw_e is likely to be great if the deviation of the detected location y_r of the floating axis **66** from the initial floating location **70** is great. The location of the fixed axis **62** is unchanged by the use of the rolls **60**, **64** and only the location of the floating axis **66** is altered as the rolls **60**, **64** wear out and the diameters of the rolls **60**, **64** thus become smaller. For example, the fixed axis **62** and the floating axis **66** can be shifted to points X_1 and X_2-d respectively from the initial fixed location **68** and the initial floating location **70**, and the second sensor **94** would detect that the floating axis **66** has moved toward the left by a distance d. Based on such detection, assuming each of the rolls **60**, **64** undergo the same amount of roll wear over time, the estimator **102** may determine that a roll wear of d/2 is attributable to each of the fixed roll **60** and the floating roll **64**, and the controller **54** may determine that the fixed axis **62** and the floating axis **66** need to be moved by d/2 to the right in **FIG. 4B** or i.e., points X_1+d/2 and X_2-d/2 to accomplish a vertical and straight orientation of the ribbon **19**. Then, based on the location of the floating axis **66**, the estimated roll wear rw_e from the estimator **102** is relayed to an outer-loop feed forward controller **104** which generates a first auxiliary target location u_{fd} of the fixed axis **62**. Next, at the adder-subtractor **106**, a final target location u_f of the fixed axis **62** is determined based on the first auxiliary target location u_{fd} of the fixed axis **62** from the outer-loop feed forward controller **104** and the detected location y_r of the floating axis **66** from step **114**. For example, a value of the final target location u_f may be equal to the first auxiliary target location u_{fd} minus the detected location y_r of the floating axis **66**, as shown in **FIG. 5A**. Next, an inner-loop feedback controller **108** generates, based on the final target location u_f of the fixed axis **62** from the adder-subtractor **106**, a correction amount u_r by which the fixed axis **62** must be moved from its present location. At step **110**, a second set of factors d which may be disturbance factors representing effects arising from waves propagating upward from the TAM, a flow rate of molten glass, a process drift arising from temperature, etc. can be input for consideration in the position control scheme **100**. Thereafter, at step **112**, the second set of factors can be taken into account to further adjust the correction amount u_r, and the location of the fixed axis **62** can be moved by the correction amount u_r to realign the rolls **60**, **64**. Step **112** can also accumulate as data the correction amount u_r, disturbance factors d and detected location y_r of the floating axis **66** so that a physical, mathematical or other relationship between these parameters can be determined. Then, the entire position control scheme **100** can be repeated starting from step **114**.

[0025] **FIG. 5B** shows a second embodiment of the position control scheme **101** for adjusting the locations of the rolls **60**, **64**. The second embodiment (i.e., “a feed-forward and feedback control scheme") includes the first embodiment of the position control scheme **101**, which is enclosed within a dotted line, and incorporates a measurement of a ribbon position y_b into the position control scheme **101**. At step **118**, the ribbon position y_b is detected by the measurement device **96** as described above and is relayed to adder-subtractor **122**. The adder-subtractor **122** is also input with a reference ribbon position r which is provided by a reference block **120**. The adder-subtractor **122** thus determines an error amount r-y_b by which the ribbon **15** is offset from the reference ribbon position r by subtracting the detected ribbon position y_b from the reference ribbon position r. The error amount r-y_b is then relayed to an outer-loop feedback controller **124** which determines a second auxiliary target location u_{fb}. The second auxiliary target location u_{fb} is then relayed to adder-subtractor **106** which subtracts the detected location y_r of the floating axis **66** from the sum of the first auxiliary target location u_{fd} and the second auxiliary target location u_{fb} to obtain the final target location u_f of the fixed axis **62**. Thus, the second embodiment of the position control scheme **101** differs from the first embodiment in that the final target location u_f of the fixed axis **62** is determined by further taking into account the ribbon position y_b. Moreover, in the second embodiment, step **116** can also accumulate as data the ribbon position y_b and the detected location y_r of the floating axis **66** so that a physical, mathematical or other relationship between these parameters can be determined. Furthermore, a relationship between the ribbon position y_b, the DSR roll position and the ISR roll position can also be determined from the obtained data. Then, the entire position control scheme **101** can be repeated at step **118**

[0026] Exemplary, non-limiting embodiments include:

