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(54) **METHOD FOR CONTROLLING A LATERAL POSITION OF AN ENDLESS BELT OF A BELT CONVEYOR SYSTEM**

(57) The present invention relates to a method for controlling a lateral position of an endless belt (110) of a belt conveyor system (200), the belt conveyor system comprising a steering roller (224) arranged for supporting the endless belt and controlling the lateral position of the endless belt in a lateral direction, the lateral direction being transverse to a circulation path of the belt; the method comprising the steps of circulating the belt along the circulation path; controlling a first rotation position of the

steering roller by a belt steering device about a first rotation axis (P1) to control the lateral position of the belt; and controlling a second rotation position of the steering roller by the belt steering device about a second rotation axis (P2) independently of the first rotation position about the first rotation axis to adjust the lateral position of the belt; wherein the second rotation axis is arranged substantially perpendicular to the first rotation axis.

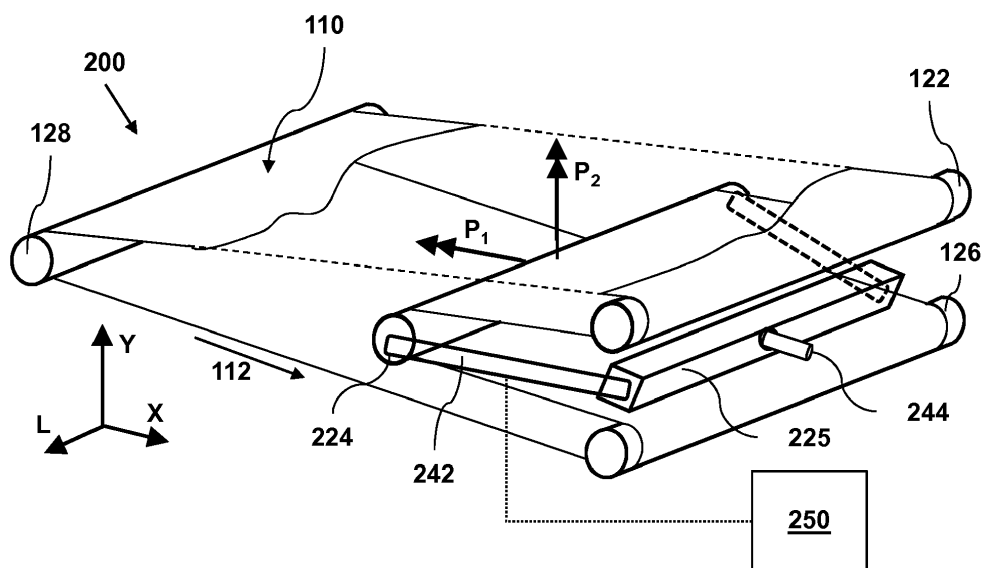


Fig. 2A

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a method for controlling a lateral position of an endless belt of a belt conveyor system. The present invention further relates to a belt conveyor system for controlling a lateral position of an endless belt.

BACKGROUND ART

[0002] A known inkjet printing apparatus comprises a belt conveyor system and an inkjet print head assembly. The belt conveyor system comprises an endless transport belt, a steering roller and a belt steering device. The endless transport belt is arranged for transporting a substrate along a transport path, such as along the inkjet print head assembly. The steering roller is arranged for supporting said belt and for controlling a lateral position of the belt in a lateral direction, the lateral direction being transverse to a circulation path of the belt. The steering roller extends along a longitudinal axis. In the belt conveyor system a method is used, wherein the belt steering device is arranged for controlling a rotation position of the steering roller about a rotation axis to control the lateral position of the belt.

In the known control method, the belt steering device is arranged for adjusting the rotation position of the steering roller about the rotation axis over a certain steering range, i.e. a certain rotational range about the rotation axis. The rotation axis is arranged substantially perpendicular to the longitudinal axis of the steering roller.

The belt steering device occupies an operational space inside the belt conveyor system for rotating the steering roller over the steering range. Said steering range of the belt steering device including the steering roller may be limited by the belt conveyor system, such as due to other components of the belt conveyor system.

For example, the steering roller may be positioned inside the belt conveyor system between two portions of the belt, which portions of the belt are transported by other rollers of the belt conveyor system. The steering range of the belt steering device about the rotation axis is limited between a first ultimate rotational position and a second ultimate rotational position, as the rotational position of the steering roller is restricted by said portions of the belt at both sides of the steering range about the rotation axis.

[0003] At the same time, a desire may exist to enlarge a steering capacity of the belt steering device for controlling the lateral position of the belt, such as in case the steering range of the steering roller about the rotation axis is insufficient for reliably controlling the lateral position of the belt.

[0004] In WO2012/045622 a method is disclosed of adjusting a lateral position of an endless belt that is passed around at least two rollers, wherein the method comprises controlling a lateral position of at least one of

the rollers in a translation direction in combination with controlling the rotation position about a rotation axis of said roller.

[0005] WO2012/021059A1 discloses a steering device for an endless belt looped around a pair of rollers. At least one of the rollers is a steering roller, which may be rotated perpendicular to its rotation axis to adjust the position of the endless belt. A drawback of WO2012/021059A1 is that its implementation extends the length of the belt, increasing the overall volume of the belt conveyor system. This is particularly disadvantageous when upgrading existing system, wherein space is limited. Also, sheets cannot be reliably transferred onto the belt near the steering rollers, as there the position of the belt is continuously being adjusted. During transfer, a sheet will then be deformed or ruptured as the belt pulls the sheet sideways before the sheet is free of the system it is being transferred from. Further, two steering rollers are a costly and their control scheme is relatively complex.

SUMMARY OF THE INVENTION

[0006] It is accordingly an object of the present invention to provide a method providing an enlarged steering capacity of a belt steering device for steering a steering roller to control a lateral position of an endless belt in the belt conveyor system, wherein the steering capacity is enlarged independently of the steering range of the belt steering device about the rotation axis, without increasing the overall dimensions of the belt steering device.

[0007] According to an aspect of the present invention a method is provided for controlling a lateral position of an endless belt of a belt conveyor system, the belt conveyor system comprising:

- three rollers around which the endless belt extends, which three rollers define an inner volume;
 - a steering roller arranged for supporting the endless belt and controlling the lateral position of the endless belt in a lateral direction, the lateral direction being transverse to a circulation path of the belt, which steering roller is entrained or positioned within the inner volume defined by the three rollers;
- the method comprising the steps of:

- a) circulating the belt along the circulation path, such that the belt passes through the inner volume via the entrained steering roller;
- b) controlling a first rotation position of the steering roller by a belt steering device about a first rotation axis to control the lateral position of the belt; and
- c) controlling a second rotation position of the steering roller by the belt steering device about a second rotation axis independently of the first rotation position about the first rotation axis to adjust the lateral position of the belt; wherein the

second rotation axis is arranged substantially perpendicular to the first rotation axis.

[0008] The control of the second rotation position of the steering roller by the belt steering device about the second rotation axis enlarges the steering capacity of the belt steering device, i.e. including the steering roller, independently of the first rotation position of the steering roller about the first rotation axis. In this way, the method provides an enhanced control on the lateral position of the belt, without enlarging the steering range, i.e. the rotational range, of the belt steering device and the steering roller about the first rotation axis.

The control step of the second rotation position does substantially not affect the first rotation position due to the substantially perpendicular arrangement of the second rotation axis relative to the first rotation axis. As such, a control on the lateral position of the belt in the lateral direction by the belt steering device and the steering roller is enhanced. Preferably, the second rotation axis is arranged perpendicular to the first rotation axis.

For example, the additional adjustment of the second rotation position of the steering roller about the second rotation axis independently of the first rotation position may substantially double the steering effect of the steering roller on the lateral position of the belt, while maintaining a steering range of the belt steering device and the steering roller about the first rotation axis substantially constant.

The first rotation axis may be arranged substantially perpendicular to a longitudinal axis of the steering roller. This arrangement provides a reliable control on the lateral position of the belt. Additionally the second rotation axis may be arranged substantially perpendicular to the longitudinal axis of the steering roller. This arrangement enhances the reliable control on the lateral position of the belt.

[0009] It is the insight of the inventors that the steering range is improved by entraining the steering roller within the inner volume. In this manner, existing printing systems may be easily upgraded, as the sheet conveyor system according to the present invention may be implemented within the volume of an existing belt conveyor system.

[0010] In an embodiment, the method further comprises the step of:

- d) selecting a second rotation position of the steering roller to be maintained by the belt steering device while feedback-controlling the lateral position of the belt by rotating the steering roller about the first rotation axis.

The second rotation position of the steering roller about the second rotation axis is selected from a range of possible second rotation positions of the belt steering device, including the steering roller, about the second rotation axis. The second rotation position of the steering roller

may be suitably selected in order to feedback-controlling the lateral position of the belt by rotating the steering roller about the first rotation axis only, while maintaining the selected second rotation position of the steering roller about the second rotation axis. As defined herein, feedback-controlling the lateral position of the belt is controlling the lateral position of the belt based on a detection of the lateral position of the belt by adjusting the lateral position of the belt by rotating the steering roller about the first rotation axis and / or the second rotation axis independently one another.

In this step, the second rotation position may be selected based on an attribute of the endless belt, such as a skewness property and / or a stiffness property of the endless belt. For example, a skewness property of the endless belt may indicate a difference of a length of the endless belt along a circulation direction of the belt relative to the lateral direction, i.e. transverse of the circulation path of the endless belt.

[0011] In an embodiment, the method further comprises a calibration procedure comprising the steps of:

- e) maintaining the second rotation position of the steering roller fixed relative to the second rotation axis;
- f) determining a first nominal rotation position T_1 of the steering roller about the first rotation axis for maintaining the lateral position of the belt stationary during the circulating step; and
- g) determining an offset ΔT of the first nominal rotation position T_1 relative to a reference rotation position T_0 of the belt steering device about the first rotation axis, wherein $\Delta T = T_1 - T_0$.

The steps of the calibration procedure enable determining an offset of the first nominal rotation position of the steering roller about the first rotation axis, based on the endless belt used, such as a mesh belt.

The second rotation position of the steering roller maintained in step e) may be a nominal second rotation position C_0 , e.g. wherein the steering roller is aligned with the lateral direction relative to the second rotation axis. In any way, during the determining step f) of the first nominal rotation position T_1 , the second rotation position of the steering roller is maintained fixed.

The reference rotation position T_0 may be a first rotation position of a predetermined range of the belt steering device about the first rotation axis. As defined herein, the steering range of the belt steering device about the first rotation axis extends between a first ultimate rotational position about the first rotation axis and a second ultimate rotational position about the first rotation axis.

The reference rotation position T_0 may be a first rotation position for providing an optimum steering capacity to the steering roller for controlling the lateral position of the belt.

For example, the reference rotation position T_0 of the steering roller may be aligned parallel to the lateral di-

rection, i.e. transverse to the circulation path. In this example, the offset ΔT may also be referred to as a skewness of the steering roller relative to the lateral direction. In another example, the reference rotation position T_0 of the steering roller may be a midpoint rotation position T_0 of the predetermined range about the first rotation axis. As defined herein a midpoint rotation position T_0 of the predetermined range is a midpoint rotation position of the steering roller about the first rotation axis between ultimate first rotation positions arranged at both ends of the predetermined range about the first rotation axis.

[0012] Knowing the offset of the first nominal rotation position of the steering roller about the first rotation axis supports determining in what way the steering capacity of the steering roller can be improved. A larger offset may indicate a sub-optimal use of the steering range of the steering roller about the first rotation axis to actively control the lateral position of the belt. Furthermore the direction of the offset relative to the first nominal rotation position of the steering roller indicates in which direction the second rotation position may need to be adjusted in order to reduce or increase the offset.

[0013] Alternatively, the reference rotation position T_0 may be selected a virtual first rotation position of the belt steering device about the first rotation axis outside the predetermined range. In this embodiment, the belt steering device is not capable of attaining the reference rotation position T_0 about the first rotation axis. However, the offset ΔT of the first nominal rotation position T_1 relative to the reference rotation position T_0 also indicates a desired adjustment of the second rotation position of the steering roller to obtain a larger steering capacity of the belt steering device. As such, the offset is not reduced to zero in order to attain the larger steering capacity of the belt steering device. Instead, the offset may be corrected to a predetermined value, which indicates an optimal use of the steering range of the steering roller about the first rotation axis to actively control the lateral position of the belt.

[0014] In an embodiment, the method further comprises the step of:

- h) determining a correction rotation position of the steering roller C_2 about the second rotation axis in order that the offset ΔT determined in step g) is reduced substantially to zero.

The step h) provides determining a correction rotation position about the second rotation axis for correcting the offset ΔT of the first nominal rotation position T_1 , i.e. relative to a reference rotation position T_0 of the predetermined range about the first rotation axis. The correction rotation position C_2 of the steering roller about the second rotation axis may be determined by iteratively changing the second rotation position of the steering roller about the second rotation axis and performing steps e) - g) to determine the offset ΔT .

