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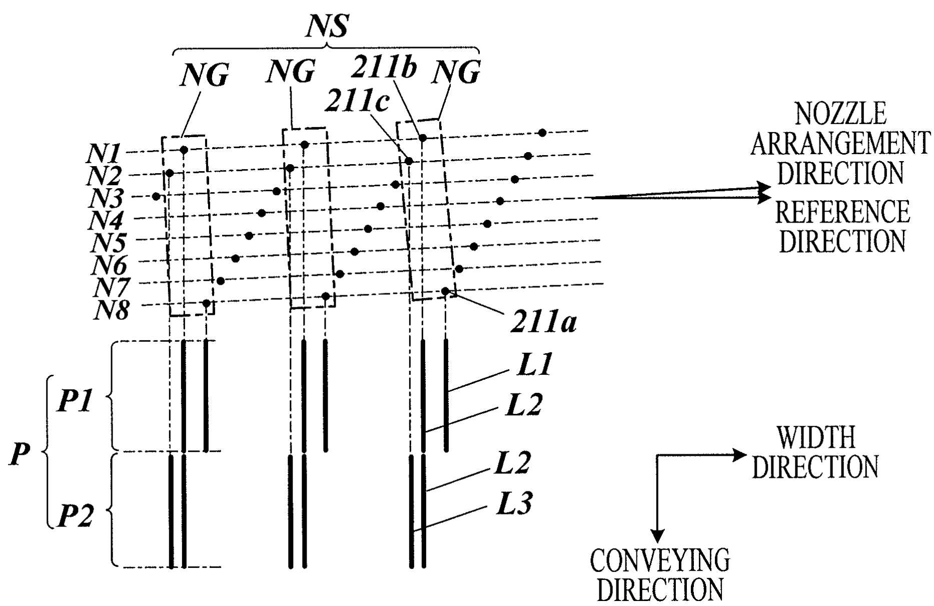
(54) INKJET RECORDING APPARATUS, DEVIATION DETECTION APPARATUS, AND DEVIATION DETECTION METHOD

(57) An inkjet recording apparatus (1) includes an ink ejector (21), an ejection control unit (50) and a detection unit (50). The ink ejector includes nozzle lines (N1, N2). In each nozzle line, nozzles (211) are arranged in a nozzle arrangement direction. The ejection control unit (50) causes a plurality of nozzle groups (NG) each including first, second and third nozzles (211a, 211b, 211c) having a predetermined positional relationship to form a detection pattern (P). The detection pattern has first and second density patterns (PI, P2). In the first density pattern, first unit patterns (U1) are arranged by being formed by the first and second nozzles of the respective nozzle groups. In the second density pattern, second unit patterns (U2) are arranged by being formed by the second and third nozzles of the respective nozzle groups. The detection unit detects deviation of the nozzle arrangement direction from a reference direction based on representative values of densities in density distributions of the first and second density patterns.

FIG.11A



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Description

[Technological field]

[0001] The present invention relates to an inkjet recording apparatus, a deviation detection apparatus, and a deviation detection method.

[Background]

[0002] There is an inkjet recording apparatus which ejects ink from nozzles provided in an ink ejector(s) to a recording medium that is moved in a predetermined moving direction relatively with the ink ejector, thereby forming an image(s) or the like on the recording medium. In the ink ejector of the inkjet recording apparatus, the nozzles are arranged so as to form one or more nozzle lines. By arranging the ink ejector such that a direction of the nozzle line(s) (i.e., direction in which the nozzle line(s) extends, hereinafter "nozzle arrangement direction") coincides with a predetermined reference direction which intersects the moving direction (typically a width/side-to-side direction orthogonal to the moving direction), an image(s) can be recorded in a predetermined recording width in the width direction with predetermined resolution.

[0003] As a method for positioning the ink ejector, there is known a method of: causing the nozzles of the ink ejector to eject ink, thereby forming a predetermined detection pattern; obtaining information on positions of the nozzles from read data of the detection pattern generated by a reader, such as a line sensor; and detecting, on the basis of the obtained information, deviation of the nozzle arrangement direction from the reference direction. (Refer to, for example, Patent Literature 1.)

[Citation List]

[Patent Literature]

[0004] [PTL 1] JP 2009-137015 A

[Summary]

[Technical Problem]

[0005] However, in order to accurately detect the deviation of the nozzle arrangement direction with the conventional method described above, the read data need to accurately reflect points on the detection pattern on the recording medium, the points corresponding to the positions of the nozzles. This requires accurate prior positioning of the reader or the recording medium so as to make the reader and the recording medium have a predetermined positional relationship, which takes much time and effort.

[0006] Objects of the present invention include providing an inkjet recording apparatus, a deviation detection apparatus and a deviation detection method which can accurately detect deviation of the nozzle arrangement direction of an ink ejector(s) in a simpler manner.

[Solution to Problem]

[0007] To achieve at least one of the abovementioned objects, according to a first aspect of the present invention, there is provided an inkjet recording apparatus including:

an ink ejector which (i) includes a plurality of nozzle lines in each of which two or more nozzles that eject ink droplets of ink are one-dimensionally arranged in a predetermined nozzle arrangement direction, and (ii) ejects the ink from the nozzles, which each of the nozzle lines has, to a recording medium that is placed on a placement surface and moved in a predetermined moving direction relatively with the ink ejector;

an ejection control unit which causes a plurality of nozzle groups each including, among the nozzles, a first nozzle, a second nozzle and a third nozzle having a predetermined positional relationship to eject the ink, thereby forming, in a plane parallel to the placement surface, a predetermined detection pattern for detecting deviation of the nozzle arrangement direction from a predetermined reference direction intersecting the moving direction; and

a detection unit which detects the deviation based on read data of the detection pattern, wherein

in a proper arrangement state in which the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged such that (i) arrangement areas of the nozzles of the respective nozzle lines coincide in a width direction orthogonal to the moving direction, (ii) positions of the nozzles are different from one another in the width direction, and (iii) the nozzles are arranged at equal intervals in the width direction,

the ejection control unit causes the nozzle groups to form the detection pattern including:

a first density pattern in which a first unit pattern is repeatedly arranged in the width direction so that first unit patterns are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the first unit patterns; and

a second density pattern in which a second unit pattern is repeatedly arranged in the width direction so that second unit patterns are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the second unit patterns,

the ejection control unit causes each of the nozzle groups to form at least one of the first unit pattern and the second unit pattern,

(i) arrangement intervals of the first nozzle, the second nozzle and the third nozzle in the width direction in the proper arrangement state are equal intervals which make the ink droplets ejected from the first nozzle, the second nozzle and the third nozzle overlap on the recording medium, (ii) the second nozzle is between the first nozzle and the third nozzle in the width direction, and (iii) the first nozzle and the third nozzle are on one side in the moving direction with respect to the second nozzle,
the nozzle groups have a same positional relationship about the nozzle lines to which the first nozzle, the second nozzle and the third nozzle belong,
the ejection control unit causes the first nozzle and the second nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the first unit pattern, and causes the second nozzle and the third nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the second unit pattern, and
the detection unit detects direction and magnitude of the deviation based on a representative value of densities in the density distribution of the first density pattern and a representative value of densities in the density distribution of the second density pattern read from the read data.

[0008] Preferably, in the inkjet recording apparatus, the nozzle groups are arranged at equal intervals in the width direction.

[0009] Preferably, in the inkjet recording apparatus, the ejection control unit causes the nozzle groups to form the detection pattern in which forming areas of the first density pattern and the second density pattern do not overlap in the moving direction, but coincide in the width direction.

[0010] Preferably, in the inkjet recording apparatus, the detection unit detects the direction and the magnitude of the deviation based on a difference between the representative value of the densities of the first density pattern and the representative value of the densities of the second density pattern in the read data.

[0011] Preferably, in the inkjet recording apparatus, each of the first unit pattern and the second unit pattern is a line pattern extending in the moving direction.

[0012] Preferably, in the inkjet recording apparatus, in each of the nozzle groups, the first nozzle and the second nozzle are adjacent to one another in the width direction, and the second nozzle and the third nozzle are adjacent to one another in the width direction.

[0013] Preferably, in the inkjet recording apparatus,
the ink ejector includes a plurality of ink ejectors each having a nozzle arrangement region where the nozzles are arranged,
the ink ejectors are arranged such that the nozzle arrangement region of each one of the ink ejectors overlaps, in a nearby area of an edge of the nozzle arrangement region in the width direction, with the nozzle arrangement region of another one of the ink ejectors in the width direction, and
the nozzle groups are constituted of the nozzles arranged outside an area in which the nozzle arrangement regions overlap in the width direction.

[0014] Preferably, the inkjet recording apparatus further includes a reader which reads the detection pattern, thereby generating the read data.

[0015] Preferably, the inkjet recording apparatus further includes a nozzle arrangement direction changing unit for adjusting a relationship between the nozzle arrangement direction and the reference direction.

[0016] Preferably, the inkjet recording apparatus further include:

a display; and
a display control unit which causes the display to display the direction and the magnitude of the deviation detected by the detection unit.

[0017] According to a second aspect of the present invention, there is provided a deviation detection apparatus for an inkjet recording apparatus including: an ink ejector which (i) includes a plurality of nozzle lines in each of which two or more nozzles that eject ink droplets of ink are one-dimensionally arranged in a predetermined nozzle arrangement direction, and (ii) ejects the ink from the nozzles, which each of the nozzle lines has, to a recording medium that is placed on a placement surface and moved in a predetermined moving direction relatively with the ink ejector; and an ejection control unit which causes a plurality of nozzle groups each including, among the nozzles, a first nozzle, a second nozzle and a third nozzle having a predetermined positional relationship to eject the ink, thereby forming, in a plane parallel to the placement surface, a predetermined detection pattern for detecting deviation of the nozzle arrangement direction from a predetermined reference direction intersecting the moving direction, the deviation detection apparatus detecting the deviation in the inkjet recording apparatus, including a detection unit, wherein
in a proper arrangement state in which the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged such that (i) arrangement areas of the nozzles of the respective nozzle lines coincide in a width direction orthogonal to the moving direction, (ii) positions of the nozzles are different from one another in the width direction, and (iii) the nozzles are arranged at equal intervals in the width direction,
the ejection control unit causes the nozzle groups to form the detection pattern including:

a first density pattern in which a first unit pattern is repeatedly arranged in the width direction so that first unit patterns are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the first unit patterns;

and

a second density pattern in which a second unit pattern is repeatedly arranged in the width direction so that second unit patterns are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the second unit patterns,

the ejection control unit causes each of the nozzle groups to form at least one of the first unit pattern and the second unit pattern,
(i) arrangement intervals of the first nozzle, the second nozzle and the third nozzle in the width direction in the proper arrangement state are equal intervals which make the ink droplets ejected from the first nozzle, the second nozzle and the third nozzle overlap on the recording medium, (ii) the second nozzle is between the first nozzle and the third nozzle in the width direction, and (iii) the first nozzle and the third nozzle are on one side in the moving direction with respect to the second nozzle,
the nozzle groups have a same positional relationship about the nozzle lines to which the first nozzle, the second nozzle and the third nozzle belong,
the ejection control unit causes the first nozzle and the second nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the first unit pattern, and causes the second nozzle and the third nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the second unit pattern, and
the deviation detection apparatus includes the detection unit which detects direction and magnitude of the deviation based on a representative value of densities in the density distribution of the first density pattern and a representative value of densities in the density distribution of the second density pattern read from read data of the detection pattern.

[0018] According to a third aspect of the present invention, there is provided a deviation detection method for an inkjet recording apparatus including an ink ejector which (i) includes a plurality of nozzle lines in each of which two or more nozzles that eject ink droplets of ink are one-dimensionally arranged in a predetermined nozzle arrangement direction, and (ii) ejects the ink from the nozzles, which each of the nozzle lines has, to a recording medium that is placed on a placement surface and moved in a predetermined moving direction relatively with the ink ejector, the deviation detection method for detecting, in a plane parallel to the placement surface, deviation of the nozzle arrangement direction from a predetermined reference direction intersecting the moving direction, including an ejection step and a detection step, wherein
in a proper arrangement state in which the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged such that (i) arrangement areas of the nozzles of the respective nozzle lines coincide in a width direction orthogonal to the moving direction, (ii) positions of the nozzles are different from one another in the width direction, and (iii) the nozzles are arranged at equal intervals in the width direction,
the deviation detection method includes:

the ejection step of causing a plurality of nozzle groups each including, among the nozzles, a first nozzle, a second nozzle and a third nozzle having a predetermined positional relationship to eject the ink, thereby forming a predetermined detection pattern for detecting the deviation; and
the detection step of detecting the deviation based on read data of the detection pattern,
the ejection step includes causing the nozzle groups to form the detection pattern including:

a first density pattern in which a first unit pattern is repeatedly arranged in the width direction so that first unit patterns are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the first unit patterns; and
a second density pattern in which a second unit pattern is repeatedly arranged in the width direction so that second unit patterns are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the second unit patterns,

the ejection step includes causing each of the nozzle groups to form at least one of the first unit pattern and the second unit pattern,
(i) arrangement intervals of the first nozzle, the second nozzle and the third nozzle in the width direction in the proper arrangement state are equal intervals which make the ink droplets ejected from the first nozzle, the second nozzle and the third nozzle overlap on the recording medium, (ii) the second nozzle is between the first nozzle and the third nozzle in the width direction, and (iii) the first nozzle and the third nozzle are on one side in the moving direction with respect to the second nozzle,
the nozzle groups have a same positional relationship about the nozzle lines to which the first nozzle, the second nozzle and the third nozzle belong,
the ejection step includes causing the first nozzle and the second nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the first unit pattern, and causing the second nozzle and the third nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the second unit pattern, and
the detection step includes detecting direction and magnitude of the deviation based on a representative value of densities in the density distribution of the first density pattern and a representative value of densities in the density distribution of the second

density pattern read from the read data.

[Advantageous Effects of Invention]

[0019] The present invention can accurately detect deviation of the nozzle arrangement direction of an ink ejector(s) in a simpler manner.