[0027] C1. A method of making a glass sheet comprising: forming a ribbon of molten glass with a glass manufacturing apparatus comprising a fixed roll with a fixed axis of rotation and a floating roll with a floating axis of rotation, the fixed roll and the floating roll arranged parallel to one another such that the fixed and floating rolls are a predetermined distance apart, the fixed and floating rolls adapted to draw the ribbon of molten glass between the rolls, the fixed axis of rotation including an initial fixed location and the floating axis of rotation including an initial floating location; detecting a second location of the floating axis; and executing a position control scheme if a difference between the second location of the floating axis and the initial floating location of the floating axis exceeds a predetermined value, the position control scheme comprising the steps of: determining a final target location of the fixed axis based on a first set of one or more factors including the second location of the floating axis; determining a correction amount by which the fixed axis is to be moved to reach the final target location; and moving the fixed axis by the correction amount to the final target location of the fixed axis.

[0028] C2. The method of C1, wherein the position control scheme comprises the step of estimating roll wear based on the second location of the floating axis, the first set of factors further including roll wear.

[0029] C3. The method of C1 or C2, wherein the glass manufacturing apparatus further comprises a measurement device configured to detect a second ribbon position relative to an initial ribbon position, the first set of factors further including the second ribbon position.

[0030] C4. The method of C3, wherein executing the position control scheme comprises the steps of estimating the roll wear based on the second location of the floating axis, and determining a first auxiliary target location of the fixed axis based on the roll wear, the first set of factors further including the second location of the floating axis, the second ribbon position and the roll wear, the position control scheme further comprising the step of determining a second auxiliary target location of the fixed axis based on the second ribbon position, the final target location defined as the second location of the floating axis subtracted from the sum of the first auxiliary target location and the second auxiliary target location.

[0031] C5. The method of any of C1 to C4, wherein the position control scheme further comprises the step of adjusting the correction amount based on a second set of one or more factors.

[0032] C6. The method of C5, wherein the second set of factors comprises at least one disturbance factor.

[0033] C7. The method of any of C1 to C6, wherein the glass manufacturing apparatus comprises driven stub rolls and idle stub rolls, and the fixed roll and the floating roll controlled by the method are part of at least one of the driven stub rolls and the idle stub rolls.

[0034] C8. The method of any of C1 to C7, wherein the predetermined value is adjustable to control a frequency at which the position control scheme is executed.

[0035] C9. The method of any of C1 to C8, wherein, if a difference between the second location of the floating axis and the initial location of the floating axis is represented as a vector having a given value in a given direction with an initial point located at the initial floating location, and wherein the correction amount is one half of the given value in a direction substantially opposite the given direction.

[0036] C10. The method of any of C1 to C9, wherein the step of moving the fixed axis is by way of translation.

[0037] C11. A glass manufacturing apparatus for producing a continuously moving ribbon of glass comprising: a fixed roll comprising a fixed axis of rotation with an initial fixed location; a floating roll comprising a floating axis of rotation with an initial floating location, the fixed and floating rolls oriented parallel to one another so as to be a predetermined distance apart; a first sensor configured to monitor a location of the fixed axis; a second sensor configured to monitor a location of the floating axis; a controller in communication with the first sensor and the second sensor; and a mechanism operably connected to the controller and configured to move the fixed roll when a difference between the location of the floating axis and the initial floating location exceeds a predetermined value.

[0038] C12. The apparatus of C11, wherein, during operation of the apparatus in which the fixed roll and the floating roll draw the ribbon of molten glass between the rolls, the location of the fixed axis is fixed and the location of the floating roll is floating such that a constant amount of force is applied by the floating roll on the ribbon.

[0039] C13. The apparatus of C11 or C12, wherein the controller moves the fixed roll by a correction amount.

[0040] C14. The apparatus of any of C11 to C13, wherein the mechanism includes a servo-mechanism.

[0041] C15. The apparatus of any of C11 to C14, wherein the first sensor and the second sensor include a string potentiometer.

[0042] C16. The apparatus of any of C11 to C15, furthering comprising a measurement device configured to measure a second ribbon position relative to an initial ribbon position.

[0043] C17. The apparatus of C16, wherein the measurement device emits ultraviolet radiation.

[0044] C18. The apparatus of any of C11 to C17, further comprising driven stub rolls and idle stub rolls, the fixed roll and the floating roll controlled by the method being part of at least one of the driven stub rolls and the idle stub rolls.