Alternatively, the correction rotation position C_2 may be

calculated based on a predetermined relationship between a change of the second rotation position T_2 and a change of the first nominal rotation position T_1 , i.e. $\Delta T_1 = f(\Delta T_2)$. For example, such a relationship may be substantially linear over a certain range of the change of the second rotation position ($\Delta T_1 = \text{constant} * \Delta T_2$).

As such, the offset ΔT relative to the reference rotation position T_0 about the first rotation axis may be corrected, i.e. reduced to zero, by adjusting the second rotation position of the steering roller to said correction rotation position C_2 of the steering roller about the second rotation axis. In this way, an optimal use is achieved of the steering range of the steering roller about the first rotation axis to actively control the lateral position of the belt.

[0015] In an embodiment, the method further comprises the step of:

- i) retaining the steering roller in the correction rotation position C_2 about the second rotation axis while feedback-controlling the lateral position of the belt by rotating the steering roller about the first rotation axis.

The step i) supports a simple correction of the offset ΔT for a certain belt, such as a mesh belt. For example, a certain belt can be reliably steered in the lateral direction in operation of the steering roller by rotating the steering roller about the first rotation axis only, as the offset ΔT has been reduced to zero by the correction rotation position C_2 of the steering roller about the second rotation axis.

[0016] In an embodiment, the method further comprises the steps of: detecting a lateral position of the belt; and feedback-controlling the lateral position of the belt by rotating the steering roller about the first rotation axis over a predetermined range, while maintaining the second rotation position about the second rotation axis substantially constant.

These steps support maintaining the lateral position of the belt within a desired range in the lateral direction in a simple way while keeping the second rotation position about the second rotation axis substantially constant, preferably maintaining the second rotation position being substantially equal to the correction rotation position C_2 of the steering roller about the second rotation axis. This embodiment is useful, when the lateral position of the belt is sufficiently controlled by the first rotating position of the steering roller as such.

[0017] In an embodiment, step b) comprises rotating the steering roller about the first rotation axis and step c) comprises rotating the steering roller about the second rotation axis, and step b) and c) are carried out synchronously during the circulating step for feedback-controlling the lateral position of the belt.

This embodiment supports continuously using the enlarged steering capacity of the steering roller by synchronously rotating the steering roller about the first rotation axis and the second rotation axis independently of one

another. As defined herein, feedback-controlling the lateral position of the belt is controlling the lateral position of the belt based on a detection of the lateral position of the belt by adjusting the lateral position of the belt by rotating the steering roller about the first rotation axis and / or the second rotation axis independently one another. This embodiment is especially useful in case a steering behavior of the belt changes over time, for example due to temperature changes and / or due to wear behavior of the belt and / or the steering roller.

According to another aspect of the present invention a belt conveyor system is provided comprising an endless belt, a drive mechanism, three rollers around which the endless belt extends, the three rollers defining an inner volume, a steering roller for steering the endless belt, and a belt steering device; said drive mechanism being arranged for circulating the endless belt along a circulation path; said steering roller being arranged for supporting said belt and controlling a lateral position of the belt in a lateral direction being transverse to the circulation path; said belt steering device controlling a first rotation position of the steering roller about a first rotation axis to control the lateral position of the belt; the belt steering device further being arranged for controlling a second rotation position of the steering roller about a second rotation axis to adjust the lateral position of the belt independently of the first rotation position about the first rotation axis, wherein the second rotation axis is arranged substantially perpendicular to the first rotation axis. The steering roller is positioned within the inner volume defined by the three rollers.

The belt steering device is arranged for controlling the second rotation position of the steering roller about the second rotation axis, thereby enlarging the steering capacity of the steering roller independently to the first rotation position of the steering roller about the first rotation axis. The lateral position of the belt is controlled by the second rotation position of the steering roller independently of the first rotation position of the steering roller, as the belt steering device controls the second rotation position of the steering roller about the second rotation axis independently of the first rotation position of the steering roller about the first rotation axis. In fact, an adjustment of the second rotation position does substantially not affect the first rotation position due to the substantially perpendicular arrangement of the second rotation axis relative to the first rotation axis. The steering roller is positioned within the inner volume defined by the three rollers, resulting in a compact conveyor system. This allows the present invention to be applied in existing printing system, wherein generally no free space for adding therein a steering roller is available around the belt conveyor system.

In an embodiment, the belt conveyor system according to the present invention comprises a transport path for sheets, which transport path extends from the first roller to the third roller. The belt conveyor system further comprises:

- a sheet receiving region at the first roller for receiving sheets from an upstream sheet transport mechanism; and
- a sheet transfer region at the third roller for transferring sheets from the endless belt to a downstream sheet transport mechanism.

[0018] An upstream transport mechanism, e.g. a transport drum or a further belt conveyor, feeds sheet on the endless belt. The sheets are received on the endless belt at or near the first roller. Likewise, the sheets leave the endless at or near the third roller, which may be a drive roller. The transport path preferably extends linearly between the first and third roller. To ensure accurate receipt and transfer of the sheets, the positions of the first and third rollers are preferably well defined. Movement of the belt in one of the transfer regions may cause deformation or damage to the sheet. Thus, the present invention provides the steering roller away from the transfer regions, specifically in the inner volume between the transport path and the second roller, in a direction perpendicular to the plane of the transport path. This prevents sheet deformation while allowing for accurate belt steering.

[0019] In another embodiment, the rotation axes of the first roller and the third roller are stationary during use. The rotation axes are preferably fixed, such that the first roller is static with respect to the upstream transport mechanism and the third roller is static with respect to the downstream transport mechanism. Thereby, the positions of the endless belt adjacent the transport mechanism is well defined, e.g. by a constant gap spacing between the belt and a transport mechanism. This allows a transfer mechanism to reliably transfer a sheet from or onto the sheet transfer region or the sheet receiving region respectively.

[0020] In an embodiment, the belt conveyor system comprises only a single steering roller. The entrained position of the steering rollers allows only a single steering roller to be required for steering belt. Preferably, the belt is a mesh or woven belt, whose elasticity contributes to increasing the steering range, i.e. the angles over which the steering roller may be rotated without rupturing the belt.

[0021] In an embodiment, the belt conveyor system further comprises a control unit arranged for controlling the belt steering device to rotate the steering roller about the first rotation axis and the second rotation axis independently of one another. The control unit enables a continuous control on the first rotation position and the second rotation position of the steering roller independently of one another. The belt steering device may additionally comprise at least one actuator connected to the control

unit and arranged for rotating the steering roller about the first rotation axis and the second rotation axis independently of one another by actuating the belt steering device. In an embodiment the belt steering device may additionally comprise a first actuator connected to the control unit and arranged for rotating the steering roller about the first rotation axis and a second actuator connected to the control unit and arranged for rotating the steering roller about the second rotation axis independently of one another via the belt steering device.

[0022] In an embodiment, the belt steering device additionally comprises an adjusting mechanism for adjusting the second rotation position of the steering roller about the second axis rotation independently of the first rotation position about the first rotation axis to control the lateral position of the belt, wherein the second rotation axis of the belt steering device is arranged substantially perpendicular to the first rotation axis.

The adjusting mechanism comprises an adjusting structure for adjusting the second rotation position of the steering roller about the second axis rotation. Said adjusting structure may be formed by any suitable combination of a pivot element and / or a bearing element or a plurality thereof.

[0023] The adjusting mechanism of the belt steering device does not increase the used angular range of the belt steering device about the first rotation axis and only adds a relatively small space to the belt steering device. In this way, a compact adjusting structure of the belt steering device is provided, which enlarges the steering capacity of the steering roller and provides accurate control over the second rotation position. As such, a control on the lateral position of the belt is enhanced in a simple way.

Both the first rotation axis and the second rotation axis are arranged substantially perpendicular to a longitudinal axis of the steering roller. The steering roller may be rotatably arranged about its longitudinal axis for guiding the endless belt in the belt conveyor system along the circulation path.

[0024] In an embodiment, the endless belt is a mesh belt having a mesh structure.

The enlarged steering capacity simplifies accurate steering of mesh belts. As defined herein a mesh structure is an open structure composed by a mesh material, such as a woven fabric. The mesh structure comprises mesh elements, such as threads or fibres, and open areas or spaces interposed between the mesh elements. The mesh elements, such as threads or fibres, may comprise a polymeric material, a non-synthetic natural material, such as cotton, a metal containing material or any other suitable material.

An endless belt provides a nominal rotation position of the steering roller in the belt conveying system, wherein the endless belt is kept stationary in the lateral direction. Mesh belts have been found to have a relatively large variation of nominal rotation positions of the steering roller, wherein said variation is badly predictable from struc-

tural properties of the mesh belt. The deviation in the nominal rotation position decreases the range available from the steering range to control the lateral position of the belt. As such, mesh belts need to be selected having a small deviation from a desired nominal rotation position based on testing each mesh belt in combination with a belt conveyor system in order to determine the nominal rotation position corresponding to said mesh belt.

By increasing the steering capacity according to the present invention, mesh belts can be used having a larger variation of nominal rotation positions, even without selecting mesh belts individually based on testing the nominal lateral position of each mesh belt individually.

[0025] In an embodiment, the belt steering device comprises a pivot structure arranged for mounting the steering roller, the pivot structure comprising a pivot element arranged for rotatably supporting the pivot structure about the first rotation axis and allowing the pivot structure to rotate about the second rotation axis independently of the first rotation axis. In this embodiment, the pivot element of the belt steering device supports rotating the pivot structure about the first rotation axis and the second rotation axis independently of one another.

The steering roller is connected to the pivot structure at both its main axial ends. The pivot structure supports a controlled rotation of the steering roller about the first and second rotation axis. The pivot element is arranged for a simple rotation of the pivot structure including the steering roller about the first rotation axis.

[0026] In an embodiment, the belt steering device further comprises a support structure, wherein the pivot structure is rotatably mounted to the support structure via the pivot element.

The support structure rotatably supports the pivot structure via the pivot element. The support structure is mounted to a fixed frame.

In embodiments, the support structure may be fixed to the frame. In such an embodiment, the belt steering device may comprise a bearing structure connected to the pivot structure for controlling a rotation of the pivot structure about the second rotation axis independently of the rotation about the first rotation axis. The bearing structure may comprise a second pivot element for rotatably mounting the pivot structure about the second rotation axis coinciding with a longitudinal axis of the second pivot element.

[0027] In an embodiment, the support structure is movably arranged for rotating the pivot structure and the pivot element about the second rotation axis independently of the rotation of the pivot structure about the first rotation axis at the pivot element.

For example, the support structure may have a first portion movably arranged with respect to a first frame part and may have a second portion fixed to a second frame part. Further an adjusting mechanism may be provided fixed at the first frame part, which is arranged for controllably moving the first portion of the support structure relative to the second portion of the support structure, there-

by rotating the first portion of the support structure about the second rotation axis. As a result, the pivot structure and the pivot element are rotated by the adjusting mechanism about the second rotation axis independently of the rotation of the pivot structure about the first rotation axis at the pivot element.

[0028] In an embodiment, the pivot element is movably arranged for a translation along the first rotation axis for allowing a rotation of the pivot structure about the second rotation axis, which is arranged offset from the first rotation axis in the lateral direction.

The pivot element allows a rotation about the second rotation axis by translation along the first rotation axis, which second rotation axis is arranged offset from the first rotation axis. As such, the pivot element enables a pivot structure for rotating about the first rotation axis and the second rotation axis independently of one another, wherein the second rotation axis is arranged offset from the first rotation axis.

[0029] In an embodiment, the first rotating axis is arranged intersecting substantially the centre of the steering roller in the lateral direction.

The arrangement of the first rotation axis intersecting the centre of the steering roller in the lateral direction of the circulation path supports a symmetrical tilting of the belt relative to the lateral direction of the circulation path, thereby supporting a uniformity of tension across a width of the belt in the lateral direction.

[0030] In an embodiment, the second rotation axis is arranged proximate to an axial end portion of the steering roller in the lateral direction.

As a result, the portion of the pivot structure near to said axial end portion of the steering roller is arranged to remain substantially stationary relative to the second rotation axis independently of the second rotation position of the pivot structure. An actuator may be operatively connected to said portion of the pivot structure to rotate the pivot structure about the first rotation axis. In this way, a simple and reliable connection, such as a mechanical connection, between the actuator and the pivot structure may be formed.

[0031] In an embodiment, the adjusting mechanism comprises a retaining element arranged for retaining the steering roller stationary in a second rotation position with respect to the second rotation axis.

The retaining element is a simple means for keeping the steering roller stationary in the second rotation position with respect to the second rotation axis. The second rotation position may be predetermined based on a desired first nominal rotation position T_1 of the steering roller about the first rotation axis for the belt used.

[0032] In an embodiment, the second rotation axis is arranged offset from the centre of the steering roller in the lateral direction of the circulation path.

The arrangement of the second axis offset from the centre of the steering roller enables a simple adjusting structure for rotating the pivot structure about the second rotation axis independently of the first rotation position

about the first rotation axis.

Preferably the second rotation axis is arranged offset from the centre of the steering roller near an axial end portion of the steering roller in a direction of the longitudinal axis of the steering roller.