[Brief Description of Drawings]

[0020] The advantages and features provided by one or more embodiments of the present invention will become more fully understood from the detailed description given hereinbelow and the appended drawings which are given by way of illustration only, and thus are not intended as a definition of the limits of the present invention, wherein:

FIG. 1 schematically shows configuration of an inkjet recording apparatus;
FIG. 2 shows internal configuration of a head unit;
FIG. 3 is a block diagram showing main functional components of the inkjet recording apparatus;
FIG. 4A and FIG. 4B show a detection pattern in a case where the nozzle arrangement direction of a recording head(s) coincides with a reference direction;
FIG. 5A and FIG. 5B show the detection pattern in a case where the nozzle arrangement direction of the recording head deviates from the reference direction in a positive direction;
FIG. 6A and FIG. 6B show the detection pattern in a case where the nozzle arrangement direction of the recording head deviates from the reference direction in a negative direction;
FIG. 7A to FIG. 7C show examples of density distribution in the detection pattern;
FIG. 8A to FIG. 8C are diagrams to explain an example of a method for adjusting the nozzle arrangement direction of the recording head;
FIG. 9 is a flowchart showing a control procedure for a head position adjustment process;
FIG. 10A and FIG. 10B each show an example of a nozzle set and the detection pattern formed by the nozzle set in a case where three nozzle lines are provided in the recording head;
FIG. 11A and FIG. 11B each show an example of the nozzle set and the detection pattern formed by the nozzle set in a case where eight nozzle lines are provided in the recording head; and
FIG. 12A and FIG. 12B each show another example of the nozzle set and the detection pattern formed by the nozzle set in the case where eight nozzle lines are provided in the recording head.

[Description of Embodiments]

[0021] Hereinafter, one or more embodiments of an inkjet recording apparatus, a deviation detection apparatus and a deviation detection method of the present invention will be described with reference to the drawings.

[0022] FIG. 1 schematically shows configuration of an inkjet recording apparatus 1 according to an embodiment(s) of the present invention.

[0023] The inkjet recording apparatus 1 includes a conveyor 10, head units 20 and a reader 30 (reader).

[0024] The conveyor 10 includes a conveyor belt 11, a drive roller 12 and a driven roller 13. The drive roller 12 rotates on its rotation axis by drive of a conveyor motor 14 (FIG. 3). The conveyor belt 11 is a ring-shaped belt the inner side of which is supported by the drive roller 12 and the driven roller 13 (which hereinafter may be referred to "conveyor rollers" collectively), and circles around the conveyor rollers as the drive roller 12 rotates. The driven roller 13 rotates on its rotation axis as the conveyor belt 11 circles around the conveyor rollers. The inkjet recording apparatus 1 conveys a recording medium M in a circling direction of the conveyor belt 11 (a moving direction in which the recording medium M moves relatively with the head units 20; hereinafter "conveying direction") by the conveyor belt 11 circling around the conveyor rollers in a state in which the recording medium M is placed on a placement surface 11 a of the conveyor belt 11, at a speed corresponding to a rotation speed of the drive roller 12.

[0025] The recording medium M is, for example, rolled paper which is unwounded (drawn) from a roller (recording medium unwinding unit) around which the recording medium M is wound, and is supplied onto the conveyor belt 11. The recording medium M may be flat paper which is cut into sheets of a certain size. The recording medium M is supplied onto the conveyor belt 11 by a not-shown sheet feeder, and ejected from the conveyor belt 11 to a not-shown sheet receiver after images are recorded on the recording medium M with ink ejected from the head units 20. As the recording medium M, a variety of media can be used as far as ink landed on the surfaces thereof can be fixed. Examples thereof include paper exemplified by plain paper and coated paper, fabrics, and sheet-shaped resins.

[0026] The head units 20 eject, on the basis of image data, ink to the recording medium M at proper timings, the recording medium M being conveyed by the conveyor 10, thereby recording images on the recording medium M. In the inkjet recording apparatus 1 of this embodiment, four head units 20 for inks of four colors, yellow (Y), magenta (M), cyan (C) and black (K), are arranged at predetermined intervals so as to form a line in order of Y, M, C and K from the upstream side in the conveying direction of the recording medium M. The number of the head units 20 may be three or less, or five or more.

[0027] FIG. 2 is a schematic view of one of the head units 20 viewed from the conveyor belt 11 side, showing internal configuration of the head unit 20.

[0028] The head unit 20 includes a plurality of recording heads 21 (ink ejectors) in each of which a plurality of recording elements that eject ink is provided. Each recording element includes: a pressure chamber (channel) where ink is stored; a piezoelectric element provided on the wall surface of the pressure chamber; an electrode which applies voltage to the piezoelectric element to generate an electric field; and a nozzle 211 which communicates with the pressure chamber and ejects the ink in the pressure chamber. When a drive-waveform voltage signal for deforming the piezoelectric element is applied to the electrode of the recording element, in response to this voltage signal, the pressure chamber deforms and the pressure in the pressure chamber changes, and in response to the pressure change, the ink in the pressure chamber is ejected from the nozzle 211 which communicates with the pressure chamber.

[0029] The nozzles 211 provided in each recording head 21 are arranged so as to form two lines along a predetermined nozzle arrangement direction, thereby constituting two nozzle lines. Each nozzle line is constituted of two or more nozzles 211 which are one-dimensionally arranged at equal intervals in the nozzle arrangement direction. Each recording head 21 is attached to a base 20a of the head unit 20 in a state in which its position is adjusted such that the nozzle arrangement direction of the recording head 21 is parallel to a predetermined reference direction intersecting the conveying direction (the width direction orthogonal to the conveying direction, in this embodiment). If the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged with a positional relationship in which (i) arrangement areas of the nozzles 211 of the respective nozzle lines coincide in the width direction in a predetermined area, (ii) positions of the nozzles 211 in the predetermined area are different from one another in the width direction, and (iii) the nozzles 211 therein are arranged at equal intervals in the width direction. That is, the nozzle lines are arranged with a positional relationship in which arrangement density of the nozzles 211 in the width direction increases. More specifically, the two nozzle lines are arranged so as to be shifted (different) from one another by 1/2 of an arrangement interval of the nozzles 211 in each nozzle line in the width direction.

[0030] In the head unit 20, six recording heads 21 are arranged in a houndstooth check. The six recording heads 21 each have a nozzle arrangement region NR where the nozzles 211 are provided, and are arranged with a positional relationship in which the nozzle arrangement region NR of each one of the recording heads 21 overlaps, in a nearby area of an edge of the nozzle arrangement region NR in the width direction, with the nozzle arrangement region NR of another one of the recording heads 21 in the width direction. In an overlapping area R in which the nozzle arrangement regions NR of the recording heads 21 adjacent to one another overlap, at each of the positions of the nozzles 211 in the width direction, the nozzle 211 which belongs to one of the recording heads 21, which constitute a pair ejects ink.

[0031] This arrangement of the recording heads 21 makes an arrangement area of the nozzles 211 included in the head unit 20 in the width direction cover the width of an image formable region (recordable width) in the width direction on the recording medium M, which is conveyed by the conveyor belt 11. At the time of recording images, the head unit 20 is used with its position fixed, and consecutively ejects ink droplets of the ink to different points in the conveying direction at predetermined intervals (conveying-direction intervals) according to the conveyance of the recording medium M, thereby recording images with a single-pass system.

[0032] The head unit 20 is provided to be rotatable in an in-plane direction parallel to the placement surface 11a of the conveyor belt 11 within a predetermined angle range, so that an angle formed by the longer direction of the head unit 20 and the width direction can be finely adjusted. Hence, the nozzle arrangement direction of the recording head(s) 21, which the head unit 20 has, can be made to coincide with (adjusted to) the reference direction.

[0033] Adjustment of the position of the head unit 20 (i.e., adjustment of the nozzle arrangement direction) is performed by a head position adjuster 40 (nozzle arrangement direction changing unit) (FIG. 3). The head position adjuster 40 includes: not-shown adjuster screws to shift positions of the head units 20 with respect to not-shown supporting frames to which the head units 20 are fixed, a position adjustment drive unit(s) 41, and a position adjustment controller(s) 42 which controls operation of the position adjustment drive unit 41.

[0034] The reader 30 shown in FIG. 1 is provided on the downstream side of the head units 20 in the conveying direction so as to read the surface of the recording medium M on the placement surface 11 a of the conveyor belt 11. The reader 30 includes a line sensor 31 (FIG. 3) having imaging elements arranged in the width direction, and using the line sensor 31, obtains one-dimensional imaged data constituted of pixel data of imaging pixels one-dimensionally arranged in an imaging area which covers the recordable width in the width direction, and outputs the one-dimensional imaged data to a controller 50 (FIG. 3). The detected values in the pixel data of the imaging pixels represent intensity of incident light reflected by the surface of the recording medium M. Hence, from the imaged data (read data) generated by the reader 30, density of an image(s) on the surface of the recording medium M can be obtained.

[0035] The line sensor 31 of the reader 30 outputs a one-dimensional image(s), using the imaging elements which are arranged in the width direction and output signals corresponding to intensities of the incident light. Each imaging element has three sub-imaging elements which detect spectrum intensities of the incident light with their respective spectral sensitivity characteristics corresponding to R (red), G (green) and B (blue). This allows the reader 30 to perform imaging about three color components of R, G and B (imaging in multiple colors). As each sub-imaging element, for example, a CCD (Charge Coupled Device) sensor or CMOS (Complementary Metal Oxide Semiconductor) sensor having a photodiode as a photoelectric conversion element with a color filter which is arranged on a light receiving part and transmits light of a wavelength component of R, G or B can be used. Alternatively, each sub-imaging element may be configured, using a sensor having a spectral sensitivity characteristic corresponding to R, G or B, to detect a spectrum intensity of the incident light with the spectral sensitivity characteristic corresponding to R, G or B, without a color filter. The signals output from the line sensor 31 are subjected to current-voltage conversion, amplification, noise reduction, analog-digital conversion and so forth in a not-shown analog front-end, and output to the controller 50 as the read data indicating brightness values of a read image.

[0036] FIG. 3 is a block diagram showing main functional components of the inkjet recording apparatus 1.

[0037] The inkjet recording apparatus 1 includes: the conveyor 10 including the conveyor motor 14 and a conveyance controller 15; the head units 20 including the recording heads 21 and a head controller 22; the reader 30 including the line sensor 31 and a reading controller 32; the head position adjuster 40 including the position adjustment drive unit 41 and the position adjustment controller 42; the controller 50 (ejection control unit, detection unit, display control unit); an operation display unit 61 (display); an input output interface 62; and a bus 63. Among these, as the conveyance controller 15, the head controller 22, the reading controller 32 and the position adjustment controller 42, hardware components of the controller 50 may double, or exclusive-use CPUs, memories, logic circuits and so forth may be prepared.

[0038] The controller 50 has a CPU 51 (Central Processing Unit), a RAM 52 (Random Access Memory), a ROM 53 (Read Only Memory), and a storage 54.

[0039] The CPU 51 reads programs for various types of control and setting data stored in the ROM 53, stores the read ones in the RAM 52, and executes the programs and thereby performs various types of arithmetic processing. The CPU 51 controls the overall operation of the inkjet recording device 1.

[0040] The RAM 52 provides the CPU 51 with a memory space for work, and stores temporary data. The RAM 52 may include a nonvolatile memory.

[0041] The ROM 53 stores the programs for various types of control which are executed by the CPU 51, the setting data and so forth. Instead of the ROM 53, a rewritable nonvolatile memory, such as an EEPROM (Electrically Erasable Programmable Read Only Memory) or a flash memory, may be used.

[0042] The storage 54 stores print jobs (image recording commands) and image data of images to be recorded relevant to the print jobs input from an external information processing apparatus 2 via the input output interface 62, image data used for forming a detection pattern described below, read data generated by the reader 30, and so forth. As the storage 54, for example, an HDD (Hard Disk Drive) is used, or a DRAM (Dynamic Random Access Memory) or the like may also be used.

[0043] The conveyance controller 15 controls, on the basis of a control signal(s) supplied from the controller 50, operation of the conveyor motor 14 attached to the drive roller 12 so as to rotate the drive roller 12, thereby conveying the recording medium M at a predetermined speed.

[0044] The head controller 22 outputs various control signals and image data to not-shown head drive units provided in the recording heads 21 at proper timings in response to control signals from the controller 50 so as to cause the nozzles 211 of the recording heads 21 to eject the ink(s).

[0045] The reading controller 32 controls operation of the reader 30 so as to read (image) proper points on the recording medium M according to conveyance timing and speed of the recording medium M.

[0046] The position adjustment controller 42 controls motor drive operation of the position adjustment drive unit 41 so as to rotate the adjuster screw(s) by an adjustment amount calculated in a head position adjustment process described below, thereby adjusting an arrangement direction of the head unit 20 (i.e., the nozzle arrangement direction of the recording head(s) 21).

[0047] The input output interface 62 mediates data exchange between the information processing apparatus 2 and the controller 50. The input output interface 62 is constituted of, for example, one of or a combination of any of a variety of serial interfaces and any of a variety of parallel interfaces.

[0048] The bus 63 is a path for the controller 50 and the other components to exchange signals.

[0049] The information processing apparatus 2 is a personal computer or the like provided outside the inkjet recording apparatus 1, and supplies the print jobs, the image data and so forth to the controller 50 via the input output interface 62.

[0050] Next, various types of operation for adjusting the arrangement direction of each head unit 20 (adjusting the nozzle arrangement direction of the recording head(s) 21) in the inkjet recording apparatus 1 of this embodiment will be described.

[0051] In the inkjet recording apparatus 1, if the nozzle arrangement direction of the recording head(s) 21 deviates from the reference direction in a plane parallel to the placement surface 11a of the conveyor belt 11, an image-recording width by the recording head(s) 21 in the width direction could change, or recording resolution in the width direction could be different from a desired value. If the image-recording width by each recording head 21 changes, images are recorded by being reduced or enlarged in the width direction, and also the dimension of the overlapping area R of each adjacent recording heads 21 in the width direction changes, so that density unevenness occurs at joints of the recording heads 21.

[0052] Hence, the inkjet recording apparatus 1 of this embodiment performs head position adjustment operation which positions the recording head(s) 21 such that the nozzle arrangement direction coincides with the reference direction (e.g., rotates the recording head(s) 21 (head unit 20) on a rotation axis perpendicular to the placement surface 11a), before starting image recording operation. The head position adjustment operation is performed, in addition to when the inkjet recording apparatus 1 is manufactured, when the head unit(s) 20 or the recording head(s) 21 is replaced with another (others), for example.