[0045] It will be apparent to those skilled in the art that various modification and variations can be made to the present disclosure without departing from spirit and scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this disclosure provided they come within the scope of the appended claims and their equivalents.

CLAIMS

What is claimed is:

1. A method of making a glass sheet (17) comprising:

forming a ribbon of molten glass (15) with a glass manufacturing apparatus comprising a fixed roll (60) with a fixed axis of rotation (62) and a floating roll (64) with a floating axis of rotation (66), the fixed roll and the floating roll arranged parallel to one another such that the fixed and floating rolls are a predetermined distance apart, the fixed and floating rolls adapted to draw the ribbon of molten glass between the rolls, the fixed axis of rotation including an initial fixed location and the floating axis of rotation including an initial floating location;

detecting a second location of the floating axis; and

executing a position control scheme if a difference between the second location of the floating axis and the initial floating location of the floating axis exceeds a predetermined value, the position control scheme comprising the steps of:

determining a final target location of the fixed axis based on a first set of one or more factors including the second location of the floating axis;

determining a correction amount by which the fixed axis is to be moved to reach the final target location; and

moving the fixed axis by the correction amount to the final target location of the fixed axis.

2. The method of claim 1, wherein the position control scheme comprises the step of estimating roll wear based on the second location of the floating axis, the first set of factors further including roll wear.

3. The method of claim 1 or claim 2, wherein the glass manufacturing apparatus further comprises a measurement device (96) configured to detect a second ribbon position relative to an initial ribbon position, the first set of factors further including the second ribbon position.

4. The method of claim 3, wherein executing the position control scheme comprises the steps of estimating the roll wear based on the second location of the floating axis, and determining a first auxiliary target location of the fixed axis based on the roll wear, the first set of factors further including the second location of the floating axis, the second ribbon position and the roll wear, the position control scheme further comprising the step of determining a second auxiliary target location of the fixed axis based on the second ribbon position, the final target location defined as the second location of the floating axis subtracted from the sum of the first auxiliary target location and the second auxiliary target location.

5. The method of any of claims 1 to 4, wherein the position control scheme further comprises the step of adjusting the correction amount based on a second set of one or more factors.

6. The method of claim 5, wherein the second set of factors comprises at least one disturbance factor.

7. The method of any of claims 1 to 6, wherein the glass manufacturing apparatus comprises driven stub rolls (46, 48) and idle stub rolls (50, 52), and the fixed roll and the floating roll controlled by the method are part of at least one of the driven stub rolls and the idle stub rolls.

8. The method of any of claims 1 to 7, wherein the predetermined value is adjustable to control a frequency at which the position control scheme is executed.

9. The method of any of claims 1 to 8, wherein, if a difference between the second location of the floating axis and the initial location of the floating axis is represented as a vector having a given value in a given direction with an initial point located at the initial floating location, and wherein the correction amount is one half of the given value in a direction substantially opposite the given direction.

10. The method of any of claims 1 to 9, wherein the step of moving the fixed axis is by way of translation.

11. A glass manufacturing apparatus for producing a continuously moving ribbon of glass (15) comprising:

a fixed roll (60) comprising a fixed axis of rotation (62) with an initial fixed location;

a floating roll (64) comprising a floating axis of rotation (66) with an initial floating location, the fixed and floating rolls oriented parallel to one another so as to be a predetermined distance apart;

a first sensor configured to monitor a location of the fixed axis;

a second sensor configured to monitor a location of the floating axis;

a controller (54) in communication with the first sensor and the second sensor; and

a mechanism operably connected to the controller and configured to move the fixed roll when a difference between the location of the floating axis and the initial floating location exceeds a predetermined value.

12. The apparatus of claim 11, wherein, during operation of the apparatus in which the fixed roll and the floating roll draw the ribbon of molten glass between the rolls, the location of the fixed axis is fixed and the location of the floating roll is floating such that a constant amount of force is applied by the floating roll on the ribbon.

13. The apparatus of claim 11 or claim 12, wherein the controller moves the fixed roll by a correction amount.

14. The apparatus of any of claims 11 to 13, wherein the mechanism includes a servo-mechanism.

15. The apparatus of any of claims 11 to 14, wherein the first sensor and the second sensor include a string potentiometer.

