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(72) Inventors:
• **Boeren, Frank A.J.**
5914 CA Venlo (NL)
• **van Dongen, Peter J.W.**
5914 CA Venlo (NL)

(74) Representative: **OCE IP Department**
St. Urbanusweg 43
5914 CA Venlo (NL)

(71) Applicant: **OCE Holding B.V.**
5914 CA Venlo (NL)

(54) **CORRECTION OF WIDTH DEPENDENT CYCLIC ERRORS IN ROLL PRINTING**

(57) A scanning inkjet printing assembly comprises a driving roller for moving the recording medium. Irregularities in the surface of the driving roller affect the accuracy for positioning the recording medium, and thereby the image quality. Width dependent irregularities in the outer surface of the driving roller can be corrected by a sub-carriage moveably supported on a carriage which scans across the recording medium for printing consec-

utive swath. The sub-carriage is moveable in the transport direction of the recording medium with respect to the carriage. From stored cyclic deviation data a control unit appropriately controls the movement of the sub-carriage in the transport direction as the carriage scans over the recording medium, thereby correcting for the irregularities in the surface of the driving roller.

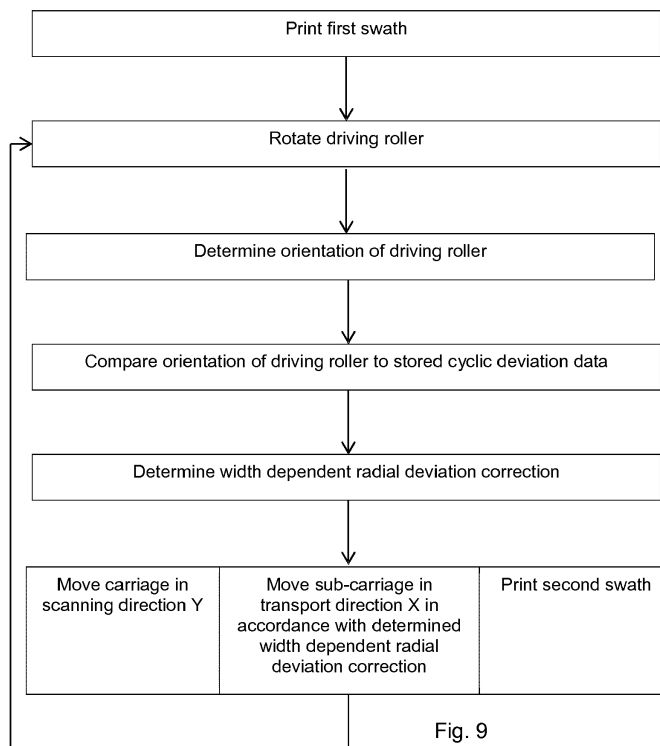


Fig. 9

Description

FIELD OF THE INVENTION

[0001] The present invention generally pertains to a scanning inkjet printing assembly and a method for printing on such an assembly.

BACKGROUND ART

[0002] It is known that the image quality in roll printers is negatively affected by cyclic deformations in the outer surface of the driving roller which driving rollers moves the recording media along the inkjet print heads. It is known that such cyclic deformations can be at least partially corrected by adjusting the displacement of the recording medium by taking into account the angular orientation and angular deformation of the driving roller, for example from US 9928453 B1. In practice however such corrections by adjusting the displacement of the recording medium were found to not fully eliminate the effects of cyclic deformations on the driving roller. Especially in wide format roll printing systems (where the width of the recording medium may exceed 3 meters) media step-based corrections were found to be insufficient to achieve the desired print quality.

SUMMARY OF THE INVENTION

[0003] In a first aspect of the present invention, a scanning inkjet printing assembly is provided. The scanning inkjet printing assembly comprises:

- a print surface for holding a recording medium;
- a driving roller for transporting the recording medium over the print surface by a displacement distance;
- a carriage supporting at least one inkjet print head, wherein the carriage is moveable over the print surface in a scanning direction for applying droplets of a liquid to the recording medium to form a swath of printed dots on the recording medium;
- a sub-carriage supported by the carriage, the sub-carriage being moveable relative to the carriage in at least the transport direction;
- a control unit operatively coupled to the carriage and the sub-carriage for controlling the movement of the carriage and the sub-carriage,

wherein the control unit is configured to:

- store on its memory predetermined cyclic deviation data relating to width dependent deviations in a circumference of the driving roller with respect to its rotation axis;
- compare the displacement distance to the cyclic deviation data to determine width dependent radial deviation corrections for different positions in the scanning direction; and

- for each of said positions in the scanning direction control the sub-carriage to move relative to the carriage in the transport direction in accordance with the determined width dependent radial deviation corrections.

[0004] It is the insight of the inventors that cyclic deformations in the driving roller vary not only in the angular direction, but in the width direction of the driving roller as well. It is a further insight of the inventors that the variations in the driving roller in the width direction can be corrected by allowing a sub-carriage to move in the transport direction with respect to a scanning carriage which moves in the scanning direction. The transport direction and the scanning direction are positioned at an angle with respect to one another, preferably perpendicularly. The relative position of the sub-carriage is adjusted proportionally to the predetermined local deformation of the driving roller.

[0005] Local deformations in the circumference of the driving rollers affect the positioning of the recording medium in the transport direction. Over the width of the recording medium there is local variation in the displacement by which the recording medium moves over the support surface. The recording medium while moving does not maintain a perfectly straight line in the width direction. These variations or irregularities become visible when the recording medium is moved in between printing two adjoining swaths of an image. Local variations in the recording medium's positioning result in print artifacts due to the local misalignment of the two swaths. The sub-carriage being moveable in the transport direction allows the inkjet print heads to be moved to correct for these local variations. The appropriate amount of displacement of the sub-carriage in the transport direction for each position in the scanning direction is determined by comparing the displacement distance to the cyclic deviation data, such that for each of said positions the appropriate displacement of the sub-carriage to correct for the variations in the driving roller can be determined. As such, width dependent cyclic corrections can be applied to scanning inkjet printing assemblies having a driving roller, thereby improving the alignment of consecutively printed swaths. As such the image quality is improved.

[0006] The present invention is particularly advantageous in wide format roll printing, where widths of recording media can exceed three meters. The difficulty and costs to achieve uniformity of the driving roller's surface increase with the axial width and diameter of the driving roller. As a roller's inertia increases, it further becomes exponentially more difficult to control its rotation accurately. With the present invention the costs for producing the driving roller can be reduced. A further advantage is that the present invention can be applied to compensate for wear or damage of the driving roller's outer surface. Thereto the cyclic deviation data stored in the controller can be replaced or outdated. Up-to-date cyclic deviation data can be obtained e.g. from a 3D laser-scan of the

driving roller's circumference or by an analysis of printed test patterns to determine localized displacement of different portions of the recording medium.

[0007] In a preferred embodiment, the cyclic deviation data relates to displacement variation of over the width of the recording medium due to the variation in the radial distance of the driving roller in the width direction. The cyclic deviation data defines a number of width positions spaced apart from one another in the width direction as well as a width dependent radial deviation correction for each of said positions. The width dependent radial deviation correction determines the displacement of the sub-carriage holding the print heads at the respective width position. When correcting for example for sagging of the driving roller, the width dependent radial deviation correction may be the same or constant for the full rotation of the driving roller.

[0008] In an embodiment, the cyclic deviation data defines a plurality of width positions spaced apart from one another in the scanning direction and comprises a width dependent radial deviation correction for each of the width positions which width dependent radial deviation correction determines a position or displacement of the sub-carriage in the transport direction at its respective width position. The cyclic deviation data is divided into width portions, such that it defines different corrective values for each width position. The control unit operates an actuator to move the sub-carriage in the transport direction by the corresponding corrective value when the sub-carriage is at the respective width position.