In this way, an actuator device for rotating the pivot structure about the first rotation axis may be operatively connected to the pivot structure near said axial end portion of the steering roller close to the second rotation axis. This provides a reliable connection of the actuator device to the pivot structure as a minimal wagging movement will occur at the connection position.

[0033] In an embodiment, the drive mechanism comprises a drive roller arranged for circulating the endless belt along the circulation path.

[0034] In an embodiment, the belt conveyor system further comprises a second roller and a third roller, the belt being fed from the second roller along the steering roller to the third roller, and wherein the belt is entrained about the steering roller along a steering angular displacement arranged in a direction opposite to an angular displacement of the belt by each of the second roller and the third roller.

The steering angular displacement of the belt at the steering roller, which is arranged opposite to the angular displacement at the other rollers, combines a compact design of the belt conveyor system and a relatively large steering capacity. In this embodiment, a belt portion may be entrained about the steering roller at a relatively large steering angular displacement, such as about 180 degrees, without considerably increasing the size of the belt conveyor system. A larger steering angular displacement at the steering roller improves a control on the lateral position of the belt while using the same steering range of the steering roller.

[0035] Furthermore, the belt steering device may be arranged in a space or volume between the transport belt portions arranged upstream and downstream of the steering roller, thereby supporting a compact design of the belt conveyor system. Furthermore the belt steering device arranged in this position may be easily replaced without replacing the belt.

[0036] In an embodiment, the first rotation axis is arranged substantially parallel to the bisector of the steering angular displacement at the steering roller.

The arrangement parallel to the bisector of the steering angular displacement supports a compact arrangement of the belt steering device in the space between the transport belt portions upstream and downstream of the steering roller.

[0037] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed de-

scription.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] Hereinafter, the present invention is further elucidated with reference to the appended drawings showing non-limiting embodiments and wherein

Figures 1A, 1B and 1C show a prior art belt conveyor system for controlling a lateral position of an endless belt.

Figures 2A - 2D show a first embodiment of the belt conveyor system according to the present invention. Figures 3A and 3B show an embodiment of the method for controlling a lateral position of the endless belt of the belt conveyor system.

Figures 4A - 4B show a second embodiment of the belt steering device of the belt conveyor system according to the present invention.

Figures 5A - 5B show a third embodiment of the belt steering device of the belt conveyor system according to the present invention.

Figure 6 shows a fourth embodiment of the belt steering device of the belt conveyor system according to the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0039] The present invention will now be described with reference to the accompanying drawings, wherein the same reference numerals have been used to identify the same or similar elements throughout the several views.

[0040] A known belt conveyor system 100, as shown in Figures 1A - 1B, comprises a conveyor belt 110. Figure 1A shows a side view of the belt conveyor system 100. The belt 110 is endless in the sense that it does not have a leading edge, nor a trailing edge. An endless belt may be formed by welding the leading edge and the trailing edge together resulting in a seam running over the width of the belt at the location where the leading and trailing edges have been welded together. In general the properties of the belt at the seam differ from the properties of the belt at other locations, for example, the belt thickness may be different due to overlap of the leading and trailing edges, and the stiffness of the belt may be different due to this same overlap, but also as a result of the welding process.

In sheet conveyor systems seamless belts 110 are preferred. Seamless belts are less subject to out-of-plane bucking. There is no danger of sheets being located on the seam, which increases sheet holding and reduces print defects. Furthermore, belt conveyor systems with seamless belts are less susceptible to wear.

Seamless belts may be manufactured by weaving tube-like forms and cutting the tube in a plane perpendicular to the longitudinal axis. Alternatively, an endless belt may be formed by taking a rectangular shaped mesh and

welding two opposing sides together thereby forming a loop.

The belt 110 is a mesh belt having a mesh structure comprising a woven fabric. The mesh is woven from threads having a thickness, e.g. said thickness being in a range from 0.1 mm to 1.0 mm, and with a certain thread density (e.g. expressed in threads per cm). Such a mesh belt has proven to be suitable for a sheet conveyor system in a reprographic apparatus. The elasticity of the woven belt 110 provides an increased range over which the steering roller 124 may be rotated with respect to conventional belts, which are formed of polymers or metals. The belt 110 is held under tension in a four roller configuration, namely a first roller 122, a steering roller 124, a second or tension roller 126, and third or a drive roller 128. The steering roller 124 is a rotating steering roller that moves the belt 110 in a lateral direction L. A rotation position of the steering roller 124 is controlled by a belt steering device 140. The tension roller 126 is movable in a direction of at the one hand the steering roller 124 and the drive roller 128 and at the other hand away from these rollers, i.e. said direction being arranged parallel to the plane of viewing indicated by direction X and direction Y. By moving the tension roller 126 and adjusting the distance to the drive roller 128 and the steering roller 124 in said direction, the tension of the belt 110 can be controlled. For example, a spring element may be provided for biasing the tension roller 126 in a direction away from the drive roller 128 and parallel to the plane of viewing indicated by direction X and direction Y, wherein the spring element provides a predetermined force in said direction to control the tension of the belt 110. The drive roller 128 is driven by a motor (not depicted) and makes the conveyor belt circulate in a transport direction along a circulation path depicted by arrow 112.

[0041] Sheets arrive at the belt 110 from an upstream transport mechanism UT, as shown in Fig. 3B. The upstream transport mechanism UT transfers the sheets onto the endless belt 110 at a sheet receiving region or area SRR. The receiving region SRR is positioned at the first roller 122. The belt 110 then transports the sheets along a linear transport path TP to the third roller 128. There, in the sheet transfer region STR the sheet are picked up from the belt 110 by a transfer mechanism and transferred onto a downstream transport mechanism DT.

[0042] The mesh belt runs over a vacuum box 130. During operation a partial vacuum exists in the vacuum box 130. The surface of the vacuum box 130, called the suction plate, is facing the mesh belt 110 is perforated. Due to the partial vacuum, sheets on the belt 110 are held against the belt 110 between the first roller 122 and the drive roller 128 and move together with the belt 110 in the direction of the arrow 112. The vacuum box 130 is sub-divided in three vacuum chambers 132, 134, and 136. The suction plate of the vacuum chamber 132 is designed to have a high air flow in order to reliably receive sheets from a preceding sheet transportation unit, especially in the case of short sheets. When a sheet is in the

vicinity of the belt 110 in the area of the vacuum chamber 132 it is forced towards the belt 110 by the high air flow. The vacuum chamber 134 is held on a moderate partial vacuum to prevent cockling of the sheet and ensure a reliable transport of the sheet. The vacuum chamber 136 is designed similar like vacuum chamber 132. A high pressure ensures reliable delivery of especially short sheets to the next sheet transportation unit.

[0043] Figure 1B shows a schematic perspective view of the belt conveyor system shown in Figure 1A with a part of the belt 110 cut away to show the steering roller 124 and the belt steering device 140 being arranged inside of the system. As shown in Figure 1B, the belt steering device 140 is arranged for rotating the steering roller 124 about a rotation axis P. The rotation axis P is arranged intersecting the centre of the steering roller in the lateral direction L of the circulation path. The belt steering device 140 comprises a pivot structure 142 for mounting both axial end portions of the steering roller 124 along the main rotational axial direction of the steering roller 124 in the lateral direction L. The belt steering device 140 comprises a pivot pin 144 mounted on a fixed frame and being arranged for rotating the pivot structure 142 about the rotation axis P relative to a frame of the belt conveyor system, thereby rotating the steering roller 124 about the rotation axis P between a first ultimate rotational position, as indicated by a solid line, and a second ultimate rotational position, as indicated by a dotted line. A rotation actuator (not shown) is controlled by a control unit 150 and is arranged in operative connection to a lateral side portion of the pivot structure 142 to rotate the pivot structure 142 about the pivot pin 144, thereby controlling the rotation position of the steering roller 124 about the rotation axis P. The steering range of the pivot structure 142 between the first ultimate rotational position and the second ultimate rotational position is limited, as the position of the steering roller 124 is restricted by a portion of the belt 110 being transported between the first roller 122 and the drive roller 128. Furthermore the rotational position of the steering roller 124 is restricted by a portion of the belt 110 being transported between the drive roller 128 and the second roller 126. As such the steering range of the pivot structure 142 is limited in angular range about the rotation axis P.

[0044] Fig. 1C shows a cross-schematic cross-section of the conveyor system 100 according to the present invention. The first, second, and third rollers 122, 126, 128 define between them an inner volume IV, a triangular cross-section of which is illustrated in Fig. 1C. The steering roller 124 is positioned with the inner volume IV, which in Fig. 1C is below the transport path TP, specifically between the transport path TP and the second roller 126, as seen in a direction perpendicular to the plane of the transport path TP. Thereby, the belt 110 is entrained within the inner volume IV. The embodiment in Fig. 1A-C is thereby very compact.

[0045] Figures 2A - 2D show a first embodiment of the belt conveyor system according to the present invention.

In Figure 2A a schematic perspective view of the belt conveyor system 200 is shown. The belt conveyor system 200 comprises a first roller 122, a steering roller 224, a second roller 126, a drive roller 128, a belt 110, a belt steering device 225 and a control unit 250.

The steering roller 224 is a rotatable steering roller that controls a lateral position of the belt 110 in a lateral direction L. The steering roller 224 extends along a longitudinal axis. The position of the steering roller 224 is controlled by the belt steering device 225. The drive roller 128 is driven by a motor (not depicted) and makes the conveyor belt 110 circulate in a transport direction along a circulation path depicted by arrow 112. In an alternative embodiment, the conveyor belt 110 may be driven by any other roller 122, 126, 224 in order to circulate in a transport direction along a circulation path depicted by arrow 112.

[0046] In Figure 2A a part of the belt 110 is cut away to show the steering roller 224 and the belt steering device 225 being arranged inside of the system. As shown in Figure 2A, the belt steering device 225 is arranged for rotating the steering roller 224 about a first rotation axis P_1 and the belt steering device 225 is further arranged for rotating the steering roller 224 about a second rotation axis P_2 . The second rotation axis P_2 is arranged perpendicular to the first rotation axis P_1 . Both the first rotation axis P_1 and the second rotation axis P_2 are arranged perpendicular to the longitudinal axis of the steering roller 224.

The first rotation axis P_1 is arranged intersecting the centre of the steering roller 224 between the axial end portions of the steering roller 224 along the longitudinal axis of the steering roller 224. The belt steering device 225 comprises a pivot structure 242 arranged for mounting both axial end portions of the steering roller 224 along the main rotational axial direction of the steering roller 224 in the lateral direction L.

The belt steering device 225 comprises a pivot element 244, such as a pivot pin, for rotating the pivot structure 242 about the first rotation axis P_1 , thereby rotating the steering roller 224 about the first rotation axis P_1 .

[0047] Now referring to Fig. 2B, which shows a side view of the steering roller 224, the belt 110, the first roller 122 and the second roller 126 in a plane along the direction Y and the lateral direction L. The side view in Figure 225 is directed from the belt steering device 225 towards the steering roller 224.

As shown in Fig. 2B, the steering roller 224 is rotatable about the first rotation axis P_1 between a first ultimate rotational position, as indicated by a solid line, and a second ultimate rotational position, as indicated by a dotted line. A rotation actuator (not shown) is controlled by a control unit 250 and is arranged in operative connection to the pivot structure 242 to rotate the pivot structure 242 about the pivot element 244, thereby controlling the rotation position of the steering roller 224 about the first rotation axis P_1 over the steering range between the first ultimate rotational position and the second ultimate rota-

tional position of the steering roller 224.

[0048] Now referring to Fig. 2C, which shows the perspective view of the belt conveyor system wherein a part of the belt 110 is cut away to show the steering roller 224 and the belt steering device 225 being arranged inside of the system. Figure 2C schematically shows the rotation of the steering roller 224 about the second rotation axis P_2 . The second rotation axis P_2 is arranged perpendicular to the first rotation axis P_1 .

Figure 2D shows a plane view of the steering roller 224, the belt 110, the first roller 122 and the drive roller 128 in a plane along the direction X and the lateral direction L. The plane view in Figure 2D is the view from above in the Figure 2C. A part of the belt 110 is cut away to show the steering roller 224.

As shown in Figures 2C and 2D the steering roller 224 is rotatable about the second rotation axis P_2 between a first ultimate rotational position, as indicated by a solid line, and a second ultimate rotational position, as indicated by a dotted line. A rotation actuator (not shown) is controlled by a control unit 250 and is arranged in operative connection to the belt steering device 225 to rotate the pivot structure 242 about the second rotation axis P_2 .

[0049] Instead of the centre location of the first rotation axis P_1 and the second rotation axis P_2 relative to the longitudinal axis of the steering roller 224, each of the first rotation axis P_1 and the second rotation axis P_2 may be arranged at another location along the longitudinal axis of the steering roller 224. For example, the second rotation axis P_2 may be arranged near an axial end portion of the steering roller 224.

[0050] Several possible embodiments of the structure of the belt steering device of the present invention are illustrated in relation to the Figures 4A - 4B, Figures 5A - 5B and Figures 6.