16. The apparatus of any of claims 11 to 15, furthering comprising a measurement device (96) configured to measure a second ribbon position relative to an initial ribbon position.

17. The apparatus of claim 16, wherein the measurement device (96) emits ultraviolet radiation.

18. The apparatus of any of claims 11 to 17, further comprising driven stub rolls (46, 48) and idle stub rolls (50, 52), the fixed roll and the floating roll controlled by the method being part of at least one of the driven stub rolls and the idle stub rolls.

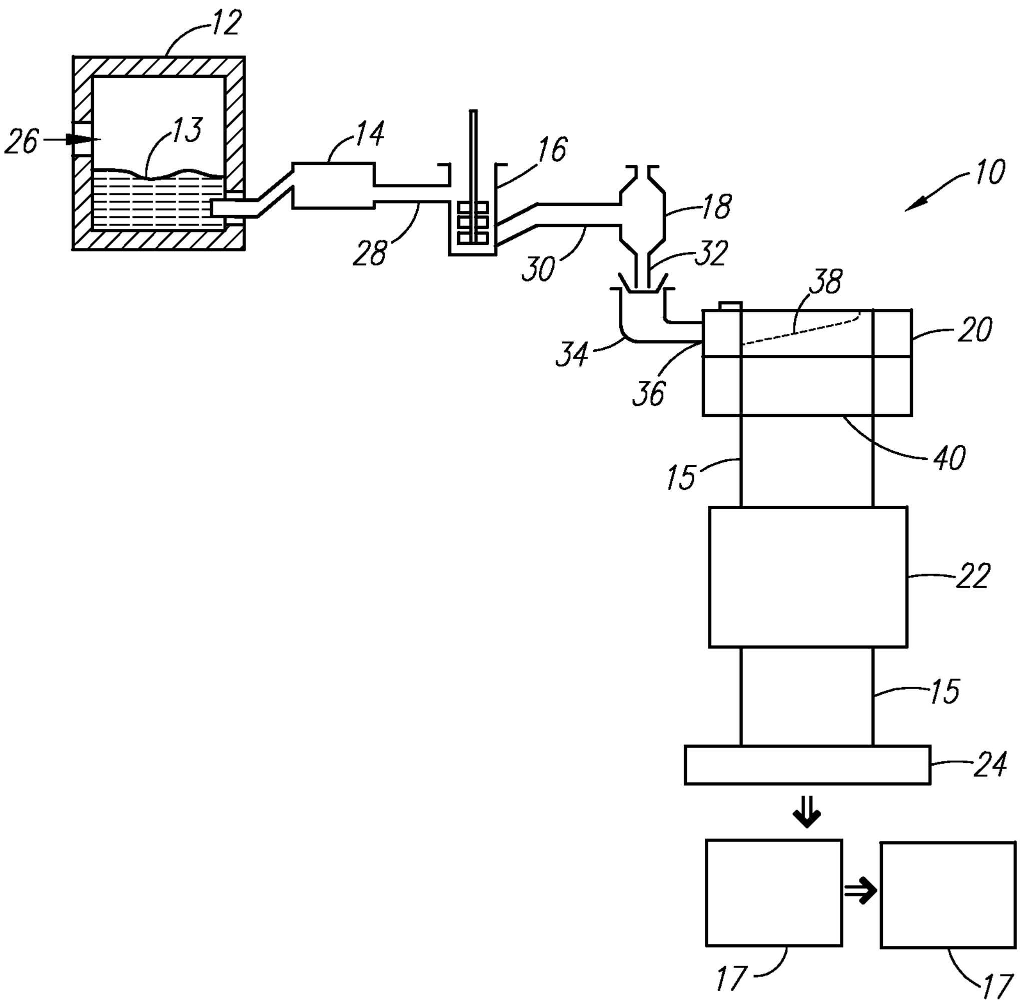

FIG. 1

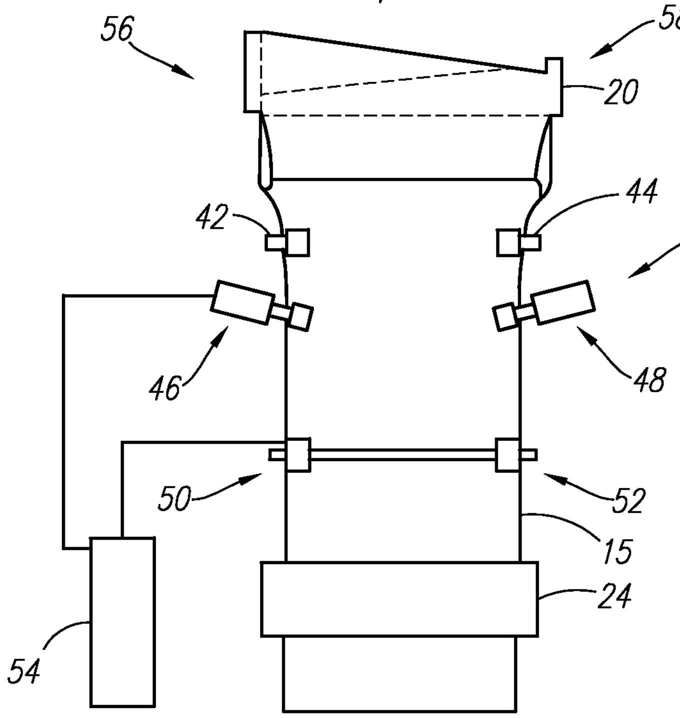