[0009] In an embodiment, the control unit is configured to store predetermined cyclic deviation data comprising angular direction deviation data and scanning direction deviation data. The cyclic deviation data may in an exemplary embodiment comprise a height map (or radial distance deviation map) of the outer surface of the driving roller defining radial deviation of the circumferential surface of the driving roller in both the angular direction and the scanning direction. The cyclic deviation data preferably comprises a plurality predetermined angle units or parts, which when summed up form a full 360° rotation. Each angle unit for example corresponds to an angular surface portion extending over the full width of the driving roller. For each angle unit the cyclic deviation data comprises a width dependent radial deviation correction, for example a height vs. width position curve describing the surface height variation of the corresponding angular portion of the driving roller in the width or scanning direction. By comparing this height curve to the displacement distance of the recording medium the required corrective displacement of the sub-carriage in the transport direction for all relevant positions in the scanning direction is determined. Instead of a surface height graph, the width dependent radial deviation correction may in another embodiment be stored in the form of corrective sub-carriage displacement data, such that the control unit need not separately calculate the displacement amount from the surface height map for every scan of the carriage. The

cyclic deviation data may be stored in the form of a height map, graph, table, etc.

[0010] Preferably, the cyclic deviation data is stored on the control unit during manufacturing of the printing assembly. However, the cyclic deviation data can be input or updated at any time, for example from a 3D scan of the driving roller. Any suitable 3D imaging technique known to the skilled person may therein be applied, such as 3D laser-scanning.

[0011] In a further embodiment, the control unit is further configured to:

- determine an angular orientation of the driving roller;
- compare the determined angular orientation to the cyclic deviation data to determine the width dependent radial deviation corrections;
- adjust the position of the sub-carriage in accordance with the determined width dependent radial deviation correction as the carriage moves in the width direction while the driving roller is in the determined angular orientation.

[0012] The control unit determines the angular orientation of the driving roller. Generally, transportation of the recording medium in scanning inkjet roll printing assemblies is step-wise, though the invention may be applied in continuously moving transportation as well. The control unit determines the current angular orientation (or angle for short) of the driving roller by tracking the rotation of the driving roller from its starting position. Therein the control unit may be aided by one or more rotation sensors, such as an encoder provided on the rotation axis. The orientation of the driving roller determines its effects on the width dependent variation in the recording medium's positioning, since generally only a portion of the driving roller contacts the recording medium at a given time. The determined angular orientation is compared to the cyclic deviation data, which may be in the form of a look-up table. For the determined angular orientation a corresponding width dependent radial deviation correction is then selected, for example by determining an appropriate angular range in the look-up table for the determined angular orientation and selecting the corresponding width dependent radial deviation correction. The width dependent radial deviation correction comprises information regarding the radial distance (or height) variation in the width direction of an angular surface portion of the driving roller.

[0013] The total outer surface of the driving roller is divided into surface angular portions, each angular surface portion covering a predetermined angular range, e.g. 1, 5, or 10°. For each angular surface portion corresponding width dependent radial deviation correction information is stored on the memory of the control unit, from which width dependent radial deviation correction information the controller is configured to derive a correctional motion of the sub-carriage to compensate for the height variation of the angular surface portion in the

width direction. The width dependent radial deviation correction information may for example comprise a height variation graph describing the height variation of the surface portion in the width direction or in another example comprise a sub-carriage corrective displacement graph, curve or table describing the appropriate adjustment of the position of the sub-carriage in the transport direction at predetermined positions along the width direction when the driving roller is in the determined angular orientation. As the carriage moves along the guide beam in the scanning direction (which in most roll printing systems is substantially parallel to the width direction of the driving roller), the control unit adjusts the position of the sub-carriage in the transport direction to compensate for the width dependent surface variations of the driving roller at the determined angular surface portion of the driving roller. Thereby a consecutive swath can be printed fittingly following the previously printed swath. It will be appreciated that additional swath aligning corrections may be applied on top of the width dependent cyclic corrections of the present invention.

[0014] In a further aspect, the present invention provides a method for printing on a scanning inkjet printing assembly, the method comprising the steps of:

- rotating a driving roller to transport a recording medium a displacement distance over a support surface in a transport direction;
- for each width position of a carriage holding print heads moving over the recording to print a swath on the recording medium;
- compare the displacement distance of the recording medium to cyclic deviation data stored on a memory of a control unit to determine a width dependent radial deviation correction for said width position;
- at said width position adjust the position of a sub-carriage moveably supported on the carriage in the transport direction in accordance with the determined width dependent radial deviation correction as the carriage moves in the width direction.

[0015] For each width position of the carriage, the control unit moves the sub-carriage in the transport direction in accordance with the width dependent radial deviation correction for said width position. The width dependent radial deviation correction is therein compared to the distance displacement as the correction required is proportional to the overall amount by which the recording medium has been moved by the driving roller. As such displacement variations due to inhomogeneities in the width direction of the driving roller can be corrected.

[0016] In a preferred embodiment, the cyclic deviation data defines a plurality of spaced apart width positions in the scanning direction as well as a width dependent radial deviation correction for each of said positions. Each width dependent radial deviation correction determines the displacement of the sub-carriage at its respective width position, e.g. by comparison to the displacement distance of the recording medium.

ment distance of the recording medium.

[0017] In an embodiment, the method according to the present invention further comprises the step of determining and storing the cyclic deviation data by measuring the cycling deviation. The cyclic deviation may be measured by printing predetermined test patterns on the recording medium and determining the relative displacement of predetermined in the patterns with respect to one another or a predetermined reference. Alternatively, the driving roller may 3D scanned to obtain a model for determining the cyclic deviation.

[0018] Additionally, the present invention allows for the correction of irregularities in the driving roller's surface which vary in both the angular and the width direction. Thereto, an embodiment of the present invention comprises the step of determining the angular position of the driving roller and comparing it to the cyclic deviation data together with the width position to determine a width dependent radial deviation correction for the section of the driving roller corresponding to said angular and width positions. From the angular orientation of the driving roller the control unit is able to determine the relevant angular surface portion of the driving roller, for example the portion in contact with the recording medium and/or the surface portion currently on top. For said relevant angular surface portion the controller determines the appropriate width dependent radial deviation correction by accessing the cyclic deviation data. The cyclic deviation data preferably comprises a plurality of width dependent radial deviation correction data sets, one for each of the angular portions. From these width dependent radial deviation correction data sets, which may be in the form of data, tables, or graphs, the control unit determines the adjustments in the sub-carriage's position in the transport direction as it moves along the guide beam in the width direction.

[0019] 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 description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying schematical drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Fig. 1A is a perspective view of an embodiment of an inkjet printing assembly;

Fig. 1B is a schematical representation of an embodiment of a scanning inkjet printing assembly;

Fig. 2 is a schematical representation of an embodiment of a scanning inkjet print head carriage and sub-carriage in accordance with the present invention;

Fig. 3A and 3B are schematical representations of an embodiment of a scanning inkjet carriage and sub-carriage in accordance with the present invention;

Fig. 4A and 4B are schematical representations of an embodiment of a scanning inkjet carriage and sub-carriage in accordance with the present invention;

Fig. 5 is a schematical representation of an embodiment of a scanning inkjet carriage and sub-carriage according to the present invention;

Fig. 6 is a schematical side view representation of an embodiment of a scanning inkjet printing assembly according to the present invention;

Figs. 7A-C are schematic representation of a driving roller in a side view (Fig.

7A), front view (Fig. 7B), and in a height map (Fig. 7C);

Fig. 8 is a graph representation of cyclic deviation data for a driving roller; and

Fig. 9 is a block diagram illustrating an embodiment of the method according to the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0021] 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.

[0022] 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.