[0051] The belt steering devices of the embodiments of the present invention illustrated herein are suitable for a method of comprising the steps of: circulating the belt along the circulation path; controlling a first rotation position of the steering roller by a belt steering device about a first rotation axis to control the lateral position of the belt; and controlling a second rotation position of the steering roller by the belt steering device about a second rotation axis independently of the first rotation position about the first rotation axis to adjust the lateral position of the belt; wherein the second rotation axis is arranged perpendicular to the first rotation axis.

[0052] Now referring to Figures 3A and 3B, which show an embodiment of the method for controlling a lateral position of the endless belt 110 of the belt conveyor system 200 in the lateral direction L. Figure 3A shows a flow diagram of a calibration procedure of the method for controlling a lateral position of the endless belt 110. The endless belt 110 may, for example, be a mesh belt having a mesh structure, such as a mesh structure comprising a woven fabric.

In a first step S202 of the method, the steering roller 224 is positioned and maintained in a preselected second

rotation position about the second rotation axis P_2 , such as a nominal second rotation position C_0 about the second rotation axis P_2 . The nominal second rotation position of the steering roller 224 is indicated in Figure 3B by a solid line.

The nominal second rotation position C_0 is preferably a rotation position, wherein the steering roller 224 is aligned with the lateral direction L in the plane of the lateral direction L and the direction X. The direction X is substantially parallel to a transport direction T of the belt 110 between the drive roller 128 and the first roller 122. In a second step S204 of the method, the belt 110 is circulated in the transport direction T along the circulation path by driving the belt 110 by way of the driving roller 128.

In a next step S206, the first rotation position of the steering roller 224 is actively controlled by the control unit 250 and the belt steering device 225 in order to attain a stationary lateral position of the belt 110 along the lateral direction L. In an example, the control unit 250 is operatively connected to a sensor (not shown), which detects the lateral position of the belt 110 along the lateral direction L. The control unit 250 determines a lateral velocity of the belt 110 in the lateral direction L based on measurements performed by the sensor of the lateral position of the belt 110. In case the lateral velocity of the belt 110 is not equal to zero, the belt 110 is not stationary in the lateral direction L. Based on the lateral velocity of the belt 110 in the lateral direction L, the control unit 250 adjusts the first rotation position of the steering roller 224 about the first rotation axis P_1 by means of rotating the belt steering device 225 about the pivot element 244. During step S206, the first rotation position of the steering roller 224 about the first rotation axis P_1 is adjusted such that the belt 110 attains a stationary lateral position in the lateral direction L. As a result of step S206, the belt has a stationary lateral position at a certain first rotation position of the steering roller 224 about the first rotation axis P_1 .

In an alternative example of step S206, the control unit 250 determines a lateral position of the belt 110 along the lateral direction L based on measurements performed by the sensor of the lateral position of the belt 110. In case the lateral position of the belt 110 is not stable equal to a desired position along the lateral direction L, the belt 110 is not stationary in the lateral direction L at the desired position. The desired position of the belt 110 may be selected to be equal to a midpoint position in a detection range of the sensor along the lateral direction L.

Based on the lateral position of the belt 110 in the lateral direction L, the control unit 250 adjusts the first rotation position of the steering roller 224 about the first rotation axis P_1 by means of rotating the belt steering device 225 about the pivot element 244. During step S206, the first rotation position of the steering roller 224 about the first rotation axis P_1 is adjusted such that the belt 110 attains a stationary lateral position at the desired position in the lateral direction L.

In a next step S208, a first nominal rotation position T_1 is determined, which is the first rotation position corresponding to the stationary lateral position of the belt of Step S206. In examples, the first nominal rotation position of the steering roller 224 may be detected by a sensor or may be calculated by the control unit 250, such as calculated by the control unit 250 based on a driving signal for the actuator for rotating the belt steering device 225 about the first rotation axis P_1 .

In a next step S210, an offset ΔT of the first nominal rotation position T_1 relative to a reference rotation position T_0 of the predetermined range of the belt steering device 225 including the steering roller 224 is determined. The reference rotation position T_0 of the predetermined range may be a first rotation position for providing an optimum steering capacity to the steering roller 224 for controlling the lateral position of the belt 110. For example, the reference rotation position T_0 of the steering roller 224 may be aligned parallel to the lateral direction L. The offset ΔT of the first nominal rotation position T_1 is a skewness angle relative to the reference rotation position T_0 of the predetermined range of the belt steering device 225.

By determining the offset ΔT relative to the reference rotation position T_0 , it is clear in what way the steering capacity of the steering roller 224 can be improved. If the offset ΔT is large, only a part of the steering range about the first rotation axis P_1 can be effectively be used for controlling the lateral position of the belt 110 by the first rotation position alone. By reducing the offset ΔT , the steering range of the steering roller 224 about the first rotation axis P_1 becomes more balanced. In this way a more effective use can be made of the rotation of the steering roller 224 about the first rotation axis P_1 .

In a next step S212, a correction rotation position C_2 of the steering roller about the second rotation axis P_2 is determined. The correction rotation position C_2 is a second rotation position about the second rotation axis P_2 , wherein the offset ΔT is reduced to zero.

The correction rotation position C_2 may be determined by iteratively changing the second rotation position of the steering roller about the second rotation axis P_2 and performing the steps S204 - S210 to determine the offset ΔT after each change of the second rotation position of the steering roller.

Alternatively, the correction rotation position C_2 may be calculated, e.g. calculated based on a predetermined relationship between a change of the second rotation position T_2 and a change of the first nominal position T_1 , i.e. $\Delta T_1 = f(\Delta T_2)$. For example, the relationship is substantially linear over a certain range. (e.g. $\Delta T_1 = x \cdot \Delta T_2$). If, for example the offset $\Delta T = T_1 - T_0 = 22$ degrees and $\Delta T_1 = 2 \cdot \Delta T_2$, the correction rotation position C_2 is the sum of the nominal second rotation position C_0 at the start of the calibration procedure plus $22 / 2 = C_0 + 11$ degrees. The direction of the correction can be determined based on the direction of the offset relative to the reference rotation position T_0 of the steering range about

the first rotation axis P_1 . For example, if the offset ΔT is directed clockwise relative to the reference rotation position T_0 of the steering range as seen in the side view Fig. 2B, the correction rotation position C_2 is directed clockwise relative to its nominal second rotation position C_0 as seen in the plane view Fig. 3B. In this way a tendency of the belt 110 to go to the left side in the lateral direction L, as seen in Fig. 3B, will be compensated by turning the steering roller clockwise about the second rotation axis P_2 .

In a next step S212, the second rotation position of the steering roller 224 is adjusted to the correction rotation position C_2 in the clockwise direction A as can be seen from Fig. 3B.

After Step S212 the offset ΔT is reduced to substantially zero. In an embodiment, the steps S204 - S210 may be repeated to check, whether the correction of the offset ΔT has been successfully performed.

In alternative embodiments of the calibration procedure shown in Fig. 3A, in step S210 the offset ΔT may be determined relative to a midpoint rotation position of the steering roller about the first rotation axis P_1 , i.e. the midpoint rotation position being a specific reference rotation position T_0 . The correction of step S212 is performed to reduce the offset ΔT relative to the midpoint rotation position of the steering roller about the first rotation axis P_1 . The predetermined range of the belt steering device 225 about the first rotation axis P_1 extends between the first ultimate rotation position and the second ultimate rotation position about the first rotation axis P_1 . The first and second ultimate rotation positions of the first rotation position may be determined by mechanical restrictions to the rotation of the belt steering device 225 about the first rotation axis P_1 or may be determined by operational restrictions to the rotation of the belt steering device 225 about the first rotation axis P_1 , such as by the actuator for rotating the belt steering device 225 or the sensor for detecting the first rotation position. The midpoint rotation position T_0 of the predetermined range is a midpoint between the first and second ultimate rotation positions about the first rotation axis P_1 .

For example if the first ultimate rotation position is 0 degrees relative to a reference orientation about the first rotation axis P_1 and the second ultimate rotation position is 10 degrees relative to said reference orientation about the first rotation axis P_1 , the midpoint rotation position T_0 is $(0 + 10) / 2 = 5$ degrees relative to said reference orientation about the first rotation axis P_1 .

[0053] In a further example of the use of the calibration method shown in Figures 3A and 3B, the steering roller 224 is retained in the correction rotation position C_2 about the second rotation axis P_2 after the calibration procedure, while feedback controlling the lateral position of the belt 110 by the control unit 250 by rotating the steering roller 224 about the first rotation axis P_1 .

[0054] Fig. 3B further illustrates the upstream and downstream transport mechanisms UT, DT, which transports sheets to and from the endless belt 110. The trans-

port path TP extends between the transport mechanisms UT, DT. To ensure reliable sheet transfer, the belt's position 110 in the vicinity of the transport mechanisms UT, DT needs to be stable. Any movement of the belt 110 may result in deformation or rupturing of a sheet being transferred. To provide stability to the sheet receiving region SRR and the sheet transfer region STR, the first and third rollers 122, 128 are fixed, meaning that during use their rotation axes are stationary with respect to the transport mechanisms UT, DT or a stationary frame of the printing system 100.

[0055] Figures 4A - 4B show a second embodiment of the belt steering device of the belt conveyor system according to the present invention. In Figure 4A a plane view of the belt steering device 325 and the steering roller 224 is shown. The steering roller 224 is a rotatable steering roller that controls a lateral position of the belt 110 (shown in Fig. 2A) in a lateral direction L. The steering roller 224 extends along a longitudinal axis R. The rotational position of the steering roller 224 about the first rotation axis P_1 and the second rotation axis P_2 is controlled by the belt steering device 325.

The belt steering device 325 comprises a pivot structure 342, which comprises a yoke 343 for mounting the steering roller 224 at both main axial ends of the steering roller 224 to the yoke portions 343a, 343b. The belt steering device 325 further comprises a pivot shaft 344 and a support structure 330. The support structure 330 comprises a support plate 333 extending between a first end 330a and a second end 330b in the lateral direction L. The first end 330a is mounted on a first fixed frame part and the second end 330b is mounted on a second fixed frame part.

The pivot structure 342 is rotatably mounted to the support plate 333 of the support structure 330 about a first rotation axis P_1 coinciding with a longitudinal axis of the pivot shaft 344. The first pivot axis P_1 is substantially perpendicular to the longitudinal axis R of the steering roller 224. To enable rotational movement of the pivot structure 342 including the steering roller 224 about the first rotation axis P_1 , the pivot shaft 344 is rotatably mounted in a journal bearing 345 of the support structure 330. The pivot shaft 344 is mounted at its first end to a midpoint of the yoke 343 and is mounted at its second end to a midpoint of the support plate 333 at the journal bearing 345. An actuator (not shown) is connected to the yoke 343 for rotating the pivot structure 342 about the first rotation axis P_1 .

[0056] The first end of the support structure 330a comprises a first mount block 331, which is fixed to the first frame part. The second end of the support structure 330b comprises a second block mount 332, which is mounted to the second frame part while being arranged for a sliding movement in a direction S relative to the second frame part. The belt steering device 325 further comprises an adjusting mechanism 334, e.g. which comprises an adjusting screw, which adjusting mechanism 334 is fixed to the second frame part and is arranged in contact to

the second block mount 332 to controllably adjust the position of the second block mount 332 along the adjusting direction S. The adjusting direction S is arranged parallel to the direction X. A spring element (not shown) is arranged for biasing the second block mount 332 upwards along the adjusting direction S towards the screw of the adjusting mechanism 334.

By handling the screw of the adjusting mechanism 334, the second block mount 332 can be moved along the adjusting direction S. For example, as shown in Fig. 4B, the second block mount 332 can be moved downwards in the direction S_1 , thereby rotating the support structure 330 about a second rotation axis P_2 , which is located at the interface between the support plate 333 at the first end of the support structure 330a and the first mount block 331. The support plate 333 is arranged to elastically deform in the plane of direction L and X near the interface to the first mount block 331, thereby allowing a substantially perfect rotation of the support plate 333 about the second rotation axis P_2 . The second rotation axis P_2 is directed parallel to the direction Y as indicated in Figure 4B and is arranged perpendicular to the first rotation axis P_1 and perpendicular to the longitudinal axis R of the steering roller 224.

In this way, the position of the pivot shaft 344 and the pivot structure 342 is rotated about the second rotation axis P_2 to an adjusted second rotation position, as is indicated in Figure 4B by the solid line of the support plate 333, the pivot shaft 344, the pivot structure 342 and the steering roller 224.

The second rotation position of the pivot structure 342 about the second rotation axis P_2 can be adjusted by the adjusting mechanism 334 independently of the first rotation position of the pivot structure 342 about the first rotation axis P_1 .

[0057] Instead of the elastic interface of the support plate 333 to the first block mount 331, a bearing structure can be provided at the interface of the support plate 333 to the first block mount 331. The bearing structure is arranged for allowing a rotation of the support plate 333 about the second rotation axis P_2 , thereby rotating the pivot shaft 344, the pivot structure 342 and the steering roller 224 about the second rotation axis P_2 independently of a rotation of the pivot structure 342 about the first rotation axis P_1 .