[0053] In the head position adjustment operation, first, predetermined nozzles 211 of the recording head(s) 21 eject ink, thereby forming a predetermined detection pattern for detecting deviation of the nozzle arrangement direction from the reference direction. Next, the reader 30 reads the detection pattern. Direction and magnitude of the deviation are detected on the basis of the obtained read data. Further, deviation information indicating the adjustment amount (a rotation direction and the number of rotations) of the adjuster screw for cancelling the deviation of the nozzle arrangement direction from the reference direction is generated.

[0054] FIG. 4A and FIG. 4B show a detection pattern P in a case where the nozzle arrangement direction of the recording head(s) 21 coincides with the reference direction.

[0055] FIG. 4A shows a positional relationship between two nozzle lines which the recording head 21 has and points (corresponding to the positions of the nozzles 211) on the detection pattern P. Hereinafter, of the two nozzle lines, the nozzle line on the upstream side in the conveying direction and the nozzle line on the downstream side in the conveying direction are referred to as a nozzle line N1 and a nozzle line N2, respectively.

[0056] In FIG. 4A, the nozzle arrangement direction of the recording head 21 coincides with the reference direction (width direction), so that the recording head 21 is arranged in a proper arrangement direction. Hereinafter, a state in which the recording head 21 and the nozzles 211 are thus arranged is referred to as a proper arrangement state.

[0057] The detection pattern P is formed with ink ejected from a nozzle set NS constituted of predetermined nozzles 211 among the nozzles 211 provided in the recording head 21. The nozzle set NS is determined/set (i.e., the nozzles 211 constituting the nozzle set NS are selected) so as to satisfy the following conditions (1) to (5).

[0058] The condition (1) is that the nozzle set NS is constituted of a plurality of nozzle groups NG each of which is constituted of a first nozzle 211a, a second nozzle 211b and a third nozzle 211c. The condition (2) is that the nozzle set NS is constituted of the plurality of nozzle groups NG arranged in an area in which the nozzle arrangement region NR of the recording head 21 does not overlap with that of another recording head 21 (i.e., arranged outside the overlapping area(s) R). Hence, the detection pattern P is formed over an area which corresponds to the nozzle arrangement region NR except the overlapping area(s) R of one recording head 21 in the width direction.

[0059] The condition (3) is that the first nozzle 211a, the second nozzle 211b and the third nozzle 211c have a positional relationship in which (i) their arrangement intervals in the width direction in the proper arrangement state are equal intervals which make ink droplets ejected from the first nozzle 211a, the second nozzle 211b and the third nozzle 211c overlap (partly coincide) on the recording medium M, (ii) the second nozzle 211b is between the first nozzle 211a and the third nozzle 211c in the width direction, and (iii) the first nozzle 211a and the third nozzle 211c are on one side in the conveying direction with respect to the second nozzle 211b. In this embodiment, the first nozzle 211a, the second nozzle 211b and the third nozzle 211c are adjacent nozzles 211 in the width direction, namely, nozzles having consecutive arrangement numbers. The arrangement numbers are ordinals indicating the arrangement order of the nozzles 211, which the recording head 21 has, in the width direction.

[0060] The condition (4) is that the nozzle groups NG have the same positional relationship about the nozzle lines to which the first nozzle 211a, the second nozzle 211b and the third nozzle 211c belong. In this embodiment, in any of the nozzle groups NG, the first nozzle 211a and the third nozzle 211c belong to the nozzle line N2, and the second nozzle 211b belongs to the nozzle line N1.

[0061] The condition (5) is that the nozzle groups NG are selected such that their arrangement intervals in the width direction are equal intervals. In this embodiment, the nozzle groups NG are selected such that between the nozzle groups NG adjacent to one another, one nozzle 211 which does not belong to either of the nozzle groups NG is present.

[0062] As shown in FIG. 4A, the detection pattern P is constituted of a first density pattern P1 and a second density pattern P2 formed such that their forming areas do not overlap in the conveying direction, but coincide in the width direction. The first density pattern P1 is formed of a plurality of first unit patterns U1 in the width direction. Each first unit pattern U1 is formed with ink droplets landed on the position of a line L1 from the first nozzle 211a and ink droplets landed on the position of a line L2 from the second nozzle 211b. The second density pattern P2 is formed of a plurality of second unit patterns U2 in the width direction. Each second unit pattern U2 is formed with ink droplets landed on the position of the line L2 from the second nozzle 211b and ink droplets landed on the position of a line L3 from the third nozzle 211c.

[0063] FIG. 4B is an enlarged view of a part of FIG. 4A, showing landing areas of the ink droplets with which the first density pattern P1 and the second density pattern P2 are formed.

[0064] As shown in FIG. 4B, the first density pattern

P1 is made of ink droplets IA ejected from the first nozzle 211a and landed, and ink droplets IB ejected from the second nozzle 211b and landed so as to overlap (at least partly coincide) with the ink droplets IA. That is, in forming the first density pattern P1, the first nozzle 211a and the second nozzle 211b eject the ink droplets at timings which make the ink droplets overlap (partly coincide) on the recording medium M. Also, as shown in FIG. 4B, the second density pattern P2 is made of ink droplets IB ejected from the second nozzle 211b and landed, and ink droplets IC ejected from the third nozzle 211c and landed so as to overlap (at least partly coincide) with the ink droplets IB. That is, in forming the second density pattern P2, the second nozzle 211b and the third nozzle 211c eject the ink droplets at timings which make the ink droplets overlap (partly coincide) on the recording medium M. Thus, the ink droplets landed on the positions of the lines L1 and L2 in the first density pattern P1 overlap (partly coincide), thereby forming the first unit pattern U1 which is one line pattern, and the ink droplets landed on the positions of the lines L2 and L3 in the second density pattern P2 overlap (partly coincide), thereby forming the second unit pattern U2 which is one line pattern.

[0065] The first density pattern P1 and the second density pattern P2 are made of a large number (the number of the nozzle groups NG) of the first unit patterns U1 and a large number (the number of the nozzle groups NG) of the second unit patterns U2, respectively. The first unit patterns U1 and the second unit patterns U2 extend in the conveying direction, and the first density pattern P1 and the second density pattern P2 are macroscopically recognized as solid images each having uniform density of a gray level.

[0066] In FIG. 4A, the nozzle arrangement direction of the recording head 21 coincides with the reference direction, and intervals of the adjacent nozzles 211 in the width direction are uniform. Hence, the interval(s) between the line(s) L1 and the line(s) L2 is equal to the interval(s) between the line(s) L2 and the line(s) L3. Consequently, as shown in FIG. 4B, the area of a part(s) in which the ink droplet(s) IA and the ink droplet(s) IB overlap in the first density pattern P1 is approximately equal to the area of a part(s) in which the ink droplet(s) IB and the ink droplet(s) IC overlap in the second density pattern P2. As a result, the first unit patterns U1 in the first density pattern P1 and the second unit patterns U2 in the second density pattern P2 have the same thickness (width in the width direction) and the same interval(s), so that the first density pattern P1 and the second density pattern P2 have the same density (which hereinafter is referred to as "reference density D") as shown in FIG. 7A.

[0067] In this detection pattern P, the widths in the width direction of the first unit patterns U1 increase as the nozzle arrangement direction deviates from the reference direction to one side (in a positive (upper) direction in FIG. 4A), and decrease as the nozzle arrangement direction deviates from the reference direction to the other side (in a negative (lower) direction in FIG. 4A). The first density pattern P1 has density distribution corresponding to the widths in the width direction of the first unit patterns U1.

[0068] On the other hand, the widths in the width direction of the second unit patterns U2 decrease as the nozzle arrangement direction deviates from the reference direction to the one side, and increase as the nozzle arrangement direction deviates from the reference direction to the other side. The second density pattern P2 has density distribution corresponding to the widths in the width direction of the second unit patterns U2.

[0069] Thus, the density distribution of the first density pattern P1 and the density distribution of the second density pattern P2 change according to the direction and the magnitude (i.e., vector) of the deviation of the nozzle arrangement direction from the reference direction.

[0070] Hereinafter, this characteristic will be described in detail.

[0071] FIG. 5A and FIG. 5B show the detection pattern P in a case where the nozzle arrangement direction of the recording head 21 deviates from the reference direction in the positive direction.

[0072] In FIG. 5A, the nozzle arrangement direction of the recording head 21 deviates from the reference direction by an angle θ in the positive direction. In such arrangement, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is wider than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is narrower than that in the proper arrangement direction. Hence, the interval(s) between the line(s) L1 and the line(s) L2 in the first density pattern P1 is wider than the interval(s) between the line(s) L2 and the line(s) L3 in the second density pattern P2. Consequently, as shown in FIG. 5B, the area of the part(s) in which the ink droplet(s) IA and the ink droplet(s) IB overlap in the first density pattern P1 is smaller than the area of the part(s) in which the ink droplet(s) IB and the ink droplet(s) IC overlap in the second density pattern P2. As a result, the first unit patterns U1 in the first density pattern P1 are thicker (wider in the width direction) than the second unit patterns U2 in the second density pattern P2, and accordingly a percentage of the area of parts covered with ink (which hereinafter is referred to as "covered area percentage") in the first density pattern P1 is higher than the covered area percentage in the second density pattern P2. Hence, the density of the first density pattern P1 is a density D1 which is higher (darker) than the reference density D, and the density of the second density pattern P2 is a density D2 which is lower (lighter) than the reference density D. Accordingly, in this case, the density of the first density pattern P1 is higher than the density of the second density pattern P2 as shown in FIG. 7B.

[0073] FIG. 6A and FIG. 6B show the detection pattern P in a case where the nozzle arrangement direction of the recording head 21 deviates from the reference direction in the negative direction.

[0074] In FIG. 6A, the nozzle arrangement direction of the recording head 21 deviates from the reference direction by an angle θ in the negative direction. In such arrangement, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is narrower than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is wider than that in the proper arrangement direction. Hence, the interval(s) between the line(s) L1 and the line(s) L2 in the first density pattern P1 is narrower than the interval(s) between the line(s) L2 and the line(s) L3 in the second density pattern P2. Consequently, as shown in FIG. 6B, the area of the part(s) in which the ink droplet(s) IA and the ink droplet(s) IB overlap in the first density pattern P1 is larger than the area of the part(s) in which the ink droplet(s) IB and the ink droplet(s) IC overlap in the second density pattern P2. As a result, the second unit patterns U2 in the second density pattern P2 are thicker than the first unit patterns U1 in the first density pattern P1, and accordingly the covered area percentage in the second density pattern P2 is higher than the covered area percentage in the first density pattern P1. Hence, the density of the first density pattern P1 is the density D2 which is lower (lighter) than the reference density D, and the density of the second density pattern P2 is the density D1 which is higher (darker) than the reference density D. Accordingly, in this case, the density of the second density pattern P2 is higher than the density of the first density pattern P1 as shown in FIG. 7C.

[0075] As described above, in the detection pattern P recorded by the nozzle set NS which satisfies the conditions (1) to (5), if the nozzle arrangement direction of the recording head 21 coincides with the reference direction, the first density pattern P1 and the second density pattern P2 have the same density; if the nozzle arrangement direction of the recording head 21 deviates from the reference direction in the positive direction, the density of the first density pattern P1 is higher than the density of the second density pattern P2; and if the nozzle arrangement direction of the recording head 21 deviates from the reference direction in the negative direction, the density of the second density pattern P2 is higher than the density of the first density pattern P1. Further, an absolute value of a difference (hereinafter "density difference") between the density of the first density pattern P1 and the density of the second density pattern P2 is larger as the deviation of the nozzle arrangement direction from the reference direction is larger.

[0076] Thus, by forming the above detection pattern P with the recording head 21, and obtaining the density difference between the first density pattern P1 and the second density pattern P2 from read data of the detection pattern P, whether or not the nozzle arrangement direction deviates can be determined from the obtained density difference, and if it deviates, the direction and the magnitude of the deviation can also be detected therefrom.

[0077] Further, by adjusting the nozzle arrangement direction of the recording head 21 (direction/aspect of the head unit 20) so as to eliminate the density difference between the first density pattern P1 and the second density pattern P2, the nozzle arrangement direction of the recording head 21 can be made to coincide with the reference direction, and accordingly the recording head 21 (nozzles 211 therein) can be in the proper arrangement state.

[0078] Hereinafter, a head position adjustment method for adjusting the arrangement direction (nozzle arrangement direction) of the recording head(s) 21 on the basis of read data of the detection pattern P will be described in detail.

[0079] FIG. 8A to FIG. 8C are diagrams to explain an example of the head position adjustment method for adjusting the position(s) of the recording head(s) 21.

[0080] The head position adjustment method is a method of: causing a predetermined nozzle set NS of a recording head(s) 21 as the target of the adjustment to eject ink droplets so as to form the detection pattern P, thereby forming the detection pattern P first time; and calculating the density difference between the first density pattern P1 and the second density pattern P1 (a value obtained by subtracting the density of the second density pattern P2 from the density of the first density pattern P1) from read data of this detection pattern P generated by the reader 30.

[0081] More specifically, the density difference is calculated by using a representative value of densities in the density distribution of the first density pattern P1 and a representative value of densities in the density distribution of the second density pattern P2. In this embodiment, as the representative value of the densities in the density distribution of each density pattern, the average value of densities at multiple points in the density pattern is used. The representative value is not limited thereto, and may be the median or the maximum value of the densities in the density distribution. Here, it is assumed that the calculated density difference is -17.44 as an example.

[0082] If the line sensor 31 of the reader 30 inclines from the reference direction, in read data of the detection pattern P, a boundary line between the first density pattern P1 and the second density pattern P2 deforms so as to incline from the reference direction according to the inclination of the line sensor 31. Hence, for calculation of the density difference, of the read data, data of areas not affected by the inclination (areas not including (parts of) the circumferences of the first density pattern P1 and the second density pattern P2) are used. Alternatively, the density difference may be calculated after the inclination in the read data is corrected.