[0023] Fig. 1A shows an image forming apparatus 36, in particular an inkjet printer, wherein printing is achieved using a wide-format inkjet printing assembly. The wide-format image forming apparatus 36 comprises a housing 26, wherein the printing assembly, for example the inkjet printing assembly shown in Fig. 1B is placed. The image forming apparatus 36 also comprises a storage means for storing image receiving member 28, 30 (also referred to as a recording medium), a delivery station to collect the image receiving member 28, 30 after printing and storage means for marking material 20. In Fig. 1A, the delivery station is embodied as a delivery tray 32. Optionally, the delivery station may comprise processing means for processing the image receiving member 28, 30 after printing, e.g. a folder or a puncher. The wide-format image forming apparatus 36 furthermore comprises means for receiving print jobs and optionally means for manipulating print jobs. These means may include a user interface unit 24 and/or a control unit 34, for example

a computer.

[0024] Images are printed on an image receiving member, for example paper, supplied by a roll 28, 30. The roll 28 is supported on the roll support R1, while the roll 30 is supported on the roll support R2. Alternatively, cut sheet image receiving members may be used instead of rolls 28, 30 of image receiving member. Printed sheets of the image receiving member, cut off from the roll 28, 30, are deposited in the delivery tray 32.

[0025] Each one of the marking materials for use in the printing assembly are stored in four containers 20 arranged in fluid connection with the respective print heads for supplying marking material to said print heads.

[0026] The local user interface unit 24 is integrated to the print engine and may comprise a display unit and a control panel. Alternatively, the control panel may be integrated in the display unit, for example in the form of a touch-screen control panel. The local user interface unit 24 is connected to a control unit 34 placed inside the printing apparatus 36. The control unit 34, for example a computer, comprises a processor adapted to issue commands to the print engine, for example for controlling the print process. The image forming apparatus 36 may optionally be connected to a network N. The connection to the network N is diagrammatically shown in the form of a cable 22, but nevertheless, the connection could be wireless. The image forming apparatus 36 may receive printing jobs via the network. Further, optionally, the controller of the printer may be provided with a USB port, so printing jobs may be sent to the printer via this USB port.

[0027] Fig. 1B shows an ink jet printing assembly 3. The ink jet printing assembly 3 comprises supporting means for supporting an image receiving member 2. The supporting means are shown in Fig. 1B as a platen 1, but alternatively, the supporting means may be a flat surface. The platen 1, as depicted in Fig. 1B, is a rotatable drum, which is rotatable about its axis as indicated by arrow A. The supporting means may be optionally provided with suction holes for holding the image receiving member in a fixed position with respect to the supporting means. The ink jet printing assembly 3 comprises print heads 4a - 4d, mounted on a scanning print carriage 5. The scanning print carriage 5 is guided by suitable guiding means 6, 7 to move in reciprocation in the main scanning direction Y. In the embodiment shown the scanning direction Y is substantially parallel to the width direction of the receiving member 28, 30 on the roll support R1, R2. Each print head 4a - 4d comprises an orifice surface 9, which orifice surface 9 is provided with at least one orifice 8. The print heads 4a - 4d are configured to eject droplets of marking material onto the image receiving member 2. The platen 1, the carriage 5 and the print heads 4a - 4d are controlled by suitable controlling means 10a, 10b and 10c, respectively.

[0028] The image receiving member 2 may be a medium in web or in sheet form and may be composed of e.g. paper, cardboard, label stock, coated paper, plastic or textile. Alternatively, the image receiving member 2

may also be an intermediate member, endless or not. Examples of endless members, which may be moved cyclically, are a belt or a drum. The image receiving member 2 is moved in the sub-scanning direction A by the platen 1 along four print heads 4a - 4d provided with a fluid marking material.

[0029] A scanning print carriage 5 carries the four print heads 4a - 4d and may be moved in reciprocation in the main scanning direction Y parallel to the platen 1, such as to enable scanning of the image receiving member 2 in the main scanning direction Y. Only four print heads 4a - 4d are depicted for demonstrating the invention. In practice an arbitrary number of print heads may be employed. In any case, at least one print head 4a - 4d per color of marking material is placed on the scanning print carriage 5. For example, for a black-and-white printer, at least one print head 4a - 4d, usually containing black marking material is present. Alternatively, a black-and-white printer may comprise a white marking material, which is to be applied on a black image-receiving member 2. For a full-color printer, containing multiple colors, at least one print head 4a - 4d for each of the colors, usually black, cyan, magenta and yellow is present. Often, in a full-color printer, black marking material is used more frequently in comparison to differently colored marking material. Therefore, more print heads 4a - 4d containing black marking material may be provided on the scanning print carriage 5 compared to print heads 4a - 4d containing marking material in any of the other colors. Alternatively, the print head 4a - 4d containing black marking material may be larger than any of the print heads 4a - 4d, containing a differently colored marking material.

[0030] The carriage 5 is guided by guiding means 6, 7. These guiding means 6, 7 may be rods as depicted in Fig. 1B. The rods may be driven by suitable driving means (not shown). Alternatively, the carriage 5 may be guided by other guiding means, such as an arm being able to move the carriage 5. Another alternative is to move the image receiving material 2 in the main scanning direction Y.

[0031] Each print head 4a - 4d comprises an orifice surface 9 having at least one orifice 8, in fluid communication with a pressure chamber containing fluid marking material provided in the print head 4a - 4d. On the orifice surface 9, a number of orifices 8 is arranged in a single linear array parallel to the sub-scanning direction A. Eight orifices 8 per print head 4a - 4d are depicted in Fig. 1B, however obviously in a practical embodiment several hundreds of orifices 8 may be provided per print head 4a - 4d, optionally arranged in multiple arrays. As depicted in Fig. 1B, the respective print heads 4a - 4d are placed parallel to each other such that corresponding orifices 8 of the respective print heads 4a - 4d are positioned in-line in the main scanning direction Y. This means that a line of image dots in the main scanning direction Y may be formed by selectively activating up to four orifices 8, each of them being part of a different print head 4a - 4d. This parallel positioning of the print heads 4a - 4d with

corresponding in-line placement of the orifices 8 is advantageous to increase productivity and/or improve print quality. Alternatively multiple print heads 4a - 4d may be placed on the print carriage adjacent to each other such that the orifices 8 of the respective print heads 4a - 4d are positioned in a staggered configuration instead of in-line. For instance, this may be done to increase the print resolution or to enlarge the effective print area, which may be addressed in a single scan in the main scanning direction. The image dots are formed by ejecting droplets of marking material from the orifices 8.

[0032] Upon ejection of the marking material, some marking material may be spilled and stay on the orifice surface 9 of the print head 4a - 4d. The ink present on the orifice surface 9, may negatively influence the ejection of droplets and the placement of these droplets on the image receiving member 2. Therefore, it may be advantageous to remove excess of ink from the orifice surface 9. The excess of ink may be removed for example by wiping with a wiper and/or by application of a suitable anti-wetting property of the surface, e.g. provided by a coating.

[0033] While in Fig. 1B the carriage 5 is illustrated to support four print heads 4a - 4d, in practice the carriage 5 may support many print heads. For example, more than four colors of liquid marking material (hereinafter also referred to as ink) may be available. A common additional color is white, but also varnish and silver-colored and gold-colored ink are well known additional colors. Further, for increasing a print speed it is known to provide multiple print heads per color. In particular, two or more print heads per color may be staggered to form a wider print swath per scanning movement.

[0034] With an increasing number of print heads on the carriage 5, a weight of the carriage 5 increases. Inertia increases and resonance frequencies become lower. A too low resonance frequency is undesirable as such low resonance frequency may be close to an operating frequency. Consequently, such resonance frequency may become excited and distort/disrupt the operation of the inkjet printer. In order for the carriage 5 to support more print heads, it is desirable to reduce the weight of any other component. For example, a carriage plate for supporting the print heads may be reduced in weight by thinning the carriage plate.