FIG. 2

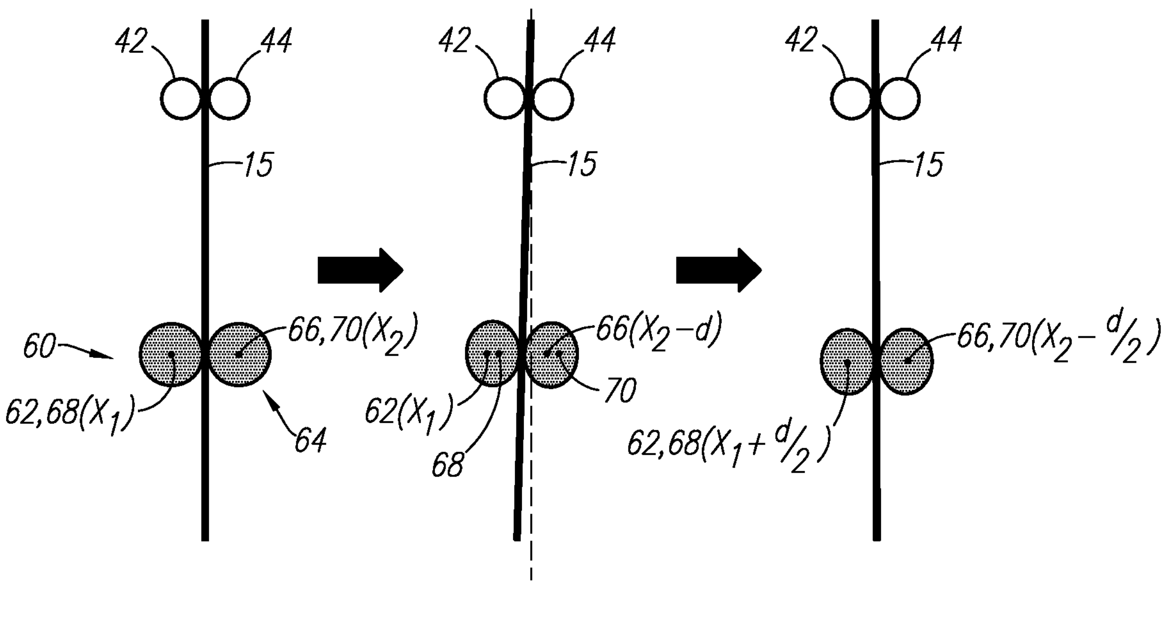

FIG. 4A FIG. 4B FIG. 4C

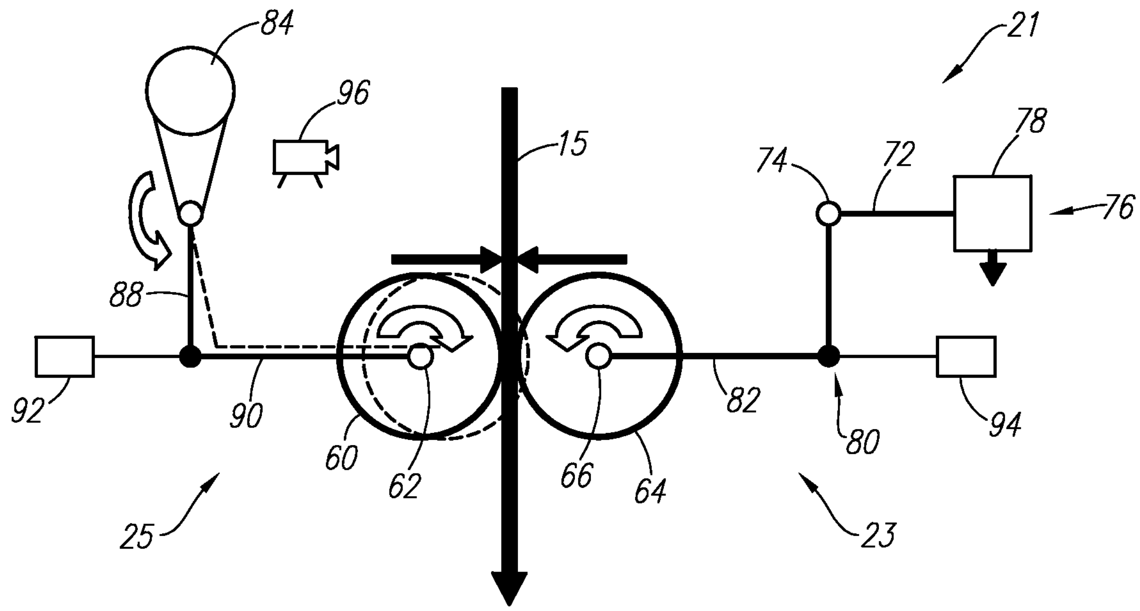
84
96
15
21
74
72
78
76
88
92
90
60
62
66
64
82
80
94
25
23

FIG. 3A

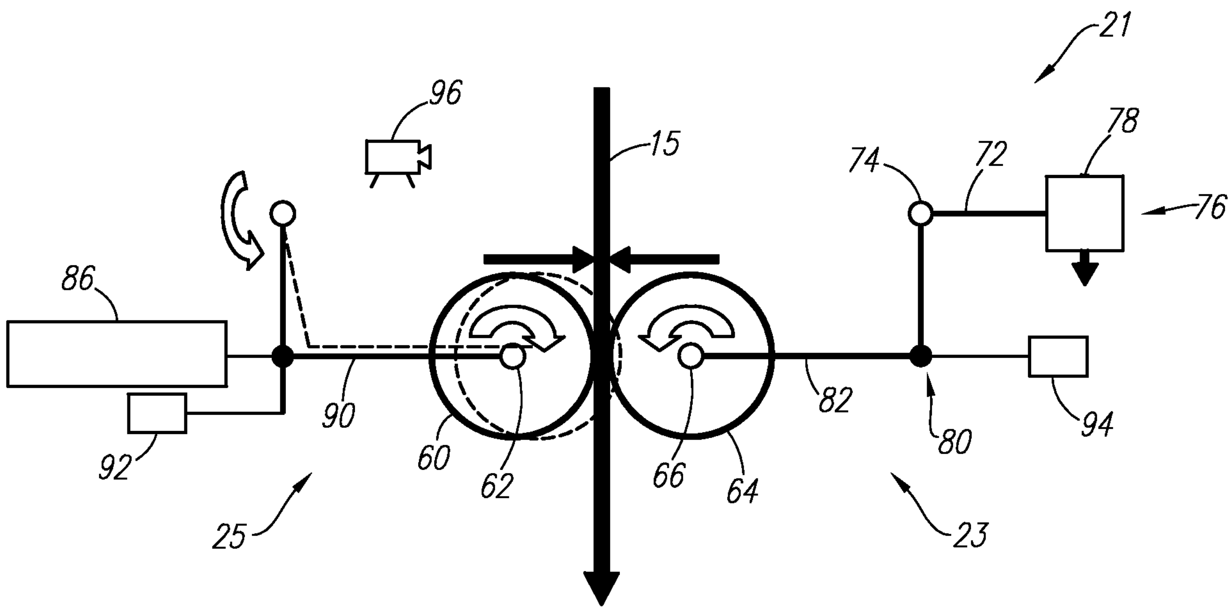
96
15
21
74
72
78
76
86
92
90
60
62
66
64
82
80
94
25
23