[0083] Next, as shown in FIG. 8A, on the assumption that the adjustment amount of the recording head 21 when the detection pattern P is formed first time is zero, the density difference at each adjustment amount in a predetermined range (±1.5, in this embodiment) centering on zero is estimated (a graph on the right side in FIG. 8A). In this embodiment, the adjustment amount is the number of rotations of the adjuster screw. The density difference is estimated on the basis of a linear function with the adjustment amount as an argument(s). At this stage, the slope of the linear function is unknown. Hence, the density difference is estimated by using a predetermined virtual value (initial value) as the slope.

[0084] Then, the arrangement direction of the recording head 21 is adjusted by the adjustment amount at which an absolute value of the estimation value of the density difference is the minimum. In the graph on the right side in FIG. 8A, the adjustment amount at which the density difference is closest to zero is +1.5, and hence the arrangement direction of the recording head 21 is adjusted by rotating the adjuster screw 1.5 rotations.

[0085] Next, the detection pattern P is formed second time by the adjusted recording head 21, and the density difference between the first density pattern P1 and the second density pattern P2 is calculated from read data of this detection pattern P generated by the reader 30. Here, it is assumed that the calculated density difference is 5.85 as an example.

[0086] Then, as shown in FIG. 8B, the density difference at each adjustment amount in the predetermined range of ±1.5 (from 0 to 3.0) centering on +1.5, which is the current adjustment amount of the recording head 21 (i.e., by which the arrangement direction of the recording head 21 has been adjusted), is estimated. Because the detection pattern P has been formed and read twice, two data sets of the adjustment amount and the density difference have been obtained. Hence, the linear function with the adjustment amount as the argument, on the basis of which the estimation value of the density difference at each adjustment amount is obtained, can be fixed. In thus-obtained graph on the right side in FIG. 8B, the adjustment amount at which the density difference is closest to zero is +1.0, and hence the arrangement direction of the recording head 21 is adjusted by rotating the adjuster screw such that the adjustment amount becomes +1.0. Here, the current adjustment amount is +1.5 by the first adjustment, and hence the arrangement direction of the recording head 21 is adjusted by rotating the adjuster screw -0.5 rotations.

[0087] Next, the detection pattern P is formed third time by the adjusted recording head 21, and the density difference between the first density pattern P1 and the second density pattern P2 is calculated from read data of this detection pattern P generated by the reader 30. Here, it is assumed that the calculated density difference is -1.08 as an example.

[0088] Then, as shown in FIG. 8C, the density difference at each adjustment amount in the predetermined range of ±1.5 (from -0.5 to 2.5) centering on +1.0, which is the current adjustment amount of the recording head 21, is estimated. In thus-obtained graph on the right side in FIG. 8C, at the current adjustment amount, namely, +1.0, the density difference is closest to zero. Thus, it is confirmed that the nozzle arrangement direction of the recording head 21 is the most coincident with the reference direction. Hence, adjustment of the position of the recording head 21 finishes.

[0089] If the adjustment amount of the adjuster screw does not need to be a discrete value, and the adjuster screw can be rotated (adjusted) by any rotation amount, instead of the above method, the adjuster screw may be rotated by the adjustment amount at which the density difference is zero in the fixed linear function.

[0090] Next, a control procedure performed by the controller 50 for the head position adjustment process performed by the inkjet recording apparatus 1 will be described.

[0091] FIG. 9 is a flowchart showing the control procedure for the head position adjustment process.

[0092] When the head position adjustment process is started, the controller 50 supplies a control signal and image data of the detection pattern P to the head controller 22 so that a predetermined nozzle set NS in a recording head 21 as the target of the adjustment ejects ink, thereby forming the detection pattern P on a recording medium M (Step S101: ejection step).

[0093] Next, the controller 50 supplies a control signal to the reading controller 32 so that the reader 30 reads the detection pattern P on the recording medium M at the timing when the detection pattern P passes through the imaging area of the reader 30, thereby generating read data of the detection pattern P, and outputs the read data to the controller 50 (Step S102).

[0094] Next, the controller 50 calculates, on the basis of the obtained read data, the average value of densities of the first density pattern P1 and the average value of densities of the second density pattern P2 on the detection pattern P, and calculates the density difference between the first density pattern P1 and the second density pattern P2 from the average values (Step S103).

[0095] Next, the controller 50 calculates the estimation value of the density difference (i.e., estimates the density difference) at each adjustment amount in a predetermined range, and causes the operation display unit 61 to display the result (Step S104). This calculation result of the estimation value of the density difference indicates the direction and the magnitude of the deviation of the nozzle arrangement direction, from a difference between the adjustment amount of the adjuster screw which makes the density difference the minimum and the current adjustment amount of the adjuster screw. This Step S104 corresponds to a detection step. Further, the calculation result of the estimation value of the density difference includes information (deviation information) on the adjustment amount of the adjuster screw which makes the density difference the minimum.

[0096] If this is the first time that Step S104 is performed from the start of the head position adjustment process, the slope of the linear function representing a relationship between the density difference and the adjustment amount is unknown, and hence the controller 50 obtains a predetermined initial value of the slope from the storage 54, and calculates the estimation value of the density difference. Meanwhile, if this is not the first time (e.g., the second time, etc.), the controller 50 fixes the linear function from the values of the density difference calculated the last two times and the values of the adjustment amount at the respective times, and calculates the estimation value of the density difference at each adjustment amount on the basis of the fixed linear function.

[0097] Next, the controller 50 determines whether or not the density difference at the current adjustment amount is the minimum value (i.e., closest to zero) (Step S105). When determining that the density difference at the current adjustment amount is not the minimum value, namely, the density difference at another adjustment amount is the minimum value (Step S105; NO), the controller 50 performs control to adjust the position of the recording head 21 (head unit 20) by the adjustment amount at which the estimation value of the density difference is the minimum (i.e., closest to zero) (Step S106). That is, the controller 50 supplies a control signal to the position adjustment controller 42 of the head position adjuster 40 so that the position adjustment drive unit 41 rotates the adjuster screw by the adjustment amount at which the estimation value of the density difference is the minimum, thereby adjusting the position of the recording head 21.

[0098] After Step S106, the controller 50 moves to Step S101.

[0099] When determining in Step S105 that the density difference at the current adjustment amount is the minimum value (Step S105; YES), the controller 50 ends the head position adjustment process.

(First Modification)

[0100] Next, a first modification of the above embodiment will be described. This modification is different from the above embodiment in that three or more nozzle lines are provided in the recording head(s) 21. Hereinafter, this different point from the embodiment will be described.

[0101] In this case, namely, in the case where three or more nozzle lines are provided in the recording head 21, too, by forming the detection pattern P with the nozzle set NS which satisfies the conditions (1) to (5), deviation of the nozzle arrangement direction of the recording head 21 can be detected from the density difference between the first density pattern P1 and the second density pattern P2 on the detection pattern P.

[0102] FIG. 10A and FIG. 10B each show an example of the nozzle set NS and the detection pattern P formed by the nozzle set NS in a case where three nozzle lines are provided in the recording head 21. The three nozzle lines are, from the upstream side in the conveying direction, referred to as a nozzle line N1, a nozzle line N2 and a nozzle line N3. In the recording head 21, in each of the nozzle lines N1 to N3, the nozzles 211 are arranged at equal intervals in the nozzle arrangement direction (such that their arrangement numbers are expressed by an arithmetic progression with a common difference of 3).

[0103] In the case of FIG. 10A and FIG. 10B, each nozzle group NG is constituted of the nozzle 211 which belongs to the nozzle line N1 as the second nozzle 211b, and the nozzle 211 and the nozzle 211 which constitute a pair, belong to the nozzle line N2 and the nozzle line N3, respectively, and are adjacent to the second nozzle 211b on its respective sides as the first nozzle 211a and the third nozzle 211c, respectively. In any of the nozzle groups NG, the first nozzle 211a to the third nozzle 211c satisfy this positional relationship.

[0104] The nozzle set NS constituted of such nozzle groups NG satisfies the conditions (1) to (5).

[0105] In the case of such a nozzle set NS, as shown in FIG. 10A, if the nozzle arrangement direction deviates from the reference direction in the positive direction, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is wider than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is narrower than that in the proper arrangement state. Hence, as with the above embodiment, the first unit patterns U1 in the first density pattern P1 are thicker than the second unit patterns U2 in the second density pattern P2, and the density of the first density pattern P1 is higher than the density of the second density pattern P2.

[0106] On the other hand, as shown in FIG. 10B, if the nozzle arrangement direction deviates from the reference direction in the negative direction, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is narrower than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is wider than that in the proper arrangement state. Hence, as with the above embodiment, the second unit patterns U2 in the second density pattern P2 are thicker than the first unit patterns U1 in the first density pattern P1, and the density of the second density pattern P2 is higher than the density of the first density pattern P1.

[0107] Further, because the absolute value of the density difference between the first density pattern P1 and the second density pattern P2 is larger as the deviation of the nozzle arrangement direction from the reference direction is larger, by obtaining the density difference between the first density pattern P1 and the second density pattern P2, whether or not the nozzle arrangement direction deviates can be determined from the obtained density difference, and if it deviates, the direction and the magnitude of the deviation can also be detected therefrom.

[0108] Further, by adjusting the nozzle arrangement direction of the recording head 21 (direction/aspect of the head unit 20) so as to eliminate the density difference between the first density pattern P1 and the second density pattern P2, the nozzle arrangement direction of the recording head 21 can be made to coincide with the reference direction, and accordingly the recording head 21 (nozzles 211 therein) can be in the proper arrangement state.

[0109] FIG. 11A and FIG. 11B each show an example of the nozzle set NS and the detection pattern P formed by the nozzle set NS in a case where eight nozzle lines are provided in the recording head 21. The eight nozzle lines are, from the upstream side in the conveying direction, referred to as a nozzle line N1, a nozzle line N2, ..., and a nozzle line N8. In the recording head 21, in each of the nozzle lines N1 to N8, the nozzles 211 are arranged at equal intervals in the nozzle arrangement direction (such that their arrangement numbers are expressed by an arithmetic progression with a common difference of 8).

[0110] In the case of FIG. 11A and FIG. 11B, each nozzle group is constituted of the nozzle 211 which belongs to the nozzle line N1 as the second nozzle 211b, and the nozzle 211 and the nozzle 211 which constitute a pair, belong to the nozzle line N8 and the nozzle line N2, respectively, and are adjacent to the second nozzle 211b on its respective sides as the first nozzle 211a and the third nozzle 211c, respectively. In any of the nozzle groups NG, the first nozzle 211a to the third nozzle 211c satisfy this positional relationship. The nozzle set NS constituted of such nozzle groups NG satisfies the conditions (1) to (5).

[0111] In the case of such a nozzle set NS, as shown in FIG. 11A, if the nozzle arrangement direction deviates from the reference direction in the positive direction, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is wider than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is narrower than that in the proper arrangement state. Hence, for the same reasons described with reference to FIG. 10A, the density of the first density pattern P1 is higher than the density of the second density pattern P2.

[0112] On the other hand, as shown in FIG. 11B, if the nozzle arrangement direction deviates from the reference direction in the negative direction, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is narrower than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is wider than that in the proper arrangement state. Hence, for the same reasons described with reference to FIG. 10B, the density of the second density pattern P2 is higher than the density of the first density pattern P1.

[0113] Hence, by obtaining the density difference between the first density pattern P1 and the second density pattern P2, whether or not the nozzle arrangement direction deviates can be determined from the obtained density difference, and if it deviates, the direction and the magnitude of the deviation can also be detected therefrom, and further by adjusting the nozzle arrangement direction of the recording head 21 (direction/aspect of the head unit 20) so as to eliminate the density difference between the first density pattern P1 and the second density pattern P2, the nozzle arrangement direction of the recording head 21 can be made to coincide with the reference direction, and accordingly the recording head 21 (nozzles 211 therein) can be in the proper arrangement state.

[0114] FIG. 12A and FIG. 12B each show another example of the nozzle set NS and the detection pattern P formed by the nozzle set NS in the case where eight nozzle lines are provided in the recording head 21. In this recording head 21 too, in each of the nozzle lines N1 to N8, the nozzles 211 are arranged at equal intervals in the nozzle arrangement direction (such that their arrangement numbers are expressed by an arithmetic progression with a common difference of 8). The nozzles 211 are arranged such that the arrangement numbers of the nozzles 211 which belong to the nozzle lines N4, N8, N3, N7, N2, N6, N1 and N5 are consecutive numbers in this order.

[0115] In the case of FIG. 12A and FIG. 12B, each odd-numberth nozzle group NG is constituted of the nozzle 211 which belongs to the nozzle line N8 as the third nozzle 211c, the nozzle 211 which belongs to the nozzle line N3 as the second nozzle 211b, and the nozzle 211 which belongs to the nozzle line N7 as the first nozzle 211a, and each even-numberth nozzle group NG is constituted of the nozzle 211 which belongs to the nozzle line N6 as the third nozzle 211c, the nozzle 211 which belongs to the nozzle line N1 as the second nozzle 211b, and the nozzle 211 which belongs to the nozzle line N5 as the first nozzle 211a. Thus, it is unnecessary for the nozzle groups NG to have the same combination of the nozzle lines to which the first nozzle 211a, the second nozzle 211b and the third nozzle 211c belong, as far as the nozzle groups NG have the same positional relationship about the nozzle lines. The nozzle set NS constituted of such nozzle groups NG shown in FIG. 12A and FIG. 12B satisfies the conditions (1) to (5).

[0116] In the case of such a nozzle set NS, as shown in FIG. 12A, if the nozzle arrangement direction deviates from the reference direction in the positive direction, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is wider than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is narrower than that in the proper arrangement state. Hence, for the same reasons described with reference to FIG. 10A, the density of the first density pattern P1 is higher than the density of the second density pattern P2.

[0117] On the other hand, as shown in FIG. 12B, if the nozzle arrangement direction deviates from the reference direction in the negative direction, in each nozzle group NG, the interval between the first nozzle 211a and the second nozzle 211b in the reference direction is narrower than that in the proper arrangement state, and the interval between the second nozzle 211b and the third nozzle 211c in the reference direction is wider than that in the proper arrangement state. Hence, for the same reasons described with reference to FIG. 10B, the density of the second density pattern P2 is higher than the density of the first density pattern P1.