[0035] Fig. 2 illustrates a part of a scanning inkjet printing assembly according to the present invention, which is arranged and configured to perform the method according to the present invention. In particular, the embodiment of Fig. 2 comprises a medium support surface 1, also referred to herein as the print surface 1, on which an image receiving member, herein also referred to as a recording medium, may be arranged. The guide beam 16 extends over the print surface 1 and the carriage 5 is moveably supported thereon. Moreover, the assembly and the method according to the present invention may be employed in both embodiments.

[0036] The carriage 5 supports a sub-carriage 51 and

the sub-carriage 51 supports - in the illustrated embodiment - eight print heads 4, but the present invention is in no way limited to a specific number of print heads. Further, the sub-carriage 51 supports - in this embodiment - two optical sensor units 40, one on either side of the array of print heads such that at least one optical sensor unit 40 is available upstream of the array of print heads 4 during printing. Hence, if the scanning printing assembly is configured to print only when the carriage 5 is moving in one direction, it suffices to have a single optical sensor unit 40 upstream of the print heads 4. Further, more optical sensor units 40 may be provided as well, for example in order to improve a detection accuracy. It is noted that, in another embodiment, the optical sensor units may be arranged on the carriage 5 or a sensor unit 40 may be supported directly on the guide beam 16. In the latter embodiment, the sensor unit 40 may be moveably supported or a sensor unit 40 extending over the full width of the guide beam 16 (in particular in the Y-axis direction as defined in Fig. 1B) may be statically arranged thereon. An advantage of providing the sensor units 40 on the sub-carriage 51 is the fact that a position of the sensor units 40 is directly coupled to a position of the print heads 4, which ensures that a detection of a position of a first swath by the sensor units 40 is easily coupled and related to the position of the print heads 4. Further, it is noted that the sensor units 40 are not restricted to optical sensor units, although optical sensor units 40 may be deemed most apparently suitable kind of sensor units. However, any other kind of sensor capable of detecting a position of a previous swath is contemplated as well.

[0037] The guide beam 16 is moveably supported and may be controlled to move either in a first beam direction X1 or a second beam direction X2. The carriage 5 is arranged to be moveable in a first carriage direction Y1 and a second carriage direction Y2. The sub-carriage 51 is moveably supported such to be controllably moved in a first sub-carriage direction X3 or a second sub-carriage direction X4 and such to be controllably moved in a sub-carriage rotation direction Rz1 around a rotation axis Rz (also referred to herein as a center of rotation) extending in the Z-direction perpendicular to the plane of the support surface 1. Although the center of rotation Rz is illustrated in a geometric center of the sub-carriage 51, a center of rotation in another embodiment may be selected to be arranged on any other suitable location.

[0038] Two adjacent swaths, a first swath 101 and a second swath 102, are depicted by three dashed lines: a first swath trailing edge 101a, a first swath leading edge 101b and a second swath leading edge 102b. A second swath trailing edge coincides with the first swath leading edge 101b and is thus not separately indicated in Fig. 2.

[0039] In the embodiment of Fig. 2, the first swath 101 may be presumed to have been printed in a previous scanning movement of the carriage 5, after which the guide beam 16 has been moved step-wise in the first beam direction X1. The second swath 102 is being printed adjacent to the first swath 101. A swath width corre-

sponds to a width of the print heads 4 and in this example perfectly straight swaths 101 and 102 are printed accurately adjacent to each other.

[0040] The sensor units 40 may be employed to detect the first swath leading edge 101b after the guide beam 16 has stepped in the first beam direction X1 (or the second beam direction X2, *mutatis mutandis*). Based on the detected first swath leading edge 101b, the sub-carriage 51 may be moved in the first sub-carriage direction X3 or the second sub-carriage direction X4 to correct for any inaccuracy of the step-wise movement of the guide beam 16. This method is shown in Figs. 3A and 3B in more detail.

[0041] Fig. 3A shows the sub-carriage 51 in a centered position with respect to the carriage 5. In other words, it is presumed that the sub-carriage 51 has not yet been moved relative to the carriage 5 and is scanning in a scanning direction 52 for applying the second swath 102. It is presumed that the guide beam 16 has previously stepped in the first beam direction X1, but the step made was larger than intended. Consequently, the print heads 4 are positioned such that a second swath trailing edge 102a does not coincide with the first swath leading edge 101b. A gap remains between the first swath 101 and the second swath 102. If the recording medium 2 is white, the gap will appear as a white stripe in the resulting printed image and hence will be considered a print artifact. Please note that a shorter step of the guide beam 16 would have resulted in the first swath 101 and the second swath 102 partly overlapping (not shown), which will be visible as a dark stripe, which is likewise considered to be a print artifact.

[0042] With reference to Fig. 3B, the sub-carriage 51 is moved in the second sub-carriage direction X4 - compared to the situation as illustrated in Fig. 3A - with an amount suitable to let the second swath trailing edge 102a and the first swath leading 101b coincide such that the first swath 101 and the second swath 102 are adjacent and no stripe will become visible in the resulting printed image. It is remarked that the use of a sub-carriage 51 for correcting a transport step of the guide beam 16 (or similarly the recording medium 2 in the embodiment of Fig. 1B) is known from the prior art.

[0043] Fig. 4A illustrates an embodiment of the method according to the present invention, wherein a direction in which the first swath leading edge 101b of the first swath 101 is not aligned with the scanning direction 52 of the carriage 5. In other words, the scanning direction and a first swath direction are at an angle. Moving the sub-carriage 51 in the second sub-carriage direction X4 may adapt to a local difference between the first swath leading edge 101b and the second swath trailing edge 102a, but when scanning in the scanning direction 52, the triangular areas 103a and 103b will become visible in the resulting printed image. In particular, a first triangular area 103a is formed by a gap between the first swath leading edge 101b and the second swath trailing edge 102a, which will appear as an area having the color

of the recording medium 2, usually white. A second triangular area 103b is formed by the first swath 101 and the second swath 102 partly overlapping and hence the second triangular area 103b will appear as a dark area. Fig. 4B illustrates the same embodiment as in Fig. 4A with the addition that the sub-carriage 51 is not only moved (translated) in one of the first and second sub-carriage beam directions X3, X4, but is also rotated in the sub-carriage rotation direction Rz1. Thus, the orientation of the print heads 4 may be controlled to be aligned with the first swath direction, i.e. the direction in which the first swath leading edge 101b extends. Now driving the carriage 5 in the scanning direction 52 does not result in the first swath 101 and the second swath 102 being arranged accurately adjacent. Instead, the second swath 102 is still arranged and extending in the scanning direction 52 and, even worse, a swath width SW has increased compared to the situation illustrated in Fig. 4A. The increase in swath width SW inevitably includes a lower dot resolution (number of dots per unit length) and more in particular a different dot resolution in the swath width direction of the second swath 102 compared to the dot resolution of the first swath 101, which will appear as a different ink coverage and hence as a lighter band in the resulting printed image, which will be perceived as a print artifact. Further, there will still be a first triangular area 103a (gap) and a second triangular area 103b (overlap area) which will also be perceived as print artifacts.

While the sub-carriage movement and positioning of the embodiment of Fig. 3B may be performed without a sensor unit for detecting the position of the first swath 101 by, for example, monitoring the movement of the guide beam 16 and/or the movement of the recording medium 2 during the step-wise movement in the transport direction (e.g. first and second beam directions X1 and X2), adjusting to the slanting of the first swath 101 compared to the scanning direction 52 requires the sensor unit 40 and active control of the sub-carriage position to ensure that the print heads 4 apply the second swath 102 of dots adjacent to the first swath 101. By tracking, for example, the first swath leading edge 101b with the sensor unit 40, in particular the sensor unit 40 arranged upstream of the print heads 4, a control unit is enabled to virtually continuously move (translate and/or rotate) the sub-carriage 51 such to achieve the best possible fit between the first swath 101 and the second swath 102. For example, if the first swath 101 is straight, it suffices to rotate the sub-carriage 51 an amount corresponding to the slanting angle between the first swath 101 and the scanning direction 52 and, during scanning movement, translate the sub-carriage 51 in the transport direction. In the situation shown in Fig. 4B, this means that the sub-carriage 52 is continuously translated in the first sub-carriage direction X3 in response to the detected position of the first swath 101.