FIG. 3B

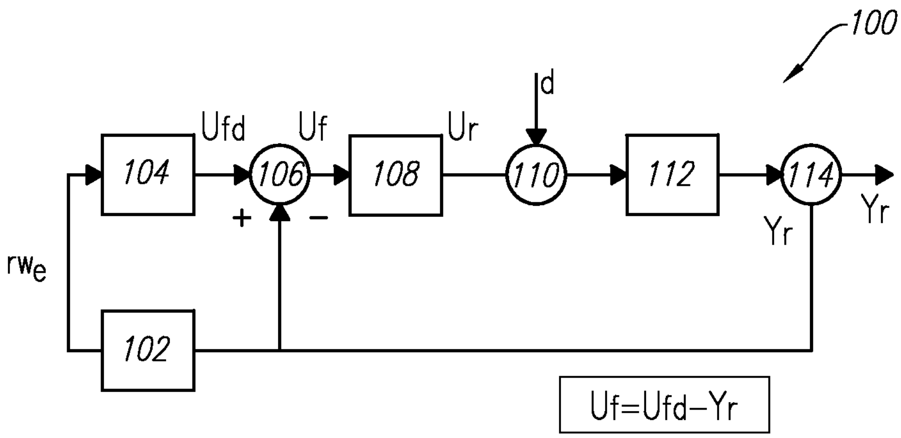
100
104
Ufd
Uf
106
108
Ur
d
110
112
114
Yr
Yr
+
−
rwe
102
Uf=Ufd−Yr

FIG. 5A

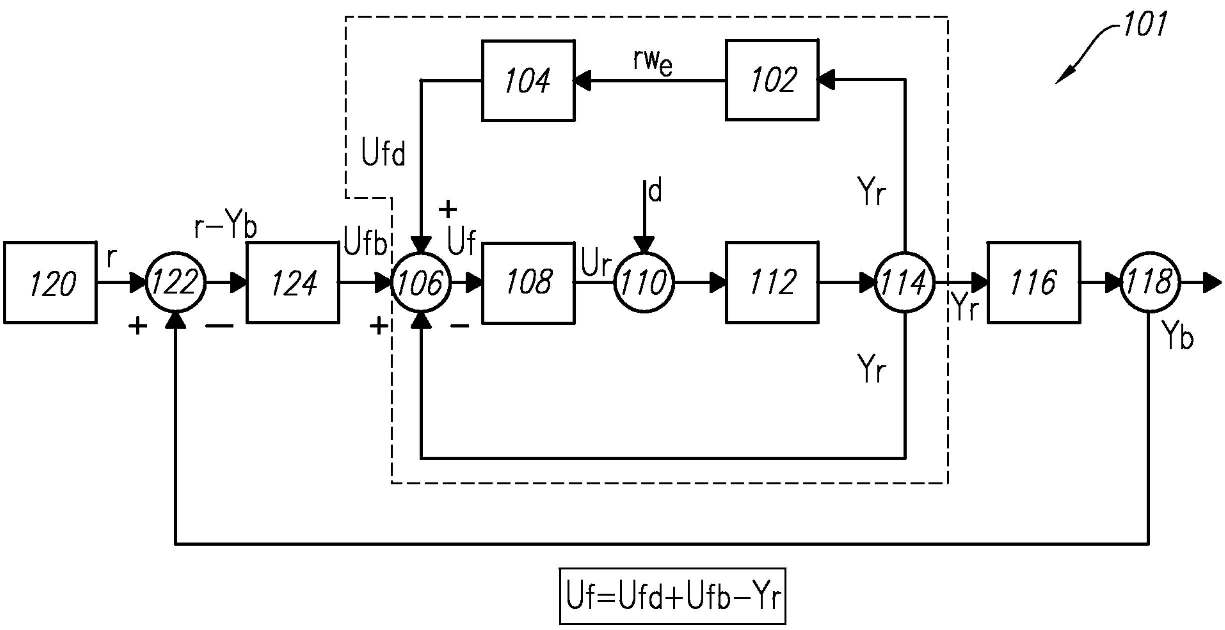
101
104
rwe
102
Ufd
d
Yr
+
120
r
122
r−Yb
124
Ufb
Uf
106
108
Ur
110
112
114
Yr
116
118
Yb
+
−
+
−
Yr
Uf=Ufd+Ufb−Yr

FIG. 5B