[0118] Hence, by obtaining the density difference between the first density pattern P1 and the second density pattern P2, whether or not the nozzle arrangement direction deviates can be determined from the obtained density difference, and if it deviates, the direction and the magnitude of the deviation can also be detected therefrom, and further by adjusting the nozzle arrangement direction of the recording head 21 (direction/aspect of the head unit 20) so as to eliminate the density difference between the first density pattern P1 and the second density pattern P2, the nozzle arrangement direction of the recording head 21 can be made to coincide with the reference direction, and accordingly the recording head 21 (nozzles 211 therein) can be in the proper arrangement state.

(Second Modification)

[0119] Next, a second modification of the above embodiment will be described.

[0120] In the embodiment, the controller 50 of the inkjet recording apparatus 1 performs the process of detecting, from the reading result of the detection pattern P, the direction and the magnitude of the deviation of the nozzle arrangement direction and generating the deviation information (i.e., process/step of detecting the deviation of the nozzle arrangement direction). However, this is not intended to limit the present invention. For example, the information processing apparatus 2 (deviation detection apparatus) provided outside the inkjet recording apparatus 1 may perform this process.

[0121] As described above, the inkjet recording apparatus 1 of the embodiment includes: the recording head(s) 21 which (i) includes a plurality of nozzle lines in each of which two or more nozzles 211 that eject ink droplets of ink are one-dimensionally arranged in the nozzle arrangement direction, and (ii) ejects the ink from the nozzles 211, which each of the nozzle lines has, to a recording medium M that is placed on the placement surface 11a and moved in the conveying direction relatively with the recording head 21; and the controller 50, wherein the controller 50, as an ejection control unit, causes the nozzle groups NG each including, among the nozzles 211, the first nozzle 211a, the second nozzle 211b and the third nozzle 211c having a predetermined positional relationship to eject the ink, thereby forming, in a plane parallel to the placement surface 11a, the detection pattern P for detecting deviation of the nozzle arrangement direction from the reference direction intersecting the conveying direction, and as a detection unit, detects the deviation based on read data of the detection pattern P; in the proper arrangement state in which the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged such that (i) arrangement areas of the nozzles 211 of the respective nozzle lines coincide in the width direction orthogonal to the conveying direction, (ii) positions of the nozzles 211 are different from one another in the width direction, and (iii) the nozzles 211 are arranged at equal intervals in the width direction; the controller 50, as the ejection control unit, causes the nozzle groups NG to form the detection pattern P including (i) the first density pattern P1 in which the first unit pattern U1 is repeatedly arranged in the width direction so that the first unit patterns U1 are arranged in the width direction, and which has density distribution corresponding to the widths in the width direction of the first unit patterns, and (ii) the second density pattern P2 in which the second unit pattern U2 is repeatedly arranged in the width direction so that the second unit patterns U2 are arranged in the width direction, and which has density distribution corresponding to the widths in the width direction of the second unit patterns; the controller 50, as the ejection control unit, causes each of the nozzle groups NG to form at least one of the first unit pattern U1 and the second unit pattern U2; (i) arrangement intervals of the first nozzle 211a, the second nozzle 211b and the third nozzle 211c in the width direction in the proper arrangement state are equal intervals which make the ink droplets ejected from the first nozzle 211a, the second nozzle 211b and the third nozzle 211c overlap on the recording medium M, (ii) the second nozzle 211b is between the first nozzle 211a and the third nozzle 211c in the width direction, and (iii) the first nozzle 211a and the third nozzle 211c are on one side in the conveying direction with respect to the second nozzle 211b; the nozzle groups NG have the same positional relationship about the nozzle lines to which the first nozzle 211a, the second nozzle 211b and the third nozzle 211c belong; the controller 50, as the ejection control unit, causes the first nozzle 211a and the second nozzle 211b to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium M, thereby forming the first unit pattern U1, and causes the second nozzle 211b and the third nozzle 211c to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium M, thereby forming the second unit pattern U2, and as the detection unit, detects the direction and the magnitude of the deviation based on a representative value of densities in the density distribution of the first density pattern P1 and a representative value of densities in the density distribution of the second density pattern P2 read from the read data.

[0122] According to this configuration, as the deviation of the nozzle arrangement direction of the recording head 21 from the reference direction is larger, the density of the first density pattern P1 and the density of the second density pattern P2 change more largely in directions opposite to one another. For example, as the deviation of the nozzle arrangement direction from the reference direction is larger in the positive direction, the density of the first density pattern P1 is higher, and the density of the second density pattern P2 is lower. On the other hand, as the deviation of the nozzle arrangement direction from the reference direction is larger in the negative direction, the density of the first density pattern P1 is lower, and the density of the second density pattern P2 is higher. Hence, the direction and the magnitude of the deviation of the nozzle arrangement direction from the reference direction can be easily detected by the simple method based on the representative value of the densities in the density distribution of the first density pattern P1 and the representative value of the densities in the density distribution of the second density pattern P2. Further, the nozzle arrangement direction of the recording head 21 can be easily and accurately adjusted on the basis of the detection result.

[0123] Further, it is not always necessary for the read data of the detection pattern P to enable accurate grasping of the positions of the first unit patterns U1 and the second unit patterns U2 formed by the nozzle groups NG, as far as the read data include the representative value of the densities in the density distribution of the first density pattern P1 and the representative value of the densities in the density distribution of the second density pattern P2. Even if the extending direction of the line sensor 31 of the reader 30 deviates from the width direction, the direction and the magnitude of the deviation of the nozzle arrangement direction of the recording head 21 can be accurately detected. Thus, according to the above configuration, the deviation of the nozzle arrangement direction of the recording head 21 can be accurately detected in a simple manner without accurate prior positioning of the reader 30.

[0124] Further, the nozzle groups NG are arranged at equal intervals in the width direction. This can make each of the density distribution of the first density pattern P1 and the density distribution of the second density pattern P2 more uniform, so that the representative value of the densities in the density distribution of the first density pattern P1 and the representative value of the densities in the density distribution of the second density pattern P2 can be detected more accurately.

[0125] Further, the controller 50, as the ejection control unit, causes the nozzle groups NG to form the detection pattern P in which forming areas of the first density pattern P1 and the second density pattern P2 do not overlap in the conveying direction, but coincide in the width direction. According to this configuration, if the recording head 21 is in the proper arrangement state, the representative value of the densities in the density distribution of the first density pattern P1 is equal to the representative value of the densities in the density distribution of the second density pattern P2, the representative values being calculated by the same method. Hence, by the simple method for adjusting the nozzle arrangement direction of the recording head 21 so as to make the difference between the representative value of the first density pattern P1 and the representative value of the second density pattern P2 zero (i.e., so as to make the density difference zero), the nozzle arrangement direction of the recording head 21 can be made to coincide with the reference direction. Further, because the direction of the deviation of the nozzle arrangement direction of the recording head 21 can be detected from the relative magnitude (high/low) relationship between the density of the first density pattern P1 and the density of the second density pattern P2, intuitively with eyes too, whether or not the deviation is present can be determined, and if it is present, the direction of the deviation can also be determined. Further, because the density of the first density pattern P1 and the density of the second density pattern P2 can be detected under the same condition from the result of imaging by the same imaging element group of the line sensor 31, influence of an error in the detected densities, the error being generated by variations or the like in characteristics of the imaging elements, on the detection result of the deviation of the nozzle arrangement direction can be suppressed.

[0126] Further, the controller 50, as the detection unit, detects the direction and the magnitude of the deviation based on the difference between the representative value of the densities of the first density pattern P1 and the representative value of the densities of the second density pattern P2 in the read data. Thus, the direction and the magnitude of the deviation can be detected by the simple method using the difference between the representative values (e.g., average values) of the densities. For example, by adjusting the nozzle arrangement direction of the recording head 21 in two ways, and calculating the difference between the representative values of the densities in the case of each adjusted nozzle arrangement direction, the linear function with the adjustment amount of the nozzle arrangement direction as the argument, on the basis of which the estimation value of the difference between the representative values of the densities at each adjustment amount is obtained, can be fixed. By adjusting the arrangement direction of the recording head 21 by the adjustment amount at which the estimation value of the difference between the representative values of the densities is zero or closest to zero in the linear function, the nozzle arrangement direction can be easily made to coincide with the reference direction.

[0127] Further, each of the first unit pattern U1 and the second unit pattern U2 is a line pattern extending in the conveying direction. Hence, the first unit patterns U1 and the second unit patterns U2 can be formed by simple ejection control to cause the nozzles 211 to continuously eject ink to the recording medium M which is moved relatively with the recording head 21.

[0128] Further, the nozzle groups NG are selected such that in each of the nozzle groups NG, the first nozzle 211a and the second nozzle 211b are adjacent to one another in the width direction, and the second nozzle

211b and the third nozzle 211c are adjacent to one another in the width direction. This can make more certain that the ink droplets ejected from the first nozzle 211a and the second nozzle 211b land with a positional relationship in which the ink droplets overlap (partly coincide), and the ink droplets ejected from the second nozzle 211b and the third nozzle 211c land with a positional relationship in which the ink droplets overlap (partly coincide). That is, by the combination of the first nozzle 211a and the second nozzle 211b and the combination of the second nozzle 211b and the third nozzle 211c, the first unit pattern U1 and the second unit pattern U2, or the like, the widths of which change according to the deviation of the nozzle arrangement direction, can be formed more certainly.

[0129] Further, the head unit 20 of the inkjet recording apparatus 1 includes the recording heads 21 each having the nozzle arrangement region NR where the nozzles 211 are arranged, the recording heads 21 are arranged such that the nozzle arrangement region NR of each one of the recording heads 21 overlaps, in a nearby area of an edge of the nozzle arrangement region NR in the width direction, with the nozzle arrangement region NR of another one of the recording heads 21 in the width direction, and the nozzle groups NG are constituted of the nozzles 211 arranged outside the overlapping area R in which the nozzle arrangement regions NR overlap in the width direction. In the overlapping area R in which the nozzle arrangement regions of the recording heads 21 that constitute a pair overlap, at each of the positions of the nozzles 211 in the width direction, the nozzle 211 which belongs to one of the recording heads 21, which constitute a pair, ejects ink. Depending on the setting of the nozzles 211 in the overlapping area R, it is difficult to determine/set the nozzle set NS which satisfies the conditions (1) to (5). Further, even if the nozzle set NS is determined/set in one of the recording heads 21, which constitute a pair, so as to satisfy the conditions (1) to (5), the ink ejected from the other recording head 21 may affect the density of the detection pattern P. Hence, it is difficult to accurately detect the deviation of the nozzle arrangement direction. Then, the nozzle set NS is constituted of the nozzle groups NG arranged outside the overlapping area(s) R. This enables easy and accurate detection of the deviation of the nozzle arrangement direction.

[0130] Further, the inkjet recording apparatus 1 further includes the reader 30 which reads the detection pattern P, thereby generating the read data. Hence, the inkjet recording apparatus 1 can perform a series of processes which include forming the detection pattern P, reading the detection pattern P, and detecting the deviation.

[0131] Further, the inkjet recording apparatus 1 further includes the head position adjuster 40 for adjusting a relationship between the nozzle arrangement direction and the reference direction. Hence, the inkjet recording apparatus 1 can adjust the nozzle arrangement direction of the recording head 21 on the basis of the detected deviation.

[0132] Further, the inkjet recording apparatus 1 further includes the operation display unit 61, and the controller 50, as a display control unit, causes the operation display unit 61 to display the direction and the magnitude of the detected deviation. Hence, the inkjet recording apparatus 1 can show an operator the information on the deviation of the nozzle arrangement direction of the recording head 21.

[0133] Further, the information processing apparatus 2 of the second modification detects the direction and the magnitude of the deviation on the basis of the representative value of the densities in the density distribution of the first density pattern P1 and the representative value of the densities in the density distribution of the second density pattern P2 read from the read data of the detection pattern P. Thus, the information processing apparatus 2 provided outside the inkjet recording apparatus 1 can detect the deviation of the nozzle arrangement direction of the recording head 21.

[0134] Further, the deviation detection method of the embodiment includes: an ejection step of causing the nozzle groups NG each including, among the nozzles 211, the first nozzle 211a, the second nozzle 211b and the third nozzle 211c having a predetermined positional relationship to eject the ink, thereby forming the detection pattern P for detecting the deviation; and a detection step of detecting the deviation based on read data of the detection pattern P, wherein the ejection step includes causing the nozzle groups NG to form the detection pattern P including (i) the first density pattern P1 in which the first unit pattern U1 is repeatedly arranged in the width direction so that the first unit patterns U1 are arranged in the width direction, and which has density distribution corresponding to the widths in the width direction of the first unit patterns U1, and (ii) the second density pattern P2 in which the second unit pattern U2 is repeatedly arranged in the width direction so that the second unit patterns U2 are arranged in the width direction, and which has density distribution corresponding to the widths in the width direction of the second unit patterns U2; causing each of the nozzle groups NG to form at least one of the first unit pattern U1 and the second unit pattern U2; and causing the first nozzle 211a and the second nozzle 211b to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium M, thereby forming the first unit pattern U1, and causing the second nozzle 211b and the third nozzle 211c to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium M, thereby forming the second unit pattern U2, and the detection step includes detecting the direction and the magnitude of the deviation based on a representative value of densities in the density distribution of the first density pattern P1 and a representative value of densities in the density distribution of the second density pattern P2 read from the read data. This method can accurately detect the deviation of the nozzle arrangement direction of the recording head 21 in a simpler manner.

[0135] The present invention is not limited to the above embodiment or modifications, and can be appropriately modified in a variety of respects.

[0136] For example, in the embodiment, a single recording head 21 corresponds to the ink ejector. Alternatively, the ink ejector may be a head module formed by combining and arranging two or more recording heads 21 each having one or more nozzle lines such that recording resolution in the width direction increase. For example, the ink ejector may be a head module formed by combining a recording head(s) 21 having the nozzle lines N1 to N4 shown in FIG. 12A and FIG. 12B and a recording head(s) 21 having the nozzle lines N5 to N8 shown in FIG. 12A and FIG. 12B. In this case, in the head unit 20, the head modules are arranged in a houndstooth check.

[0137] The number of the nozzle lines provided in the ink ejector is not limited to two, three or eight cited above, and hence may be four, five, six, seven, nine or more.

[0138] Further, in the embodiment, the long head unit 20 in which the recording heads 21 are arranged in a houndstooth check record images. This is not intended to limit the present invention. For example, the present invention may be applied to an inkjet recording apparatus which record images by using a single recording head 21 or head module.