[0044] As illustrated by Fig. 5, the situation and corresponding control method become even more challenging, if the first swath 101 is not straight. This may for

example occur in the embodiment of Fig. 1B, wherein the recording medium 2 is transported underneath the print heads 4. With a relatively wide and flexible recording medium 2, the transport of the medium 2 may result in deformation of the recording medium 2. The position of such an irregularly shaped first swath 101 may be tracked by the sensor unit 40 and the sub-carriage 51 may be driven to translate and rotate in accordance with the position detected by the sensor unit 40. This will however not result in a nice stitching of the first swath 101 and the second swath 102. In particular, it needs to be considered that the sensor unit 40 is located at a different position than each print head 4. Moreover, the respective print heads 4 have different positions and would therefore require respective position adaptations. For example, a first print head 4-1 is located near the upstream sensor unit 40, while a second print head 4-2 is located at a position farther away from the sensor unit 40. Due to the curved shape of the first swath leading edge 101b, it may be determined that the sub-carriage 51 should be translated in the second sub-carriage direction X4. Such a translation will however translate the first print head 4-1 at a different position along the scanning direction 52 compared to the second print head 4-2. Assuming that the first and the second print heads 4-1, 4-2 provide dots with different colors, a color-to-color artifact will become visible in the resulting printed image. To minimize the color-to-color artifacts, it is contemplated to not only translate but also to rotate the sub-carriage 51 by an amount to be determined on the basis of the detected position of the first swath 101.

[0045] Fig. 6 shows a preferred embodiment of a scanning inkjet printing assembly 100 according to the present invention. The scanning inkjet printing 100 is a roll printer, specifically a roll-to-roll printing assembly 100, wherein a recording medium 2 is unwound from a wound-up roll of receiving member 28 on a first roll support R1 and transported via a support surface 140 to a third roll support R3 for rewinding the recording medium 2 into a roll of printed receiving member. On the input side the recording member 2, which is in the form of web 2, is turned parallel to the support surface 140 by the turn element 120. The turn element 120 preferably exerts little or limited friction on the recording medium 2. Downstream of the support surface 140 the recording medium 2 is frictionally engaged by the driving roller 130, which is preferably provided by a high friction coating such as rubber. An actuator (not shown) is provided to rotate the driving roller 130 around its rotation axis 132. Rotation of the driving roller 130 moves, specifically pulls, the recording medium 2 over the support surface 140. The driving roller 130 may in another embodiment be positioned upstream of the support surface 140 to form a 'pushing' transport mechanism. The displacement of the recording medium 2 is preferably accurately determined by sensing the displacement of the recording medium 2. This may be for example by using the carriage 5 to print markers on the recording medium 2, which markers are then sensed by

a detector unit. By comparing the spacing between markers the displacement of the recording medium 2 can be accurately determined. More details on such a method can be found in US 2015375537 A1, which is herein incorporated by reference.

[0046] The guide beam 16 extends laterally in the scanning direction Y over the support surface 140, such that the carriage 5 is translatable along the guide beam 16 in the scanning direction Y. The sub-carriage 51 is moveably supported by the carriage 50, such that the sub-carriage 51 is further moveable with respect to the guide beam 16 in the transport direction X. It will further be appreciated that the present invention is applicable to any type of inkjet printing system comprising a driving roller 130 for moving the recording medium 2, which may be in the form of a web or sheet-like substrate.

[0047] Fig. 7A and 7B show respectively a schematic, exaggerated side and top view of the radial deformation of the driving roller 130. Uniformity of the driving roller's circumferential surface improves the accuracy whereby the recording medium 2 is transported, and thus also improves the image quality. Due the manufacturing and assembly issues the driving roller 130 generally contains one or more irregularities in its circumferential surface, meaning that the radial distance from the circumferential surface to the rotation axis is not uniform over the total surface of the driving roller 130. Fig. 7A shows a variation in the radial distance of the surface in the angular direction α . In Fig. 7A the driving roller 130 in side view shows an ellipsoid shape. Similarly, radial distance variation may occur in the width direction Y, which in the embodiment of Fig. 6 is substantially parallel to the scanning direction Y. Fig. 7C illustrates a graph illustrating the radial distance as a two-dimensional height map. The width direction Y and the angular direction α are plotted along the axes, wherein the grayscale level of the height map provides a measure for the radial distance of the respective surface portion of the driving roller 130. The radial deviation map may contain absolute or relative radial distance deviation data with respect to the rotation axis 132. The deviation data may be obtained by e.g. performing 3D laser scans of the driving roller 130.

[0048] The cyclic deviation data is preferably stored in the memory of the control unit 34. The cyclic deviation data comprises for example a plurality of radial distance deviation data sets describing a radial distance variation of the driving roller 130 in the width direction Y. The cyclic deviation data defines a series of different positions in the scanning direction Y as well as a width dependent radial deviation correction for each of said positions. The width dependent radial deviation correction may be corrective value which determines the displacement of the sub-carriage 51 in the transport direction X at the respective position in the scanning direction Y, as shown in Fig. 8. Additionally, the cyclic deviation data may further be divided into angular sections, as shown in Fig. 7C. Each radial distance deviation data set then corresponds to a predefined angular orientation of the driving roller 130.

The different angular orientations combined form a full rotation of the driving roller 130 around its rotation axis 132. Fig. 8 illustrates another embodiment of the cyclic deviation data. The cyclic deviation data in Fig. 8 was obtained by measuring the progress of printed markers as the recording medium 2 moves across the support surface 140. A plurality of markers extending in the scanning direction Y was printed on the recording medium 2 and their individual displacement was monitored as the recording medium 2 was moved by the driving roller 130, resulting in the marker displacement data set M. The data set M provides a measure for the relative displacement of different sections of the recording medium 2 in the scanning direction Y. Clearly, the recording medium 2 does not move homogeneously. For ease of analysis a marker displacement curve MF was fit to the corresponding data set M. By fitting a higher order polynomial to the marker displacement curve MF different components contributing to the individual marker displacement (and thus to the irregularities of the medium transport in the scanning direction Y) can be derived. The constant component DC describes the translation component whereby the recording medium 2 is moved. The component DC approximates the displacement distance or media step, the size of which is corrected in the prior art to correct for cyclic deviations. The inventors however found additional components which result in irregularities of the medium's positioning in the scanning direction. The first order curve RC indicates a rotational component, for example originated from a misalignment in the rotation axis 132. The second order curve PC illustrates a parabolic component, for due to the driving roller 130 sagging under the influence of gravity. Higher order components may be added to compensate for other surface irregularities. The curve MF shows that different positions in the scanning direction Y require different corrective values when adjusting the position of the sub-carriage 51 in the transport direction.

[0049] Fig. 9 schematically illustrates an embodiment of the method according to the present invention. A rotation sensor (not shown) is preferably provided to determine the angular orientation of the driving roller 130, though alternatively the angular orientation may be determined by tracking actuation commands input to the actuator which drives the driving roller 130. A rotation sensor may for example be a rotary encoder positioned in contact with the rotation axis 132.