[0058] Instead of the adjusting mechanism 334 shown in the embodiment of Figures 4A and 4B, an actuator can be provided fixed to the second frame part for moving the second moving block 332 along the adjusting direction S and operatively connected to the control unit 250. The control unit 250 provides a signal to the actuator for actively controlling the position of the second block mount 332 by the actuator along the adjusting direction S, thereby controlling the second rotation position of the support plate 333 and the pivot structure 342 about the second rotation axis P_2 independently of a rotation of the pivot structure 342 about the first rotation axis P_1 .

[0059] Instead of the second block mount 332 being

movable relative to the fixed frame as shown in the embodiment of Figures 4A and 4B, the second block mount 332 may be fixed to the frame and the support plate 333 may be movably arranged relative to the second block mount 332 at the second end of the support structure 330b. The adjusting mechanism is connected to the support plate 333 at the second end of the support structure 330b and is arranged for controlling a distance along the adjusting direction S, as indicated in Figure 4A, being parallel to the direction X, between the support plate 333 and the second block mount 332. The adjusting mechanism may comprise a screw mechanism, similar to the screw mechanism 334 shown in Figure 4A, and may comprise at least one distance element arranged in between the second block mount 332 and the support plate 333 and shaped for determining the distance between the support plate 333 and the second block mount 332.

[0060] Figures 5A - 5B show a third embodiment of the belt steering device of the belt conveyor system according to the present invention. In Figure 5A a plane view of the belt steering device 425 and the steering roller 224 is shown. The steering roller 224 is a rotatable steering roller that controls a lateral position of the belt 110 (shown in Fig. 2A) in a lateral direction L. The steering roller 224 extends along a longitudinal axis R. The rotational position of the steering roller 224 about the first rotation axis P_1 and the second rotation axis P_2 is controlled by the belt steering device 425.

The belt steering device 425 comprises a pivot structure 442, which comprises a yoke 443 for mounting the steering roller 224 at both main axial ends of the steering roller 224 to the yoke portions 443a, 443b.

The belt steering device 425 further comprises a pivot shaft 444, a bearing structure 450 and a support structure 430. The support structure 430 comprises a support plate 433 extending between a first end 430a and a second end 430b in the lateral direction L. The first end 430a is fixed on a first fixed frame part via a first mount block 431 and the second end 430b is fixed on a second fixed frame part via a second mount block 432. The pivot structure 442 is rotatably mounted to the support plate 433 of the support structure 430 about a first rotation axis P_1 coinciding with a longitudinal axis of the pivot shaft 444. The first pivot axis P_1 is substantially perpendicular to the longitudinal axis R of the steering roller 224. To enable rotational movement of the pivot structure 442 including the steering roller 224 about the first rotation axis P_1 , the pivot shaft 444 is rotatably mounted in a journal bearing 445 of the support structure 430.

The bearing structure 450 is connected to a midpoint of the yoke 443 along the lateral direction L via a second pivot shaft 452 and coincides with the first rotation axis P_1 . The second pivot shaft 452 extends in the direction Y and protrudes through the yoke 443 in this direction. The pivot shaft 444 is mounted at its first end to the bearing structure 450 and is mounted at its second end to a midpoint of the support plate 433 at the journal bearing 445. An actuator (not shown) is connected to the yoke

443 for rotating the pivot structure 442 about the first rotation axis P_1 .

The pivot structure 442 is rotatably mounted to the bearing structure 450 about a second rotation axis P_2 coinciding with a longitudinal axis of the second pivot shaft 452. The second rotation axis P_2 is directed parallel to the direction Y as indicated in Figure 5A and is arranged perpendicular to the first rotation axis P_1 and perpendicular to the longitudinal axis R of the steering roller 224.

10 The belt steering device 425 further comprises an actuator (not shown) for controlling a second rotation position of the pivot structure 442 about the second rotation axis P_2 . The actuator may be operatively connected to the bearing structure 450 or the yoke 443. The control unit 250 is connected to the actuator for providing a signal to the actuator to control the second rotation position of the pivot structure 442 about the second rotation axis P_2 independently of the first rotation position of the pivot structure 442 about the first rotation axis P_1 .

20 **[0061]** For example, as shown in Figure 5B, the actuator may rotate the pivot structure 442 about the second rotation axis P_2 as indicated by arrow A to an adjusted second rotation position, as is indicated in Figure 5B by the interrupted line of the pivot structure 442 and the steering roller 242. Note, that the bearing structure 450, the pivot shaft 444 and the support structure 430 remain stationary independently of the second rotation position of the pivot structure 442 about the second rotation axis P_2 .

25 The second rotation position of the pivot structure 442 about the second rotation axis P_2 can be adjusted by the actuator independently of the first rotation position of the pivot structure 442 about the first rotation axis P_1 .

30 **[0062]** Instead of the actuator of the third embodiment for rotating the pivot structure 442 about the second rotation axis P_2 , any other adjusting mechanism may be provided for controlling the second rotation position of the pivot structure 442 about the second rotation axis P_2 independently of the first rotation position of the pivot structure 442 about the first rotation axis P_1 .

35 **[0063]** Figure 6 shows a fourth embodiment of the belt steering device of the belt conveyor system according to the present invention. In Figure 6 a cross section view of the belt steering device 525 and the steering roller 224 in the plane along the lateral direction L and the direction X. The steering roller 224 is a rotatable steering roller that controls a lateral position of the belt 110 (shown in Fig. 2A) in a lateral direction L. The steering roller 224 extends along a longitudinal axis R. The rotational position of the steering roller 224 about the first rotation axis P_1 and the second rotation axis P_2 is controlled by the belt steering device 525.

40 The belt steering device 525 comprises a pivot structure 542, which comprises a yoke 543 for mounting the steering roller 224 at both main axial ends of the steering roller 224 to the yoke portions 543a, 543b.

45 The belt steering device 525 further comprises a pivot shaft 544 and a support structure 530. The support struc-

ture 530 comprises a support plate assembly 533 extending between a first end 530a and a second end 530b in the lateral direction L. The first end 530a is fixed on a first fixed frame part (not shown) and the second end 530b is fixed on a second fixed frame part (not shown). The support plate assembly 533 has three support plates together forming a triangular shaped support structure as seen in the plane of the direction X and L.

The pivot structure 542 is rotatably mounted to the support plate assembly 533 of the support structure 530 about a first rotation axis P_1 coinciding with a longitudinal axis of the pivot shaft 544. The first pivot axis P_1 is substantially perpendicular to the longitudinal axis R of the steering roller 224.

The pivot shaft 544 is rotatably mounted in an assembly of journal bearings 545 held by the support structure 530. The journal bearings 545 coincide with the first rotation axis P_1 . The journal bearings 545 are arranged for rotatably supporting the pivot shaft 544 about the first rotation axis P_1 and allowing a translation of the pivot shaft 544 along the first rotation axis P_1 . The pivot shaft 544 is mounted at its first end to a midpoint of the yoke 543 and is rotatably mounted at its second end by the assembly of journal bearings 545 to a midpoint of the support plate 533 relative to the lateral direction L. An actuator 560 is operatively connected to the yoke portion 543a at a first end of the yoke in the lateral direction L via a fork element 562 for rotating the pivot structure 542 about the first rotation axis P_1 . The control unit 250 is connected to the actuator 560 for driving the actuator 560.

The pivot structure 542 further comprises a first pivot block element 548 arranged into contact to a first bearing element 554a at the first end of the pivot structure 542 in the lateral direction L and a second pivot block element 549 arranged into contact to a second bearing element 554b at a second end of the pivot structure 542 in the lateral direction L. During rotation of the pivot structure 542 about the first rotation axis P_1 , the bearing elements 554a and 554b slidably support the pivot structure 542 via the first pivot block element 548 and second pivot block element 549, respectively.

[0064] The belt steering device 525 further comprises an adjusting mechanism 550 comprising a bracket structure 551, which rotatably mounts a crank element 552 about an axis parallel to the direction Y. The crank element 552 holds the second bearing element 554b, which supports the second pivot block element 549. The adjusting mechanism 550 further comprises a screw 534 connected to the support plate assembly 533 and arranged into contact to the crank element 552 for rotating the crank element 552 including the second bearing element 554b about the bracket structure 551, thereby moving the second bearing element 554b along a direction indicated by arrow A_1 . Direction A_1 is substantially parallel to the direction X. In this way, the position of the second pivot block element 549 of the pivot structure 542 is adjusted in the direction A_1 . The first bearing element 554a is mounted onto the support plate assembly 533

and is thereby held stationary. As a result, the pivot structure 542 is rotated about a second rotation axis P_2 , which coincides with the interface of the first bearing element 554a to the first pivot block element 548. The second rotation axis P_2 is arranged parallel to the direction Y. Thus, the adjusting mechanism 550 controls the second pivot position of the pivot structure 542 about the second rotation axis P_2 . The adjusting mechanism 550 controls the second pivot position of the pivot structure 542 about the second rotation axis P_2 independently of the first rotation position about the first rotation axis P_1 .

The pivot structure 542 further comprises a bearing structure 545 arranged at the midpoint of the yoke 543 in the lateral direction L for connecting the pivot structure 542 to the pivot shaft 544. The bearing structure 545 allows a rotational movement of the pivot structure 542 about the first rotation axis P_1 . When the adjusting mechanism 550 adjusts the position of the second pivot block element 549 of the pivot structure 542 in the direction A_1 , at the same time the pivot shaft 544 is allowed to translate in the direction A_2 by the assembly of journal bearings 545. The direction A_2 is substantially parallel to the direction A_1 . In this way, the assembly of journal bearing 545 supports a rotation of the pivot structure 542 about the second rotation axis P_2 independently of the first rotation position of the pivot structure 542 about the first rotation axis P_1 .

Any rotation of the pivot structure 542 about the first rotation axis P_1 or the second rotation axis P_2 determines the rotational position of the steering roller 224.

[0065] Instead of the adjusting mechanism 550 for adjusting a position of the second bearing element 554b only, the adjusting mechanism 550 may additionally comprise a second mechanism to adjust the position of the first bearing element 554a along the direction X independently of the adjustment of the position of the second bearing element 554b along the direction A_1 . In this way, the second rotation position of the pivot structure 542 may be controlled by the modified adjusting mechanism, wherein the position of the second rotation axis P_2 in the plane of direction L and X may be suitably selected. The second rotation axis in this embodiment is aligned parallel to the Y direction. For example, the second rotation axis P_2 may be arranged in the centre between the axial end portions of the steering roller 224 along the longitudinal axis R by adjusting the positions of both the bearing element 554a and the second first bearing element 554b over an equal distance along the direction X, but in opposite direction to one another.

[0066] Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately

detailed structure. In particular, features presented and described in separate dependent claims may be applied in combination and any advantageous combination of such claims are herewith disclosed.

Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention. The terms "a" or "an", as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language). The term coupled, as used herein, is defined as connected, although not necessarily directly.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A method for controlling a lateral position of an endless belt (110) of a belt conveyor system (200), the belt conveyor system comprising:

- three rollers (122, 126, 128) around which the endless belt extends, which three rollers define an inner volume (IV);
- a steering roller (224) arranged for supporting the endless belt and controlling the lateral position of the endless belt in a lateral direction (L), the lateral direction (L) being transverse to a circulation path of the belt, which steering roller is entrained within the inner volume defined by the three rollers;

the method comprising the steps of:

- a) circulating the belt along the circulation path, such that the belt passes through the inner volume via the entrained steering roller;
- b) controlling a first rotation position of the steering roller by a belt steering device (225, 325, 425, 525) about a first rotation axis (P_1) to control the lateral position of the belt; and
- c) controlling a second rotation position of the steering roller by the belt steering device (225, 325, 425, 525) about a second rotation axis (P_2) independently of the first rotation position about the first rotation axis (P_1) to adjust the lateral position of the belt;

wherein the second rotation axis (P_2) is arranged substantially perpendicular to the first ro-

tation axis (P_1).

2. The method according to claim 1, the method further comprising the step of:

- d) selecting a second rotation position of the steering roller (224) to be maintained by the belt steering device while feedback-controlling the lateral position of the belt (110) by rotating the steering roller about the first rotation axis (P_1).

3. The method according to claim 2, the method further comprising a calibration procedure comprising the steps of:

- e) maintaining (S202) the selected second rotation position of the steering roller fixed relative to the second rotation axis (P_2);
- f) determining a first nominal rotation position T_1 of the steering roller (S208) about the first rotation axis (P_1) for maintaining the lateral position of the belt stationary during the circulating step; and
- g) determining an offset ΔT of the first nominal rotation position T_1 (S210) relative to a reference rotation position T_0 of the belt steering device about the first rotation axis (P_1), wherein $\Delta T = T_1 - T_0$.

4. The method according to claim 3, wherein the calibration procedure further comprises the step of: h) determining a correction rotation position of the steering roller C_2 about the second rotation axis (P_2) in order that the offset ΔT determined in step g) is reduced substantially to zero (S212).