[0139] Further, in the embodiment, the nozzle arrangement direction of the recording head(s) 21, which the head unit 20 has, is adjusted by adjusting the arrangement direction of the whole head unit 20. This is not intended to limit the present invention. The deviation of the nozzle arrangement direction may be adjusted on a recording-head-21-by-recording-head-21 basis. For example, attachment positions (attachment angles) of the respective recording heads 21 to the base 20a of the head unit 20 may be adjustable, and the nozzle arrangement direction of each recording head 21 may be adjusted. In this case, each recording head 21 forms the detection pattern P, and the deviation of the nozzle arrangement direction of each recording head 21 is detected on the basis of read data of the detection pattern P.

[0140] Further, the adjustment method for adjusting the nozzle arrangement direction of the recording head 21 is not limited to the method with the adjuster screw, and any of various conventionally known adjustment methods can be used. Further, the nozzle arrangement direction may be adjusted by hand instead of the head position adjuster 40.

[0141] Further, instead of the method of physically adjusting the arrangement direction of the recording head 21, landing positions of ink droplets in the conveying direction may be adjusted by adjusting timings at which the ink droplets are ejected from the nozzles 211 according to the amount of the deviation of the nozzle arrangement direction of the recording head 21.

[0142] Further, the reference direction for the nozzle arrangement direction of the recording head 21 is not limited to the direction parallel to the width direction, and may be a direction intersecting the conveying direction but not orthogonal thereto.

[0143] Further, in the embodiment, the arrangement numbers of the first nozzles 211a to the third nozzles 211c are consecutive numbers. This is not intended to limit the present invention. The arrangement numbers have the same interval. That is, as far as the other conditions are satisfied, one or more nozzles 211 may be interposed between the first nozzle(s) 211a and the second nozzle(s) 211b and between the second nozzle(s) 211a and the third nozzle(s) 211c in the width direction.

[0144] Further, according to the condition (2) of the configuration of the nozzle set NS, the nozzle set NS is constituted of the nozzle groups NG arranged in the area in which the nozzle arrangement region NR of the recording head 21 does not overlap with that of another recording head 21 (i.e., arranged outside the overlapping area(s) R). However, it is not always necessary for the nozzle set NS to satisfy this condition, and the nozzle groups NG, which constitute the nozzle set NS, may be selected from the entire nozzle arrangement region NR, which includes the overlapping area(s) R. In this case, areas of the detection patterns P in the width direction formed by the respective recording heads 21 overlap in a part(s) corresponding to the overlapping area(s) R. However, by making forming positions of the detection patterns P in the conveying direction different from one another, the detection patterns P can be formed so as not to overlap.

[0145] Further, according to the condition (5) of the configuration of the nozzle set NS, the arrangement intervals of the nozzle groups NG in the width direction are equal intervals. However, it is not always necessary for the nozzle set NS to exactly satisfy this condition, and the arrangement intervals of the nozzle groups NG in the width direction may be unequal intervals, as far as the representative values of the densities of the first density pattern P1 and the second density pattern P2 can be detected properly. That is, the density of each of the first density pattern P1 and the second density pattern P2 may not be uniform, as far as the first density pattern P1 and the second density pattern P2 have their respective density distributions which reflect the widths in the width direction of the first unit patterns U1 and the widths in the width direction of the second unit patterns U2, respectively, and enable calculation of the representative values of the densities in the respective density distributions with a predetermined method.

[0146] Further, in the embodiment, in each nozzle group NG, the first nozzle 211a and the third nozzle 211c are on the downstream side of the second nozzle 211b in the conveying direction. Alternatively, the nozzle groups NG may be selected such that in each nozzle group NG, the first nozzle 211a and the third nozzle 211c are on the upstream side of the second nozzle 211b in the conveying direction.

[0147] Further, in the embodiment, one first density pattern P1 and one second density pattern P2 are formed in regions adjacent to one another in the conveying direction. This is not intended to limit the present invention.

The combination of the first density pattern P1 and the second density pattern P2 may be formed repeatedly in the conveying direction, and the average values of densities of these may be used.

[0148] Further, the first density pattern P1 and the second density pattern P2 may be formed in regions adjacent to one another in the width direction.

[0149] Further, the first unit pattern U1 and the second unit pattern U2 are not limited to the line patterns extending in the conveying direction. For example, the first unit pattern U1 may be a dot pattern formed with ink droplets ejected from the first nozzle 211a and the second nozzle 211b, and the second unit pattern U2 may be a dot pattern formed with ink droplets ejected from the second nozzle 211b and the third nozzle 211c.

[0150] Further, the present invention may be applied to the inkjet recording apparatus 1 which causes the recording heads 21 (head units 20) to record images while performing scanning. In this case, the nozzle arrangement direction of the recording head 21 and the reference direction are set in a direction intersecting a moving direction in which the recording heads 21 move relatively with the recording medium M.

[0151] In the above, one or more embodiments or the like of the present invention have been described. However, the scope of the present invention is not limited thereto, and includes the scope of claims below and the scope of their equivalents.

Claims

1. An inkjet recording apparatus (1) comprising:

an ink ejector (21) which (i) includes a plurality of nozzle lines (N1, N2) in each of which two or more nozzles (211) that eject ink droplets of ink are one-dimensionally arranged in a predetermined nozzle arrangement direction, and (ii) ejects the ink from the nozzles, which each of the nozzle lines has, to a recording medium (M) that is placed on a placement surface (11a) and moved in a predetermined moving direction relatively with the ink ejector;

an ejection control unit (50) which causes a plurality of nozzle groups (NG) each including, among the nozzles, a first nozzle (211a), a second nozzle (211b) and a third nozzle (211c) having a predetermined positional relationship to eject the ink, thereby forming, in a plane parallel to the placement surface, a predetermined detection pattern (P) for detecting deviation of the nozzle arrangement direction from a predetermined reference direction intersecting the moving direction; and

a detection unit (50) which detects the deviation based on read data of the detection pattern, wherein

in a proper arrangement state in which the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged such that (i) arrangement areas of the nozzles of the respective nozzle lines coincide in a width direction orthogonal to the moving direction, (ii) positions of the nozzles are different from one another in the width direction, and (iii) the nozzles are arranged at equal intervals in the width direction,

the ejection control unit causes the nozzle groups to form the detection pattern including:

a first density pattern (P1) in which a first unit pattern (U1) is repeatedly arranged in the width direction so that first unit patterns (U1) are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the first unit patterns; and

a second density pattern (P2) in which a second unit pattern (U2) is repeatedly arranged in the width direction so that second unit patterns (U2) are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the second unit patterns,

the ejection control unit causes each of the nozzle groups to form at least one of the first unit pattern and the second unit pattern,

(i) arrangement intervals of the first nozzle, the second nozzle and the third nozzle in the width direction in the proper arrangement state are equal intervals which make the ink droplets ejected from the first nozzle, the second nozzle and the third nozzle overlap on the recording medium, (ii) the second nozzle is between the first nozzle and the third nozzle in the width direction, and (iii) the first nozzle and the third nozzle are on one side in the moving direction with respect to the second nozzle,

the nozzle groups have a same positional relationship about the nozzle lines to which the first nozzle, the second nozzle and the third nozzle belong,

the ejection control unit causes the first nozzle and the second nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the first unit pattern, and causes the second nozzle and the third nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the second unit pattern, and

the detection unit detects direction and magnitude of the deviation based on a representative value of densities in the density distribution of the first density pattern and a representative value of densities in the density distribution of the second density pattern read from the read data.

2. The inkjet recording apparatus according to claim 1, wherein the nozzle groups are arranged at equal intervals in the width direction.

3. The inkjet recording apparatus according to claim 1 or 2, wherein the ejection control unit causes the nozzle groups to form the detection pattern in which forming areas of the first density pattern and the second density pattern do not overlap in the moving direction, but coincide in the width direction.

4. The inkjet recording apparatus according to any one of claims 1 to 3, wherein the detection unit detects the direction and the magnitude of the deviation based on a difference between the representative value of the densities of the first density pattern and the representative value of the densities of the second density pattern in the read data.

5. The inkjet recording apparatus according to any one of claims 1 to 4, wherein each of the first unit pattern and the second unit pattern is a line pattern extending in the moving direction.

6. The inkjet recording apparatus according to any one of claims 1 to 5, wherein in each of the nozzle groups, the first nozzle and the second nozzle are adjacent to one another in the width direction, and the second nozzle and the third nozzle are adjacent to one another in the width direction.

7. The inkjet recording apparatus according to any one of claims 1 to 6, wherein
the ink ejector includes a plurality of ink ejectors (211) each having a nozzle arrangement region where the nozzles are arranged,
the ink ejectors are arranged such that the nozzle arrangement region of each one of the ink ejectors overlaps, in a nearby area of an edge of the nozzle arrangement region in the width direction, with the nozzle arrangement region of another one of the ink ejectors in the width direction, and
the nozzle groups are constituted of the nozzles arranged outside an area in which the nozzle arrangement regions overlap in the width direction.

8. The inkjet recording apparatus according to any one of claims 1 to 7, further comprising a reader (30) which reads the detection pattern, thereby generating the read data.

9. The inkjet recording apparatus according to any one of claims 1 to 8, further comprising a nozzle arrangement direction changing unit (40) for adjusting a relationship between the nozzle arrangement direction and the reference direction.

10. The inkjet recording apparatus according to any one of claims 1 to 9, further comprising:

a display (61); and
a display control unit (50) which causes the display to display the direction and the magnitude of the deviation detected by the detection unit.

11. A deviation detection apparatus (2) for an inkjet recording apparatus (1) including: an ink ejector (21) which (i) includes a plurality of nozzle lines (N1, N2) in each of which two or more nozzles (211) that eject ink droplets of ink are one-dimensionally arranged in a predetermined nozzle arrangement direction, and (ii) ejects the ink from the nozzles, which each of the nozzle lines has, to a recording medium (M) that is placed on a placement surface (11a) and moved in a predetermined moving direction relatively with the ink ejector; and an ejection control unit (50) which causes a plurality of nozzle groups (NG) each including, among the nozzles, a first nozzle (211a), a second nozzle (211b) and a third nozzle (211c) having a predetermined positional relationship to eject the ink, thereby forming, in a plane parallel to the placement surface, a predetermined detection pattern (P) for detecting deviation of the nozzle arrangement direction from a predetermined reference direction intersecting the moving direction, the deviation detection apparatus (2) detecting the deviation in the inkjet recording apparatus (1), comprising a detection unit, wherein
in a proper arrangement state in which the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged such that (i) arrangement areas of the nozzles of the respective nozzle lines coincide in a width direction orthogonal to the moving direction, (ii) positions of the nozzles are different from one another in the width direction, and (iii) the nozzles are arranged at equal intervals in the width direction,
the ejection control unit causes the nozzle groups to form the detection pattern including:

a first density pattern (P1) in which a first unit pattern (U1) is repeatedly arranged in the width direction so that first unit patterns (U1) are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the first unit patterns; and
a second density pattern (P2) in which a second unit pattern (U2) is repeatedly arranged in the width direction so that second unit patterns (U2) are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the second unit patterns,

the ejection control unit causes each of the nozzle groups to form at least one of the first unit pattern and the second unit pattern,

(i) arrangement intervals of the first nozzle, the second nozzle and the third nozzle in the width direction in the proper arrangement state are equal intervals which make the ink droplets ejected from the first nozzle, the second nozzle and the third nozzle overlap on the recording medium, (ii) the second nozzle is between the first nozzle and the third nozzle in the width direction, and (iii) the first nozzle and the third nozzle are on one side in the moving direction with respect to the second nozzle,
the nozzle groups have a same positional relationship about the nozzle lines to which the first nozzle, the second nozzle and the third nozzle belong,
the ejection control unit causes the first nozzle and the second nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the first unit pattern, and causes the second nozzle and the third nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the second unit pattern, and
the deviation detection apparatus (2) comprises the detection unit which detects direction and magnitude of the deviation based on a representative value of densities in the density distribution of the first density pattern and a representative value of densities in the density distribution of the second density pattern read from read data of the detection pattern.

12. A deviation detection method for an inkjet recording apparatus (1) including an ink ejector (21) which (i) includes a plurality of nozzle lines (N1, N2) in each of which two or more nozzles (211) that eject ink droplets of ink are one-dimensionally arranged in a predetermined nozzle arrangement direction, and (ii) ejects the ink from the nozzles, which each of the nozzle lines has, to a recording medium (M) that is placed on a placement surface (11a) and moved in a predetermined moving direction relatively with the ink ejector, the deviation detection method for detecting, in a plane parallel to the placement surface, deviation of the nozzle arrangement direction from a predetermined reference direction intersecting the moving direction, comprising an ejection step (S101) and a detection step (S104), wherein
in a proper arrangement state in which the nozzle arrangement direction coincides with the reference direction, the nozzle lines are arranged such that (i) arrangement areas of the nozzles of the respective nozzle lines coincide in a width direction orthogonal to the moving direction, (ii) positions of the nozzles are different from one another in the width direction, and (iii) the nozzles are arranged at equal intervals in the width direction,
the deviation detection method comprises:

the ejection step of causing a plurality of nozzle groups (NG) each including, among the nozzles, a first nozzle (211a), a second nozzle (211b) and a third nozzle (211c) having a predetermined positional relationship to eject the ink, thereby forming a predetermined detection pattern (P) for detecting the deviation; and
the detection step of detecting the deviation based on read data of the detection pattern,
the ejection step includes causing the nozzle groups to form the detection pattern including:

a first density pattern (P1) in which a first unit pattern (U1) is repeatedly arranged in the width direction so that first unit patterns (U1) are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the first unit patterns; and
a second density pattern (P2) in which a second unit pattern (U2) is repeatedly arranged in the width direction so that second unit patterns (U2) are arranged in the width direction, and which has density distribution corresponding to widths in the width direction of the second unit patterns,

the ejection step includes causing each of the nozzle groups to form at least one of the first unit pattern and the second unit pattern,
(i) arrangement intervals of the first nozzle, the second nozzle and the third nozzle in the width direction in the proper arrangement state are equal intervals which make the ink droplets ejected from the first nozzle, the second nozzle and the third nozzle overlap on the recording medium, (ii) the second nozzle is between the first nozzle and the third nozzle in the width direction, and (iii) the first nozzle and the third nozzle are on one side in the moving direction with respect to the second nozzle,
the nozzle groups have a same positional relationship about the nozzle lines to which the first nozzle, the second nozzle and the third nozzle belong,
the ejection step includes causing the first nozzle and the second nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the first unit pattern, and causing the second nozzle and the third nozzle to eject the ink droplets at timing which makes the ink droplets overlap on the recording medium, thereby forming the second unit pattern, and
the detection step includes detecting direction and magnitude of the deviation based on a rep-

resentative value of densities in the density distribution of the first density pattern and a representative value of densities in the density distribution of the second density pattern read from the read data.