[0050] After completion of a first swath 101, the driving roller 130 is actuated to move the recording medium 2 a predetermined distance in the transport direction X. The control unit 34 then determines the angular orientation or position of the driving roller 130, for example from a rotation sensor, from a recording medium displacement distance sensor, or based on the actuation command transmitted to the driving roll actuator. The displacement distance of the recording medium 2 is compared to the predetermined cyclic deviation data. The cyclic deviation data is preferably stored on the memory of the control

unit, for example in the form of a look-up table or other suitable forms for digitally storing a cyclic deviation map as shown in Fig. 7C. By comparing the displacement distance to the cyclic deviation data the control unit 34 finds or determines a width dependent radial deviation for multiple width positions in the scanning direction Y. The width dependent radial deviation describes the variation in radial distance of the outer surface of the driving roller 130 with respect to its rotation axis 132 over the axial width of the driving roller 130. In one example, the cyclic deviation data is table or vector comprising a first row or column defining the width positions along the scanning direction. A second row or column of equal length defines for each width position the width dependent radial deviation correction, for example as a ratio or percentage describing the relative displacement correction of the sub-carriage 51 between the different width positions. The width dependent radial deviation correction may then be compared to the displacement distance to obtain the required corrective displacement of the sub-carriage 51 in the transport direction X at each respective width position. In a basic example, the width dependent radial deviation may a normalized value, such that by multiplication with the displacement distance the required adjustment of the sub-carriage 51 in the transport direction X may be obtained. More complex algorithms may be applied to achieve more accurate width dependent radial deviation corrections.

[0051] The control unit 34 then controls the carriage 5 to translate along the guide beam 16 in the width direction Y. The control unit 34 selects or determines the width dependent radial deviation correction corresponding to each width positions. The control unit 34 adjusts the position of the sub-carriage 51 in the transport direction X to correct or compensate for the width dependent radial deviation at each width position by applying the corresponding width dependent radial deviation correction. The print heads 4a-d are mounted on the sub-carriage 51 such that the sub-carriage 51 determines the position of the print heads 4a-d in the transport direction X. As such the position of the swath 101 can be adjusted in the transport direction X while the swath 101 is being printed. In a basic example, the sub-carriage 51 follows the curve determined by the width dependent radial deviation corrections as determined by the cyclic deviation data for the driving roller 130, thereby taking into account the overall displacement distance by which the recording medium 3 has been moved. Preferably, the displacement of the sub-carriage 51 in the direction X is proportional to the respective width dependent radial deviation, for example linearly. More complex proportionalities may be applied by the control unit 34 to optimize the correction.

[0052] Additionally, the cyclic deviation data may in another embodiment be divided into predefined angular units, for example of 5° or another suitable angle. The sum of these predefined angular units equals a full rotation of 360°. For every predefined angular unit a width dependent radial deviation data set is stored as a curve,

vector, or table in the memory of the control unit. In a basic example, the width dependent radial deviation is a graph plotting the radial distance of the outer surface of the driving roller 130 against the width direction Y. The combined graphs then form a height map of the outer surface of the driving roller 130. The control unit 34 then further determines the angular position of the driving roller 130 and compares this to the cyclic deviation data. The control unit then applies an angle and width dependent radial deviation correction for each of the angular width surface portions of the driving roller 130.

[0053] 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, it is contemplated that structural elements may be generated by application of three-dimensional (3D) printing techniques. Therefore, any reference to a structural element is intended to encompass any computer executable instructions that instruct a computer to generate such a structural element by three-dimensional printing techniques or similar computer controlled manufacturing techniques. Furthermore, such a reference to a structural element encompasses a computer readable medium carrying such computer executable instructions.

[0054] 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 scanning inkjet printing assembly (100) comprising:

- a print surface (1; 101) for holding a recording medium (2);
- a driving roller (130) for transporting the recording medium (2) over the print surface (1; 101) by a displacement distance;
- a carriage (5) supporting at least one inkjet print head (4a-d), wherein the carriage (5) is moveable over the print surface (1; 101) in a scanning direction for applying droplets of a liquid to the recording medium (2) to form a swath of printed dots on the recording medium (2);
- a sub-carriage (51) supported by the carriage (5), the sub-carriage (51) being moveable relative to the carriage (5) in at least the transport direction (X);
- a control unit (34) operatively coupled to the carriage (5) and the sub-carriage (51) for controlling the movement of the carriage (5) and the sub-carriage (51),

wherein the control unit (34) is configured to:

- store on its memory predetermined cyclic deviation data relating to width dependent deviations in a circumference of the driving roller (130) with respect to its rotation axis (132);
 - compare the displacement distance to the cyclic deviation data to determine width dependent radial deviation corrections for different positions in the scanning direction (Y); and
 - for each of said positions in the scanning direction (Y) control the sub-carriage (51) to move relative to the carriage (5) in the transport direction (X) in accordance with the determined width dependent radial deviation corrections.
2. The scanning inkjet printing assembly (100) according to claim 1, wherein the cyclic deviation data defines a plurality of width positions spaced apart from one another in the scanning direction (Y) and comprises a width dependent radial deviation correction for each of the width positions which width dependent radial deviation correction determines a position of the sub-carriage (51) in the transport direction (X) at each respective width position.
 3. The scanning inkjet printing assembly (100) according to any of the previous claims, wherein the width dependent radial deviation corrections define a displacement curve describing the position of the sub-carriage (51) in the transport direction (X) against the width direction (Y).
 4. The scanning inkjet printing assembly (100) according to any of the previous claims, wherein the inkjet print heads (4a-d) are mounted on the sub-carriage (51).

5. The scanning inkjet printing assembly (100) according to any of the previous claims, wherein the control unit (34) is configured to store predetermined cyclic deviation data comprising angular direction deviation data and scanning direction deviation.

6. The scanning inkjet printing assembly (100) according to claim 5, wherein the cyclic deviation data comprises deviation map information defining radial deviation of a circumferential surface of the driving roller in both the angular direction and the scanning direction.

7. The scanning inkjet printing assembly according to any of the previous claims, wherein the control unit (34) is further configured to:

- determine an angular orientation of the driving roller (130);
- compare the determined angular orientation to the cyclic deviation data to determine width dependent radial deviation corrections;
- adjust the position of the sub-carriage (51) in accordance with the determined width dependent radial deviation correction as the carriage (5) moves in the width direction (Y) while the driving roller (130) is in the determined angular orientation.

8. The scanning inkjet printing assembly (100) according to any of the previous claims, wherein the sub-carriage (51) is further rotatable around an axis (Rz) perpendicular to the scanning direction (Y) and the transport direction (X) with respect to the carriage (5).

9. The scanning inkjet printing assembly (100) according to any of the previous claims, further comprising an input roll holder (R1) for holding an input roll (28) of wound up web medium.

10. Method for printing on a scanning inkjet printing assembly (100), the method comprising the steps of:

- rotating a driving roller (130) to transport a recording medium (2) a displacement distance over a support surface (1; 101) in a transport direction (X);
- for each width position of a carriage (5) holding print heads (4a-d) moving over the recording to print a swath (101) on the recording medium (2):
- compare the displacement distance of the recording medium (2) to cyclic deviation data stored on a memory of a control unit (34) to determine a width dependent radial deviation correction for said width position;
- at said width position adjust a position of

a sub-carriage (51) moveably supported on the carriage (5) in the transport direction (X) in accordance with the determined width dependent radial deviation correction as the carriage (5) moves in the width direction (Y). 5

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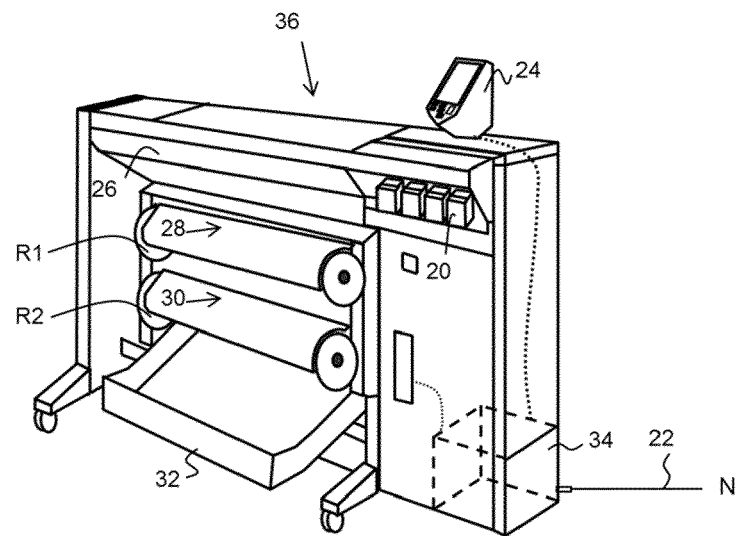