5. The method according to claim 4, the method further comprising the step of:

- i) retaining the steering roller in the correction rotation position C_2 about the second rotation axis (P_2) while feedback-controlling the lateral position of the belt by rotating the steering roller about the first rotation axis (P_1).

6. The method according to any of the previous claims, wherein step b) comprises rotating the steering roller (224) about the first rotation axis (P_1) and step c) comprises rotating the steering roller (224) about the second rotation axis (P_2), and step b) and c) are carried out synchronously during the circulating step for feedback-controlling the lateral position of the belt (110).

7. A belt conveyor system comprising an endless belt (110), a drive mechanism, three rollers (122, 126, 128) around which the endless belt extends, the three rollers (122, 126, 128) defining an inner volume

(IV), a steering roller (224) for steering the endless belt, and a belt steering device (225, 325, 425, 525); said drive mechanism (128) being arranged for circulating the endless belt along a circulation path; said steering roller (224) being arranged for supporting said belt and controlling a lateral position of the belt in a lateral direction (L) being transverse to the circulation path;

said belt steering device controlling a first rotation position of the steering roller about a first rotation axis (P_1) to control the lateral position of the belt; the belt steering device being further arranged for controlling a second rotation position of the steering roller about a second rotation axis (P_2) to adjust the lateral position of the belt independently of the first rotation position about the first rotation axis (P_1), wherein the second rotation axis (P_2) is arranged substantially perpendicular to the first rotation axis (P_1),

characterized in that

the steering roller is positioned within the inner volume (IV) defined by the three rollers (122, 126, 128).

8. The belt conveyor system of claim 7, wherein the steering roller (124) is entrained within the inner volume (IV), such that the endless belt (110) extends at least partially through the inner volume (IV).
9. The belt conveyor system of claim 7 or 8, comprising:
 - a transport path (TP) for sheets, which transport path (TP) extends from the first roller (122) to the third roller (128);
 - a sheet receiving region (SRR) at the first roller (122) for receiving sheets from an upstream sheet transport mechanism (UT); and
 - a sheet transfer region (STR) at the third roller (128) for transferring sheets from the endless belt (11) to a downstream sheet transport mechanism (DT).
10. The belt conveyor system according to claim 9, wherein rotation axes of the first roller (128) and the third roller (128) are stationary during use.
11. The belt conveyor system according to any of claims 7 to 10, comprising only a single steering roller (124).
12. The belt conveyor system of claim 7, 8, or 9, wherein the belt steering device further comprises an adjusting mechanism (334, 550) arranged for adjusting the second rotation position of the steering roller about the second rotation axis (P_2) independently of the first rotation position about the first rotation axis (P_1).
13. The belt conveyor system of any of claims 7 to 11,

wherein belt is a mesh belt having a mesh structure.

14. The belt conveyor system of any of the claims 7 - 10, wherein the belt steering device comprises a pivot structure (242, 342, 442, 542) arranged for mounting the steering roller (224), the pivot structure (242, 342, 442, 542) comprising a pivot element (244, 344, 444, 544) arranged for rotatably supporting the pivot structure (242, 342, 442, 542) about the first rotation axis (P_1) and allowing the pivot structure to rotate about the second rotation axis (P_2) independently of the first rotation axis (P_1).
15. The belt conveyor system of any of the preceding claims, wherein the belt conveyor system further comprises a second roller and a third roller, the belt being fed from the second roller along the steering roller to the third roller, and wherein the belt is entrained about the steering roller along a steering angular displacement arranged in opposite direction to an angular displacement of the belt by each of the second roller and the third roller.