FIG.1

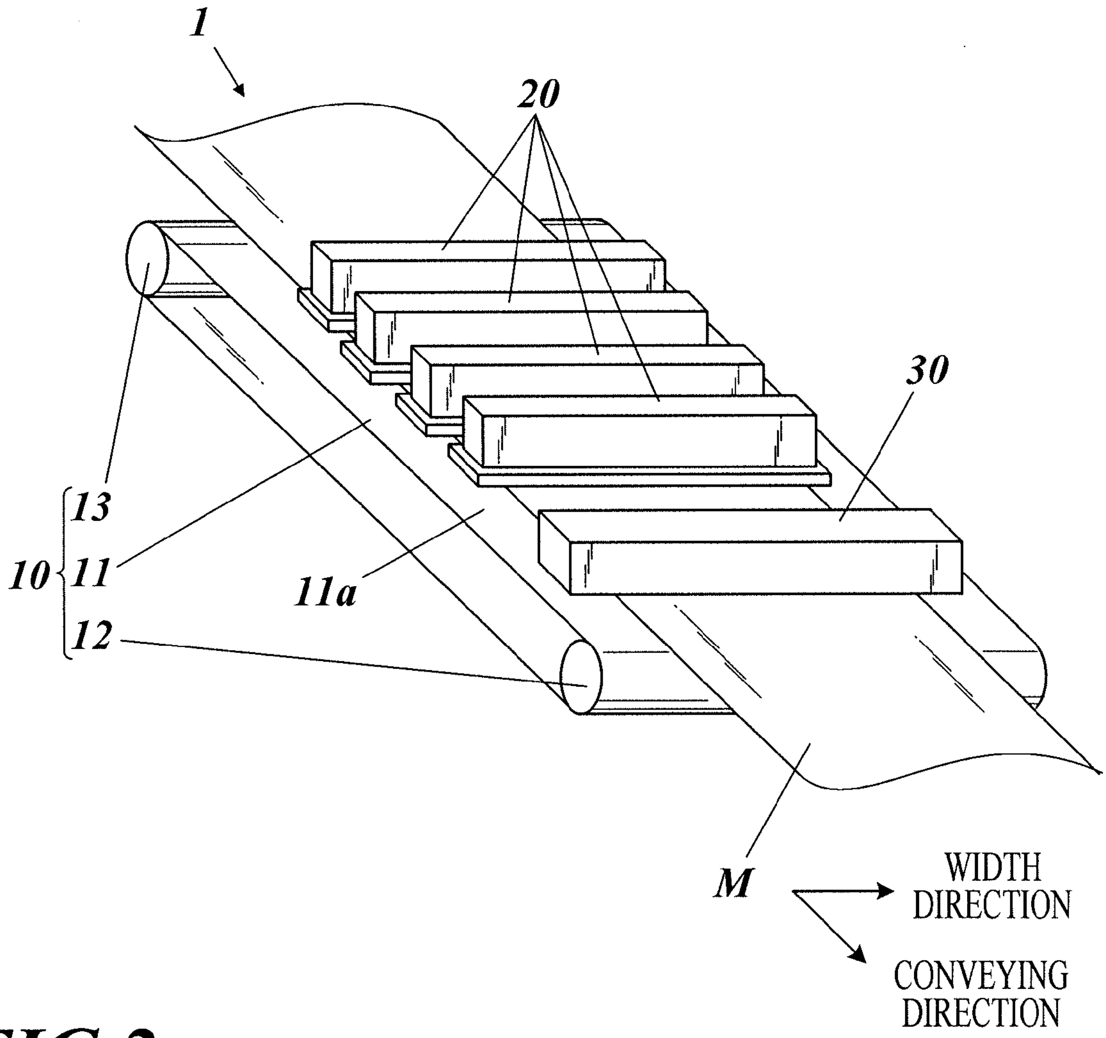

1
20
30
13
10
11
11a
12
M
WIDTH DIRECTION
CONVEYING DIRECTION

FIG.2

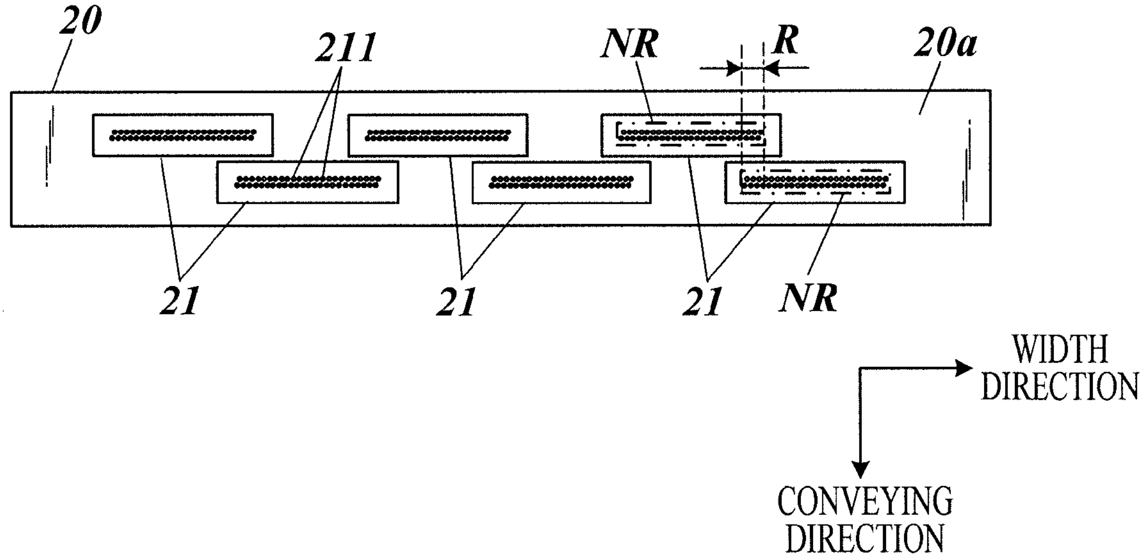

20
211
NR
R
20a
21
21
21
NR
WIDTH DIRECTION
CONVEYING DIRECTION

FIG.3

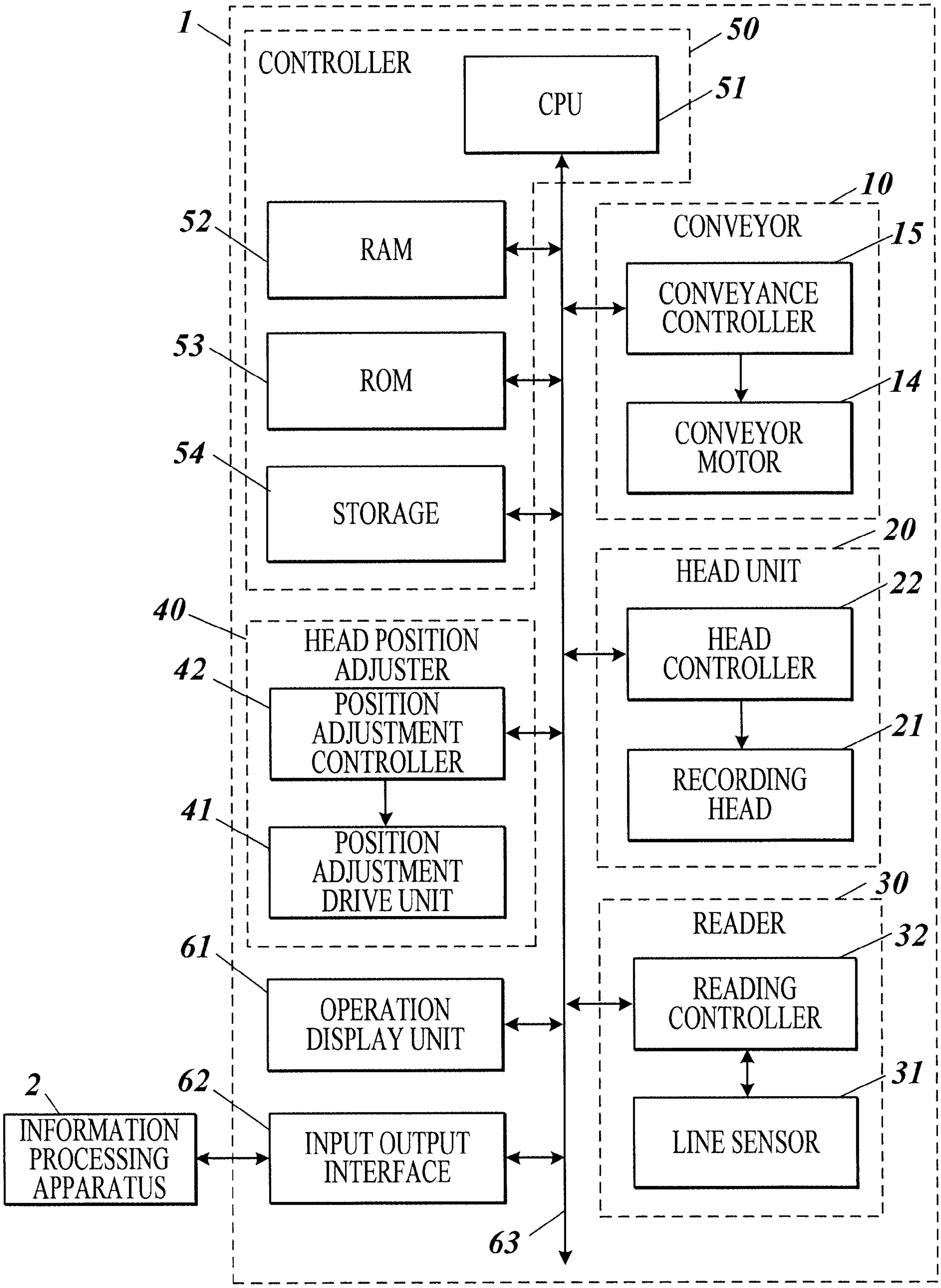

1
CONTROLLER
50
CPU
51
52
RAM
53
ROM
54
STORAGE
10
CONVEYOR
15
CONVEYANCE CONTROLLER
14
CONVEYOR MOTOR
20
HEAD UNIT
22
HEAD CONTROLLER
21
RECORDING HEAD
40
HEAD POSITION ADJUSTER
42
POSITION ADJUSTMENT CONTROLLER
41
POSITION ADJUSTMENT DRIVE UNIT
30
READER
32
READING CONTROLLER
31
LINE SENSOR
61
OPERATION DISPLAY UNIT
2
INFORMATION PROCESSING APPARATUS
62
INPUT OUTPUT INTERFACE
63

FIG.4A

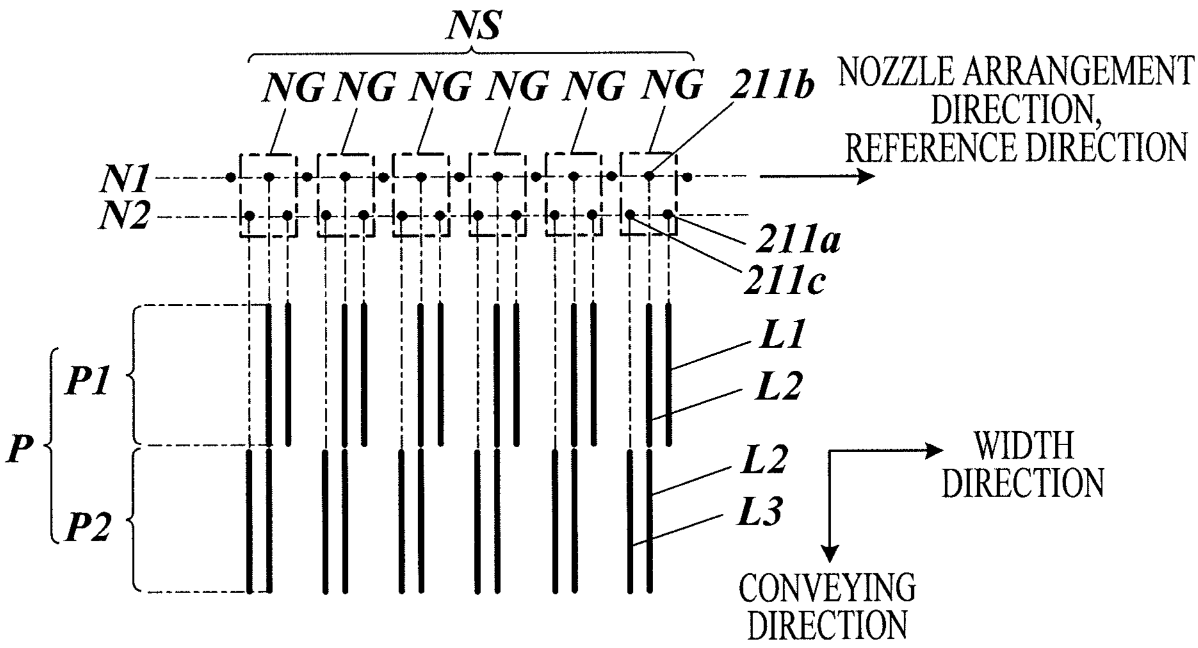

NS
NG NG NG NG NG NG
211b
NOZZLE ARRANGEMENT DIRECTION, REFERENCE DIRECTION
N1
N2
211a
211c
L1
L2
P1
P
L2
L3
P2
WIDTH DIRECTION
CONVEYING DIRECTION