Fig. 1A

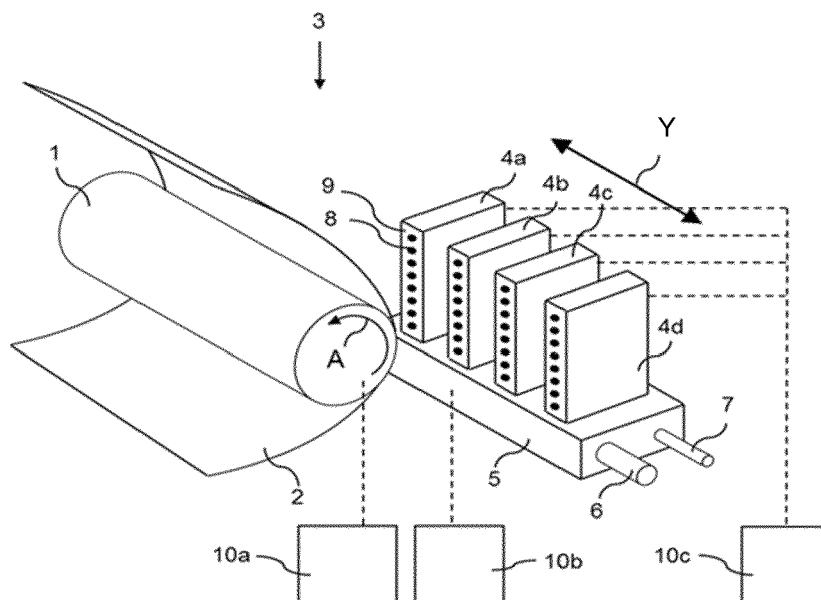


Fig. 1B

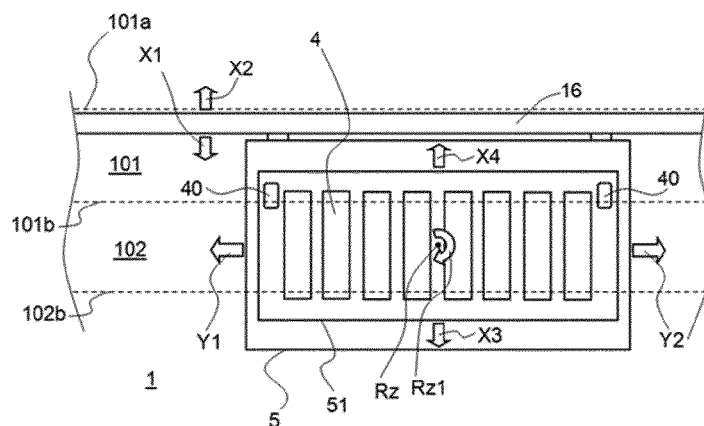


Fig. 2

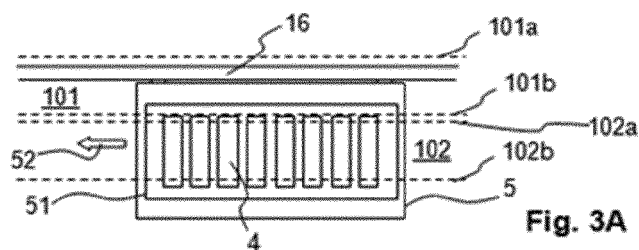


Fig. 3A

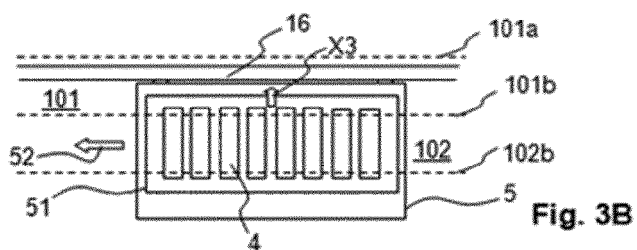


Fig. 3B

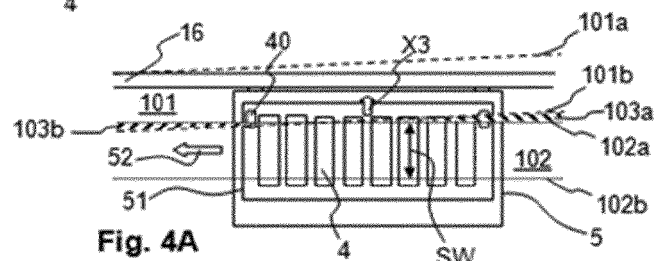


Fig. 4A

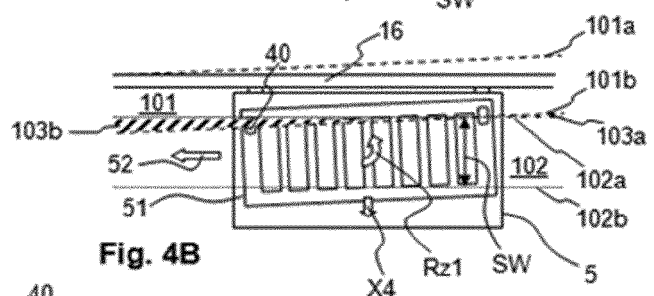


Fig. 4B

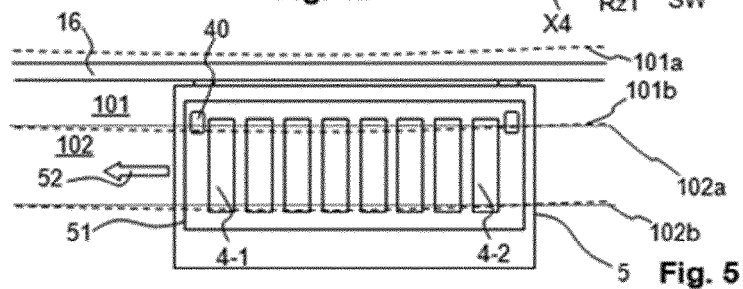


Fig. 5

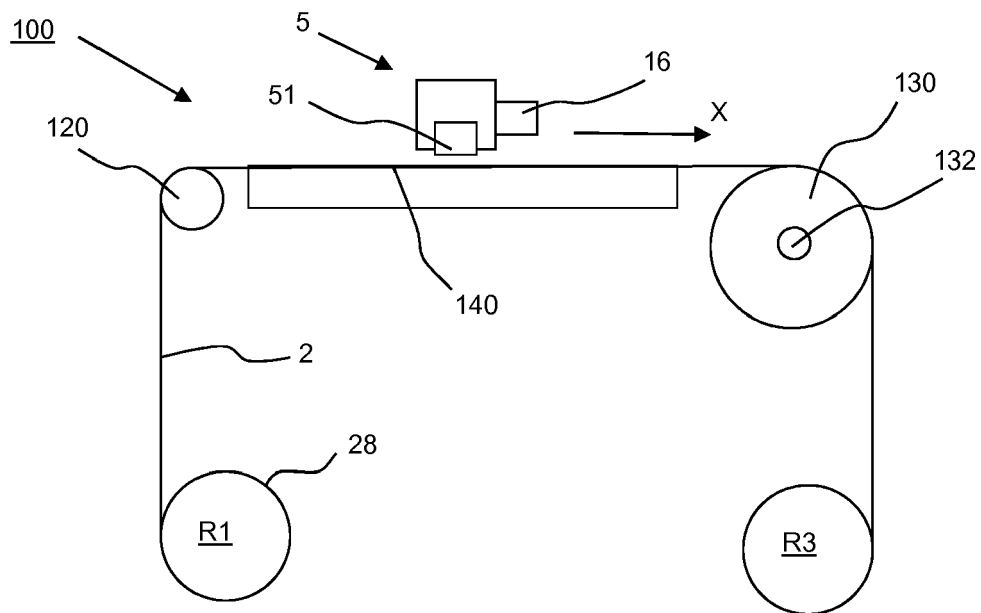


Fig. 6

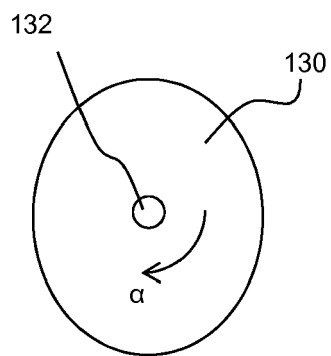