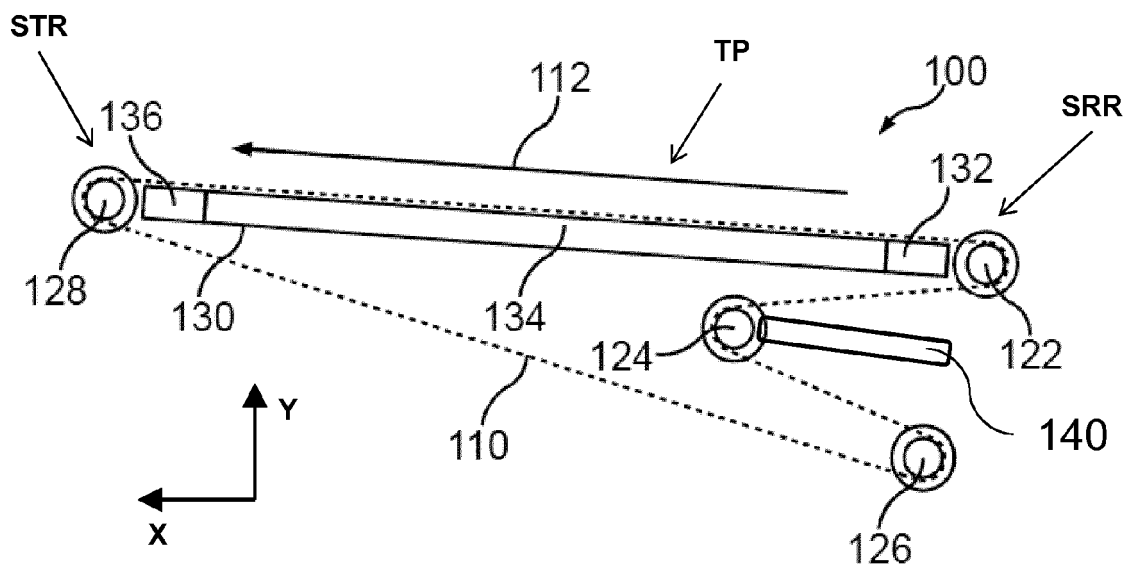


Fig. 1A

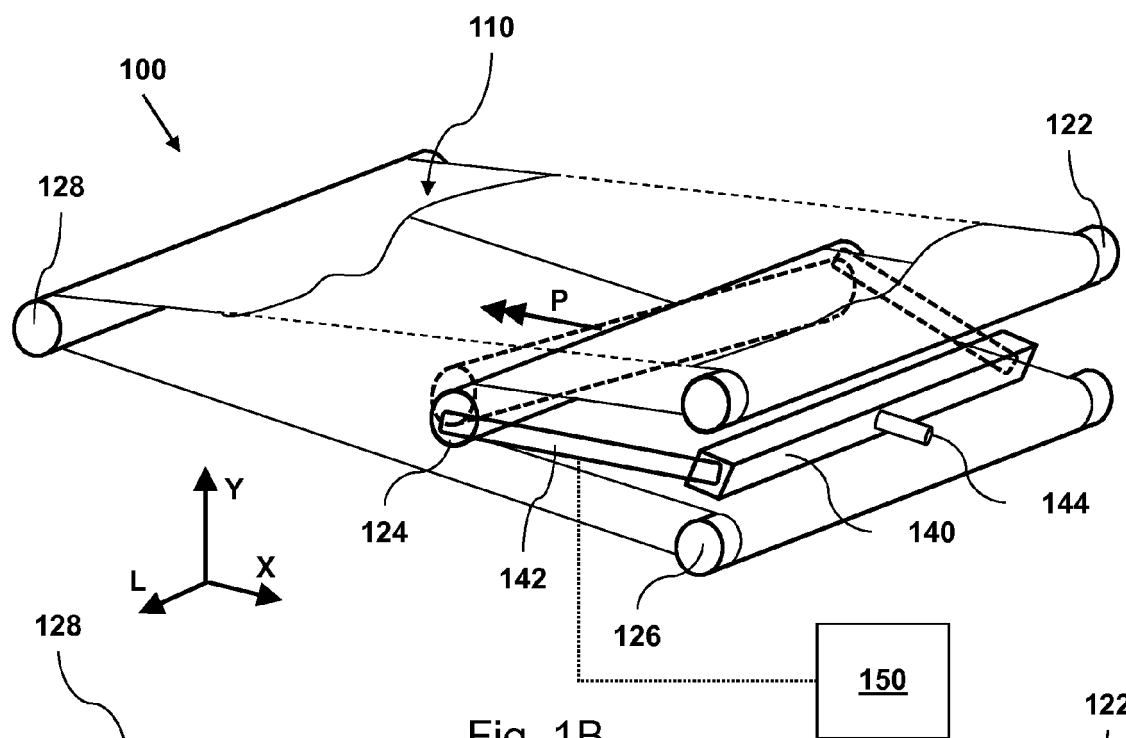


Fig. 1B

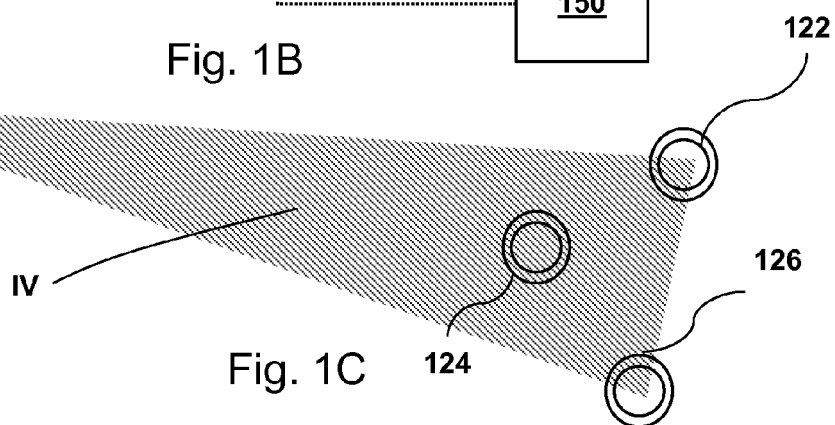


Fig. 1C

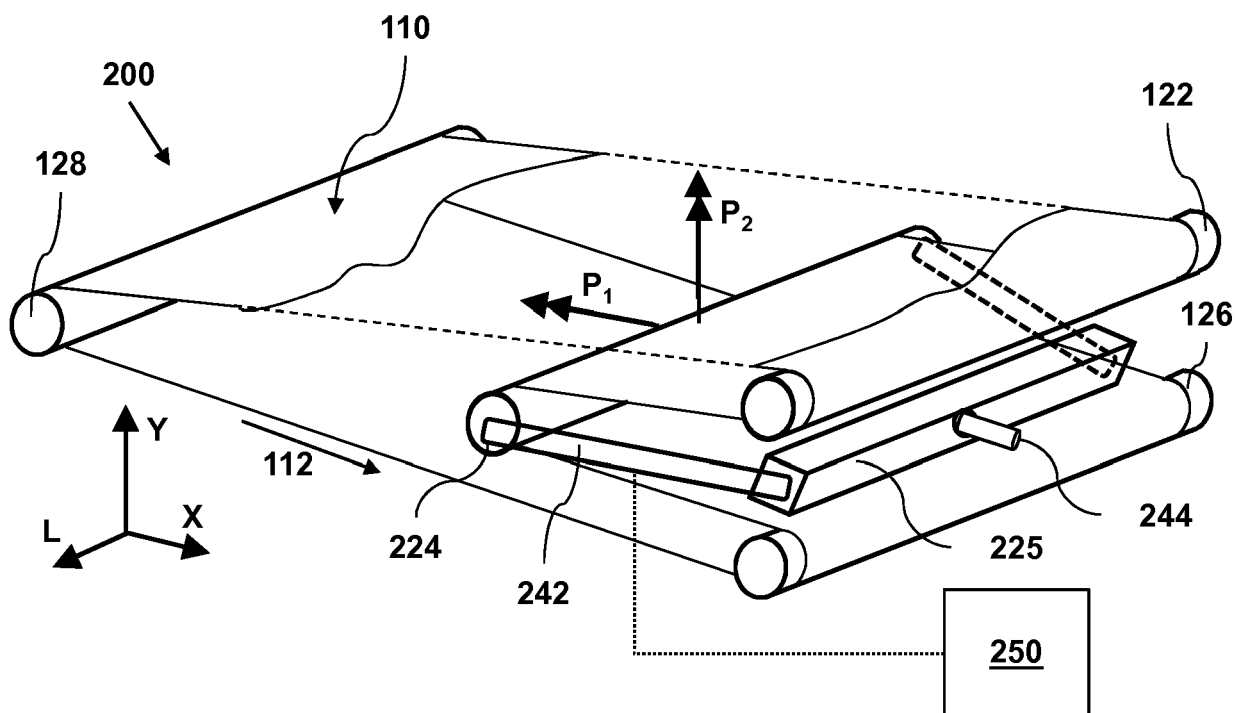


Fig. 2A

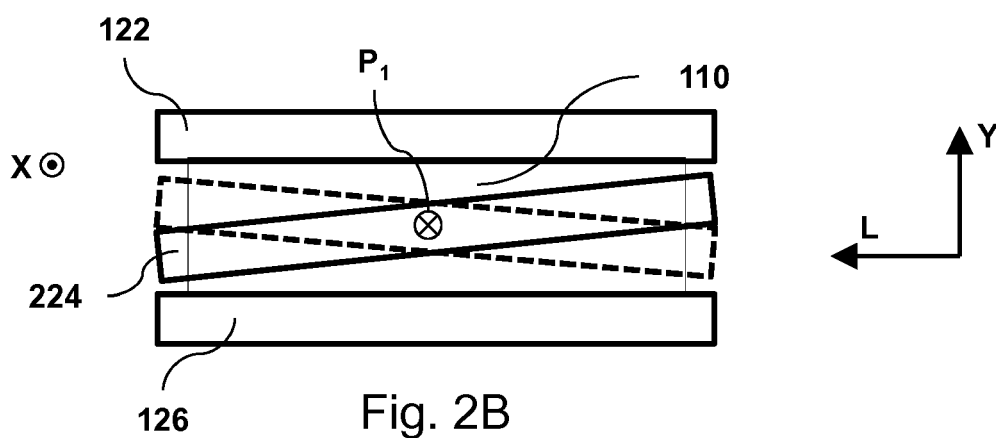


Fig. 2B

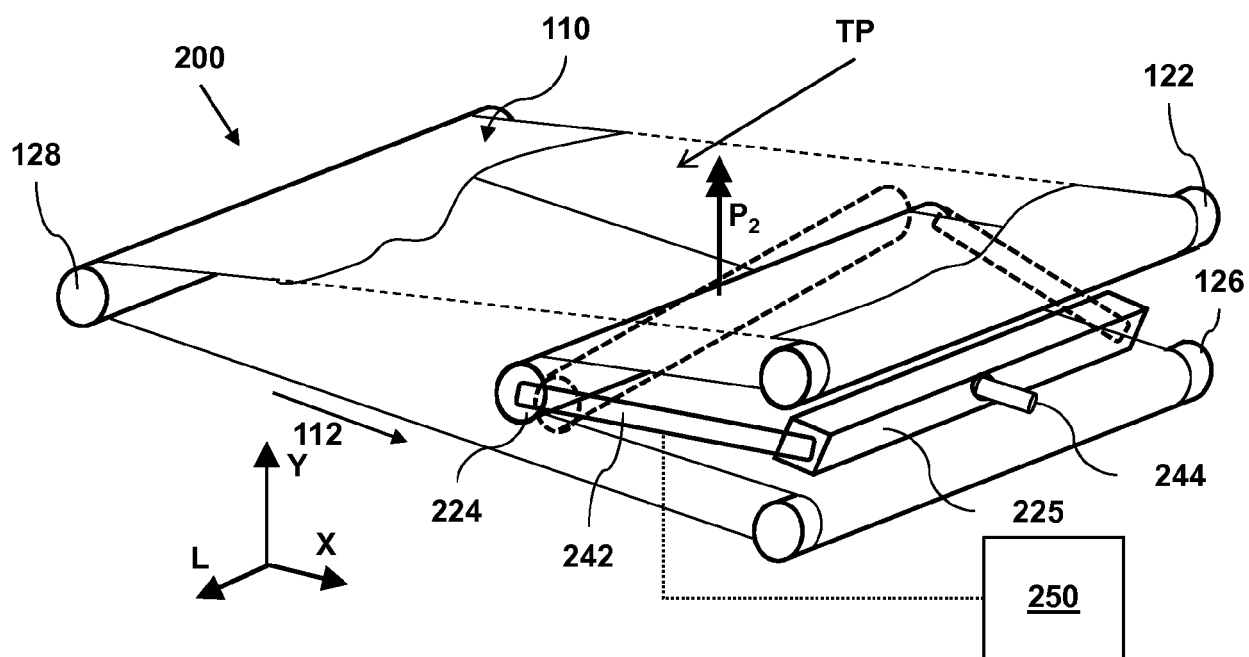


Fig. 2C

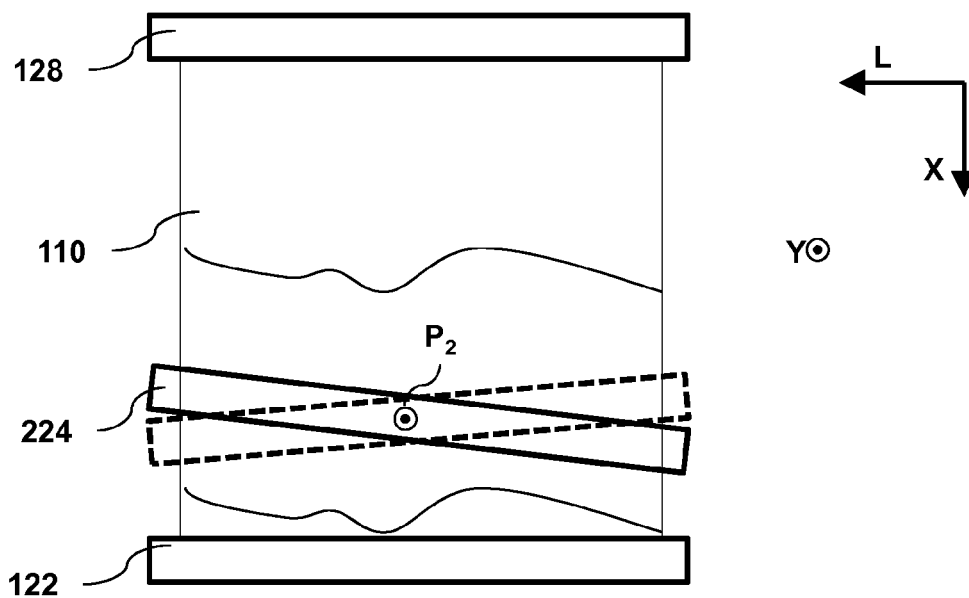
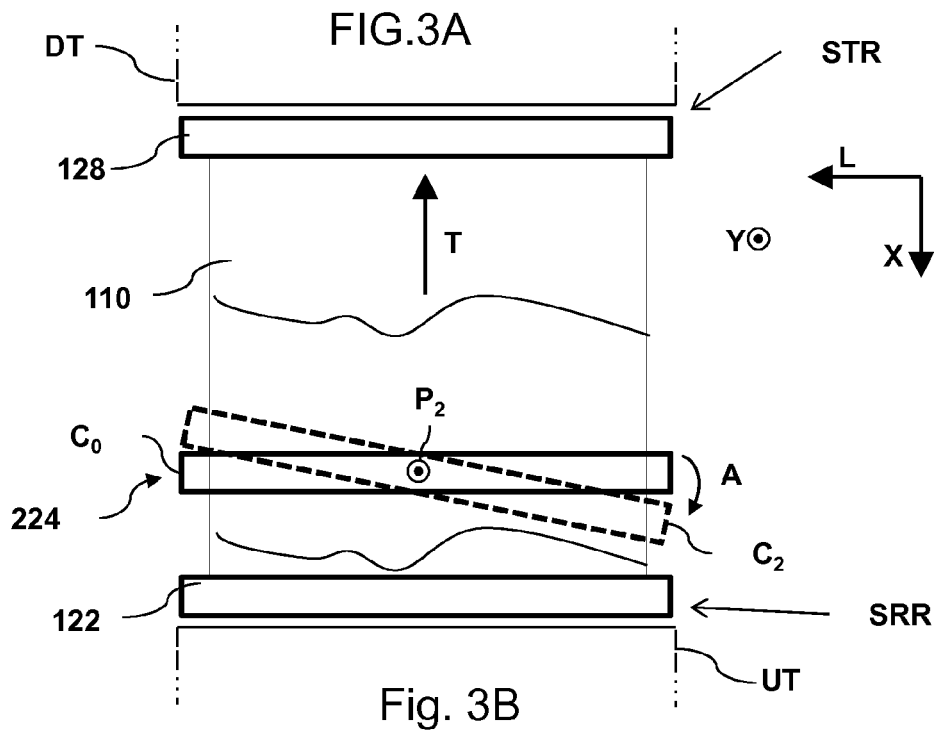
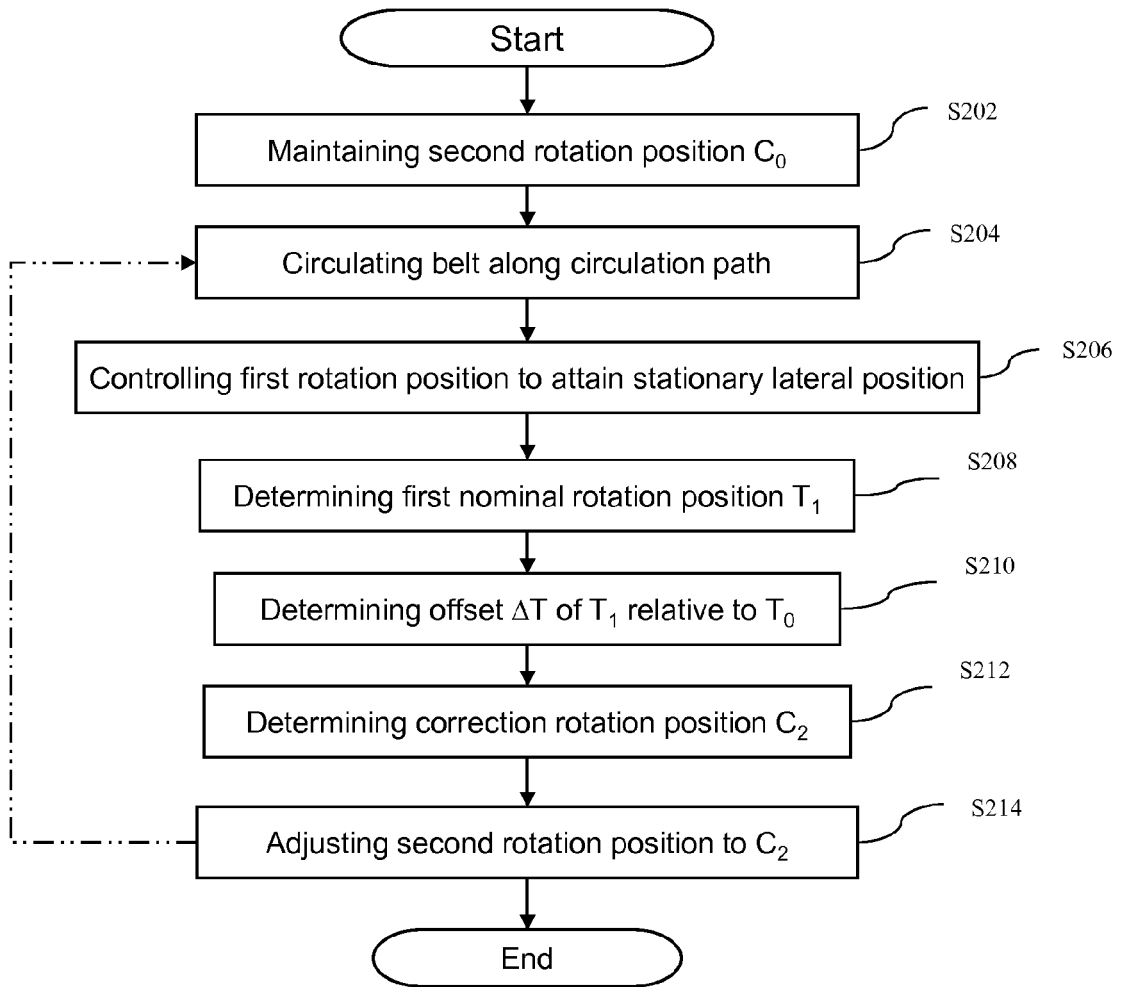
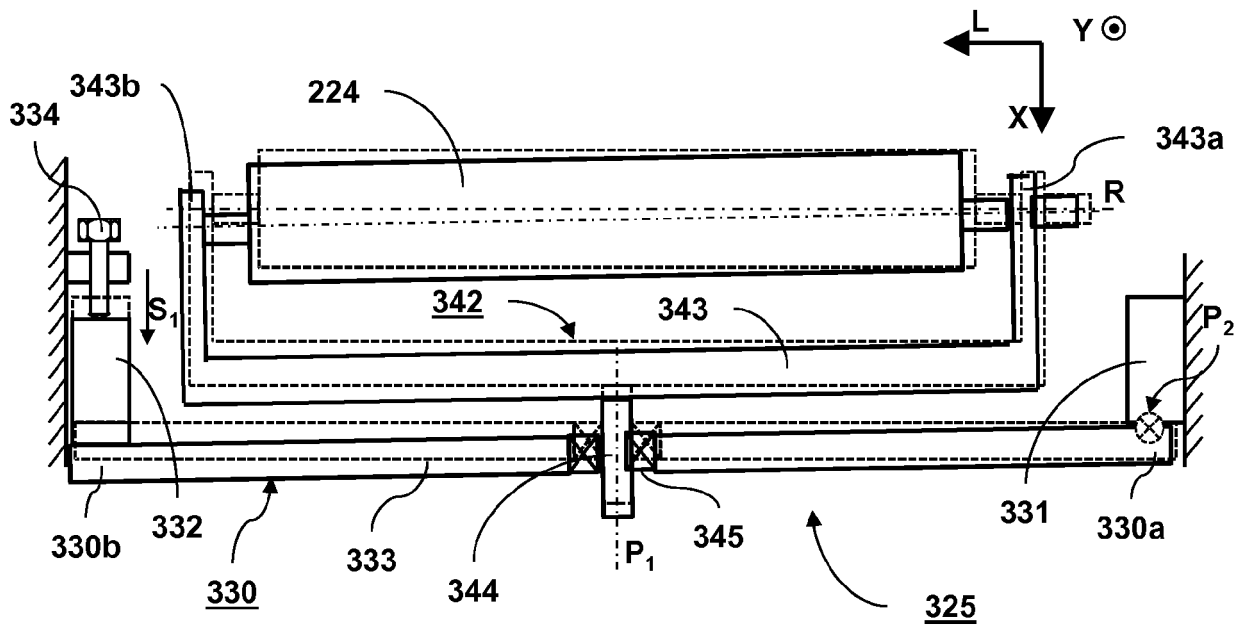
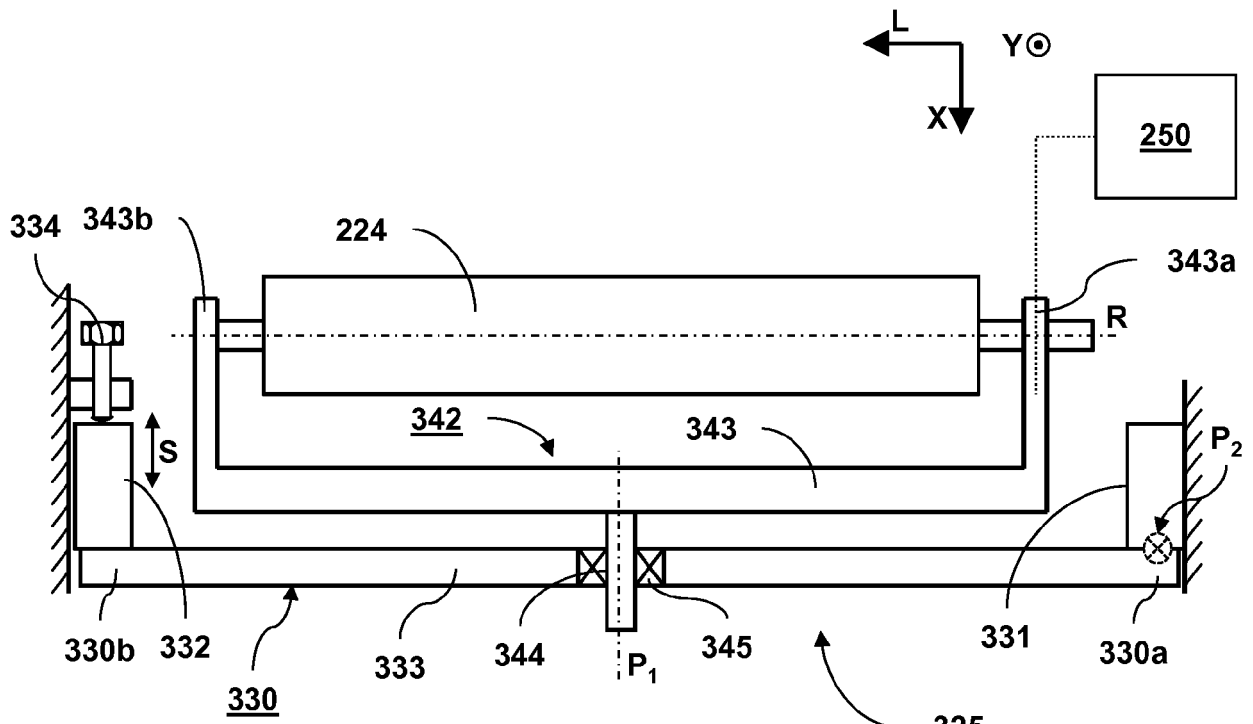


Fig. 2D





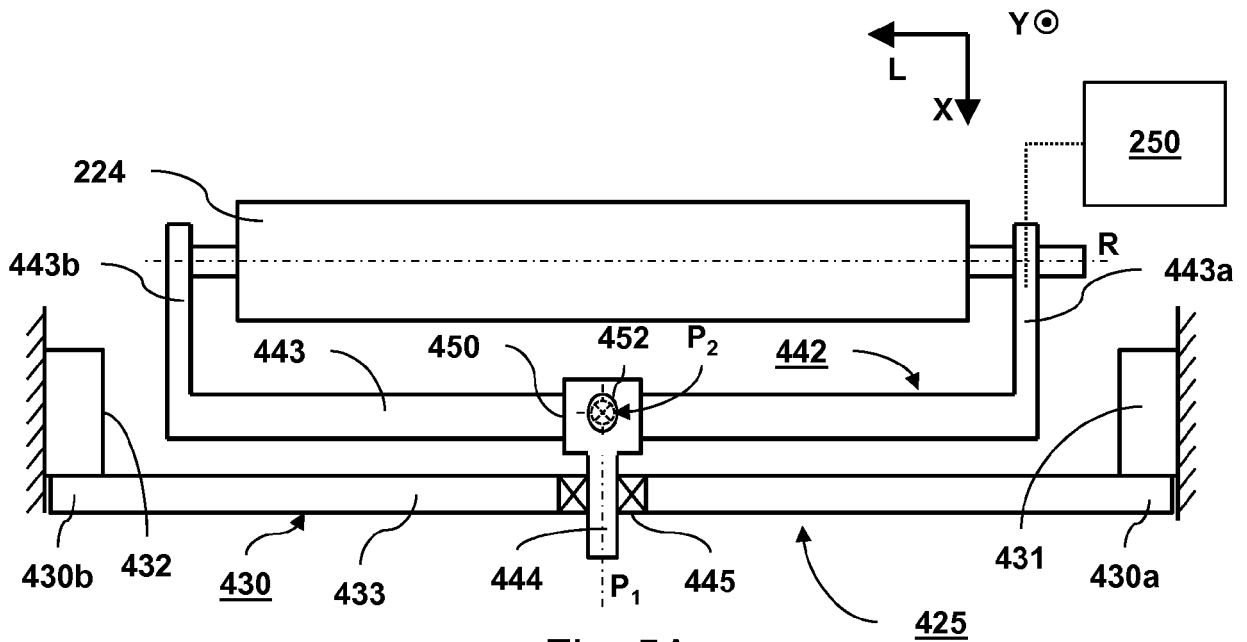


Fig. 5A

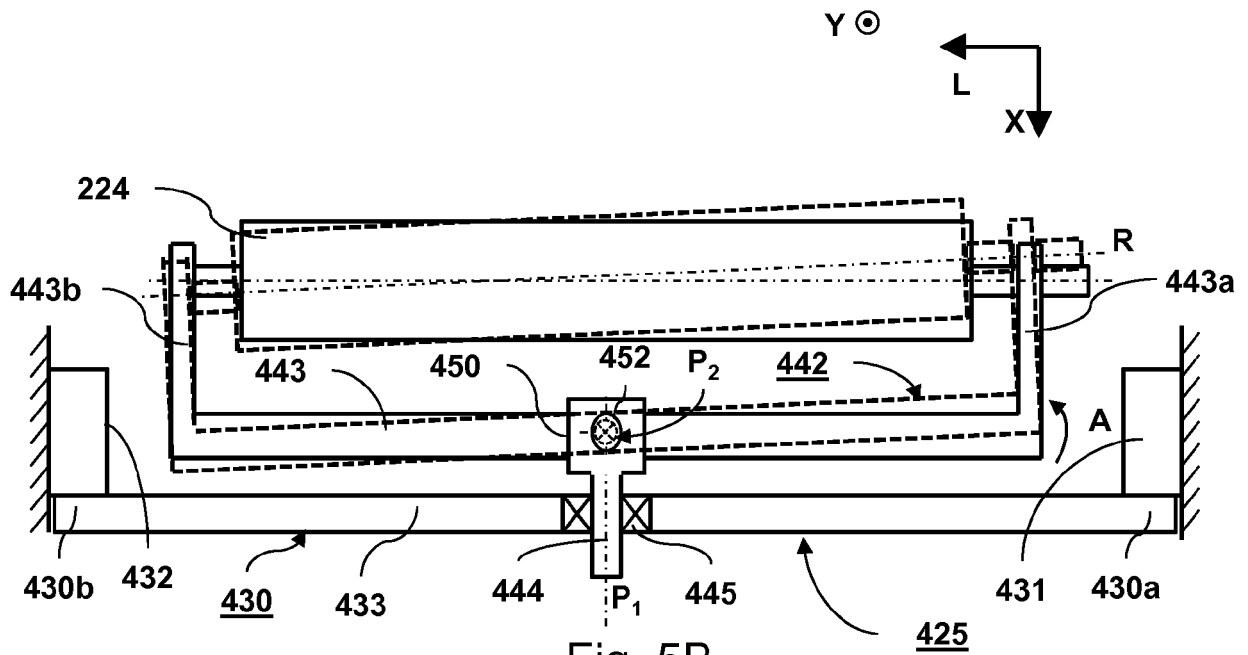


Fig. 5B

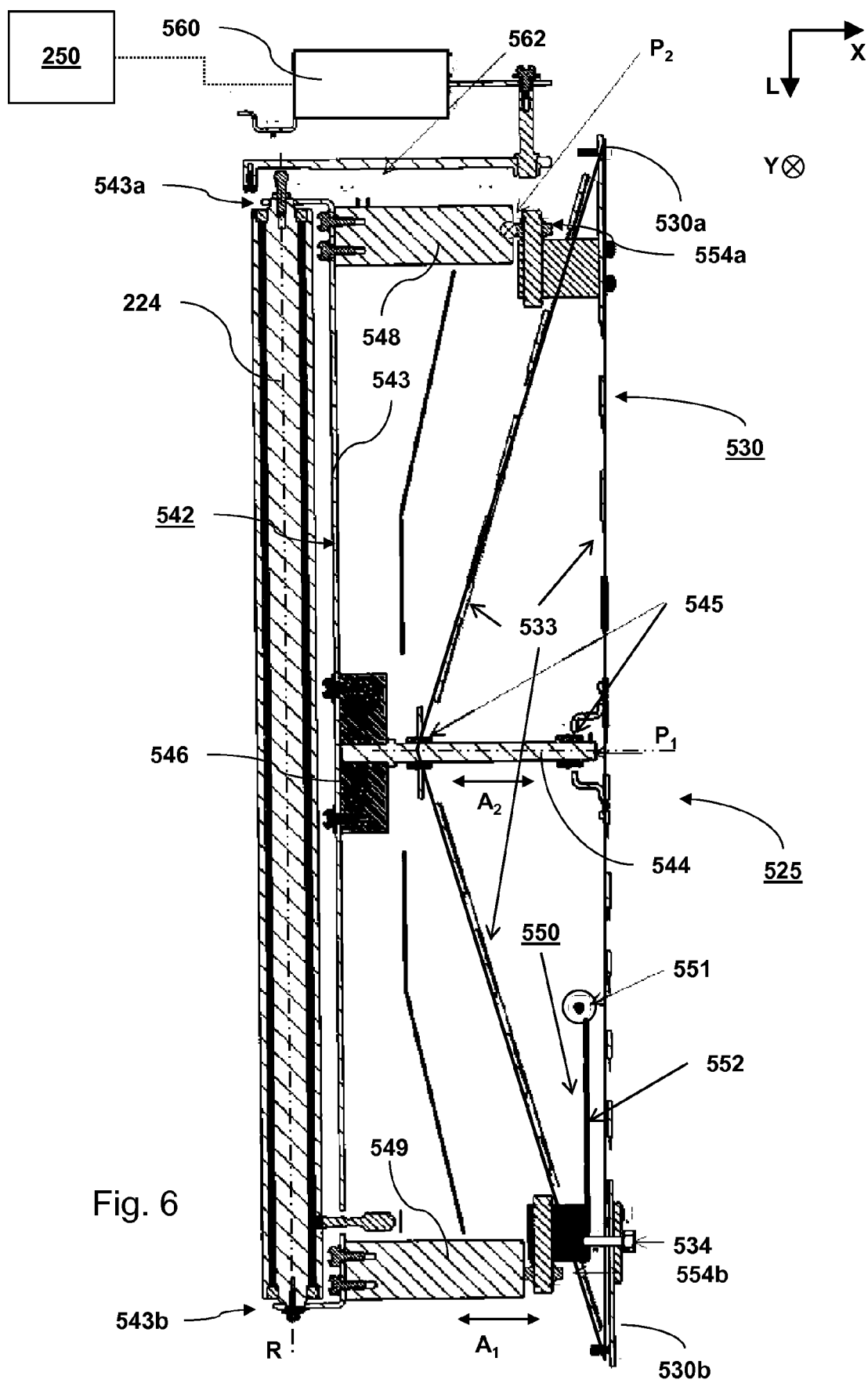


Fig. 6



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Place of search Munich		Date of completion of the search 19 May 2017	Examiner Urbaniec, Tomasz
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