Fig. 7A

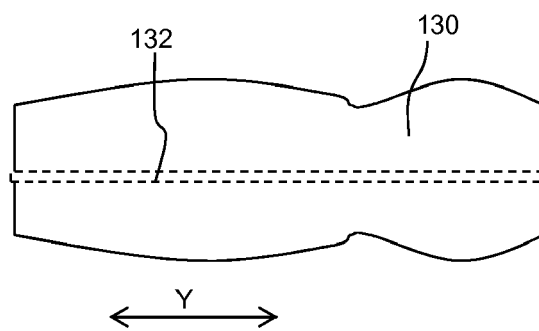


Fig. 7B

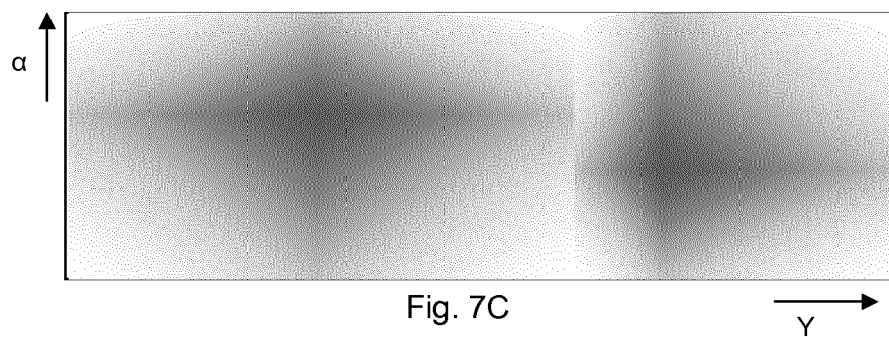


Fig. 7C

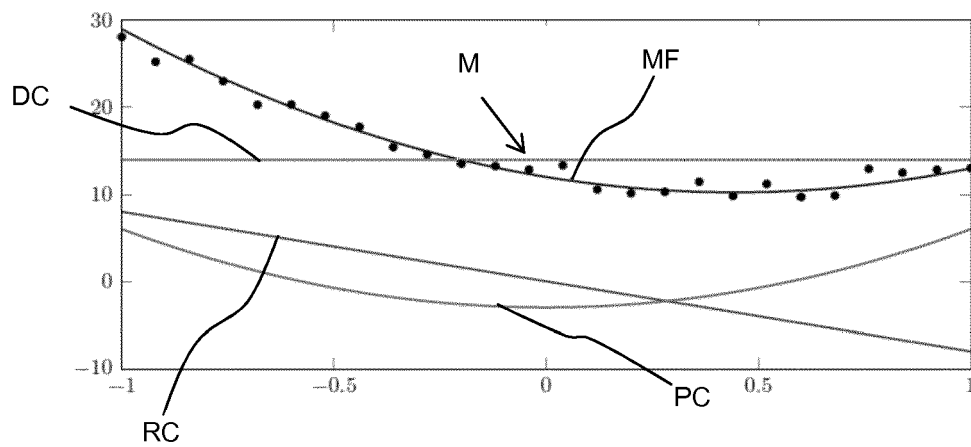


Fig. 8

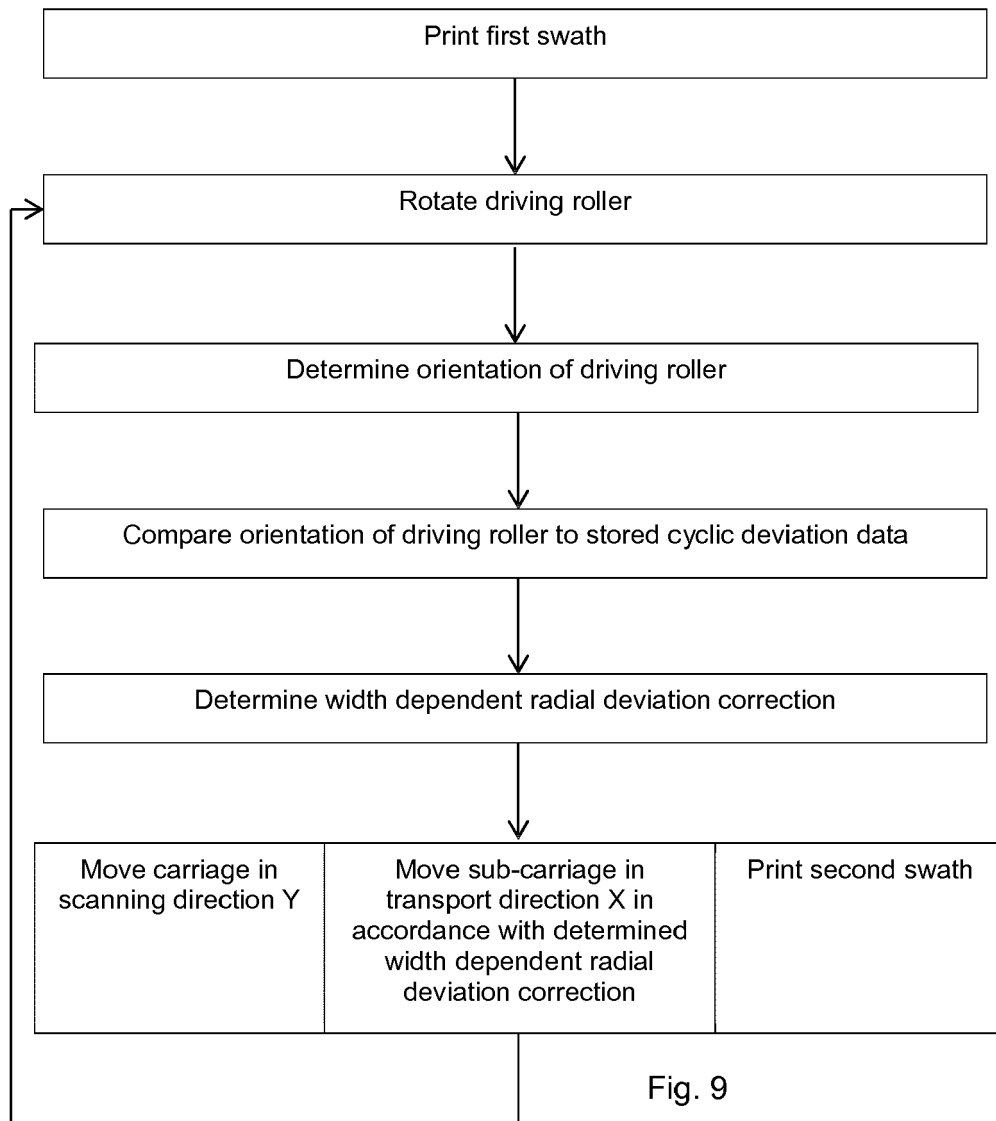


Fig. 9



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 Application Number
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 21 February 2019	Examiner João, César
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