FIG.4B

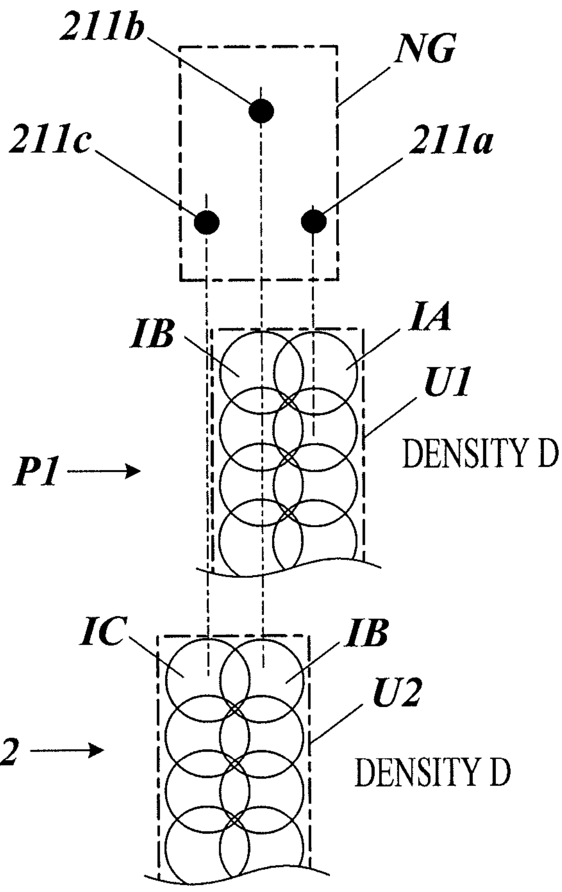

211b
NG
211c
211a
IB
IA
U1
DENSITY D
P1
IC
IB
U2
P2
DENSITY D

FIG.5A

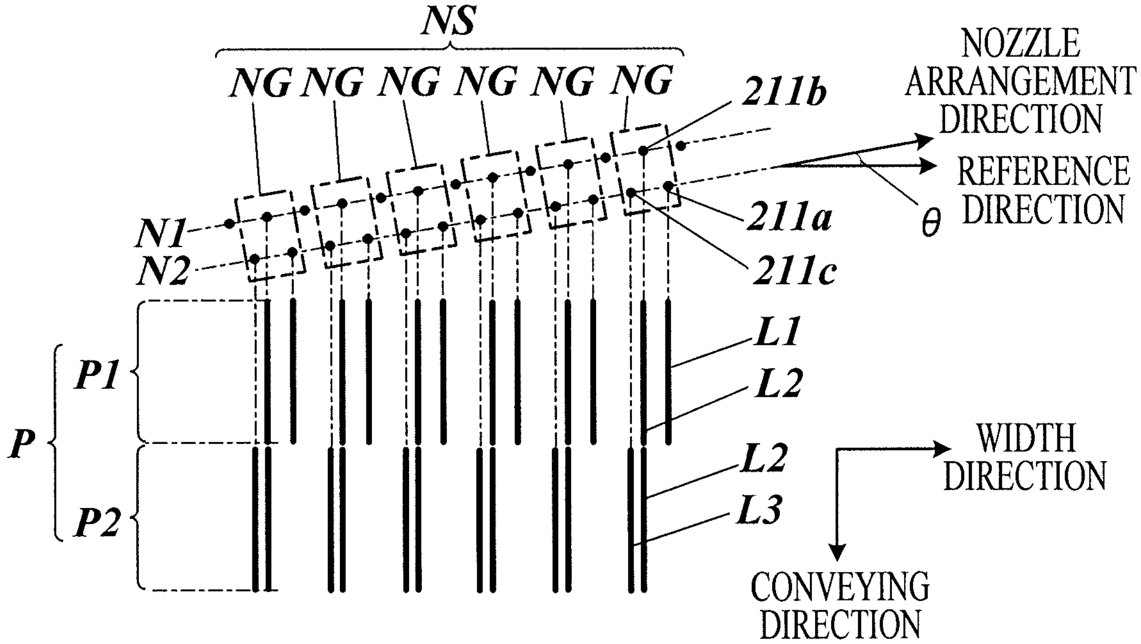

NS
NG NG NG NG NG NG
211b
NOZZLE ARRANGEMENT DIRECTION
REFERENCE DIRECTION
θ
211a
211c
N1
N2
P1
P
P2
L1
L2
L2
L3
WIDTH DIRECTION
CONVEYING DIRECTION

FIG.5B

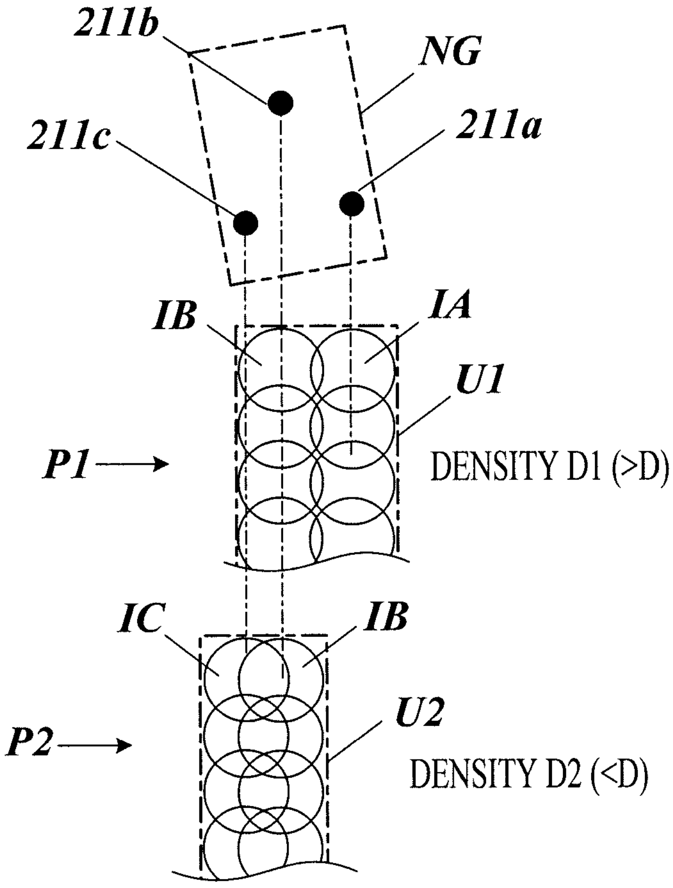

211b
NG
211c
211a
IB
IA
U1
P1
DENSITY D1 (>D)
IC
IB
U2
P2
DENSITY D2 (<D)

FIG.6A

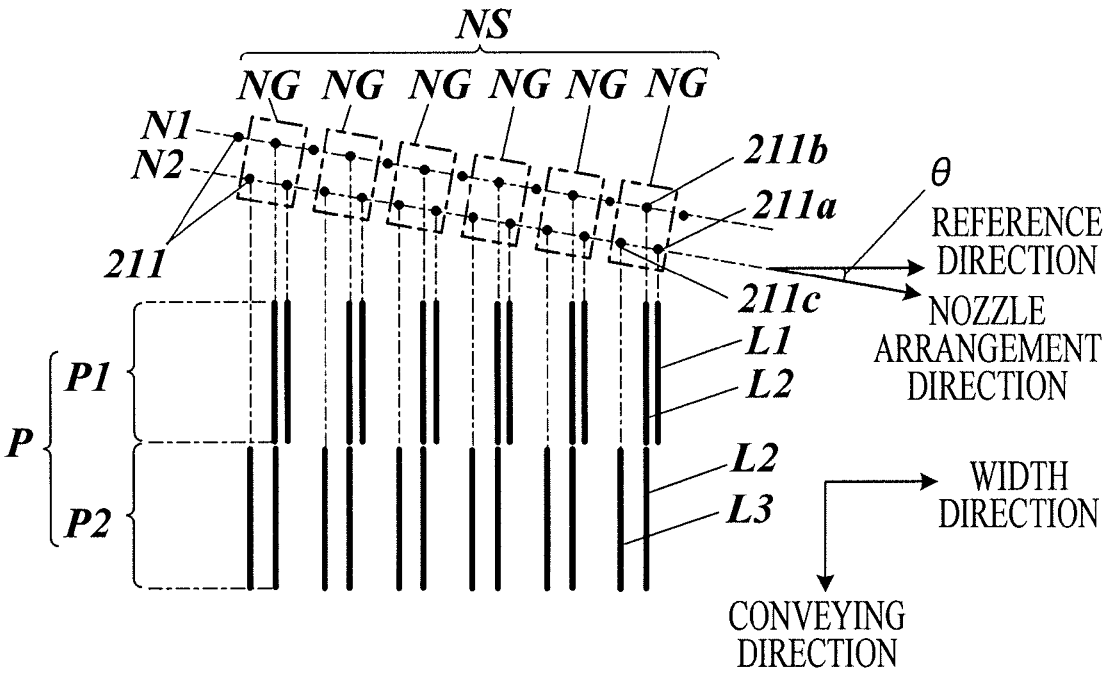

NS
NG
NG
NG
NG
NG
NG
N1
N2
211
211b
211a
211c
θ
REFERENCE DIRECTION
NOZZLE ARRANGEMENT DIRECTION
P
P1
P2
L1
L2
L2
L3
WIDTH DIRECTION
CONVEYING DIRECTION

FIG.6B

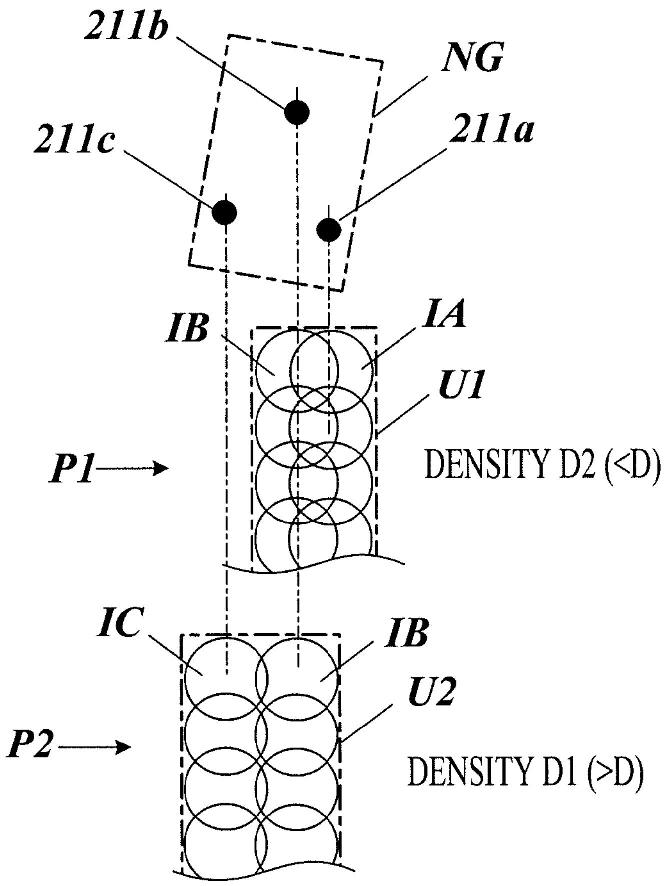

211b
NG
211c
211a
IB
IA
U1
P1
DENSITY D2 (<D)
IC
IB
U2
P2
DENSITY D1 (>D)

FIG. 7A

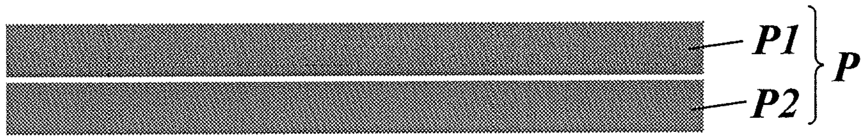


FIG. 7B

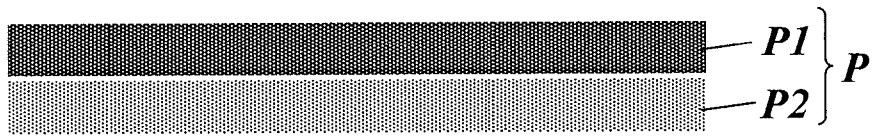


FIG. 7C

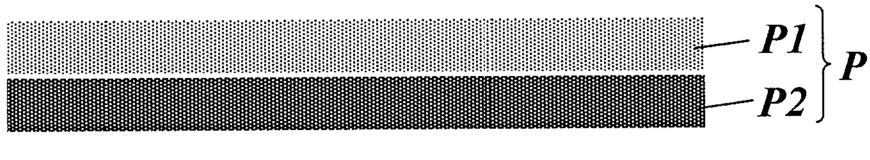


FIG.8A

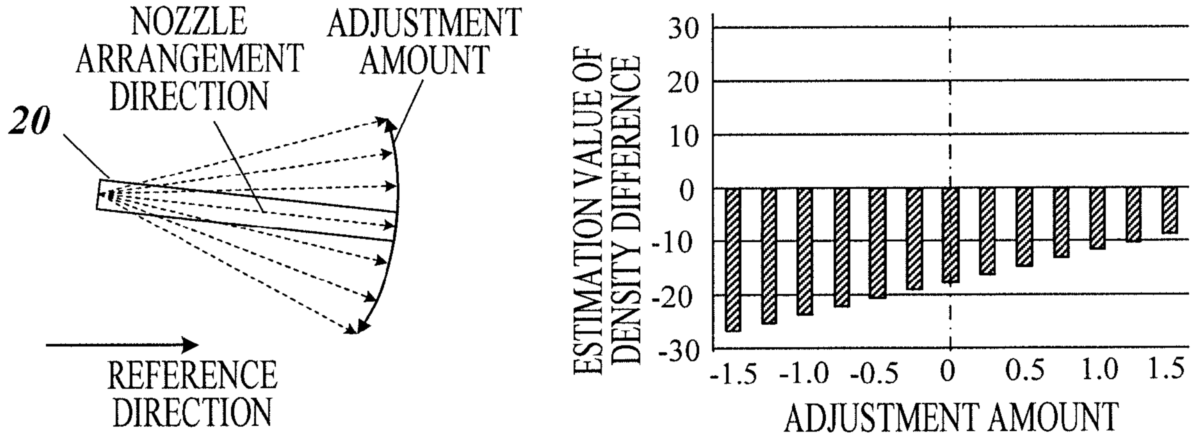


FIG.8B

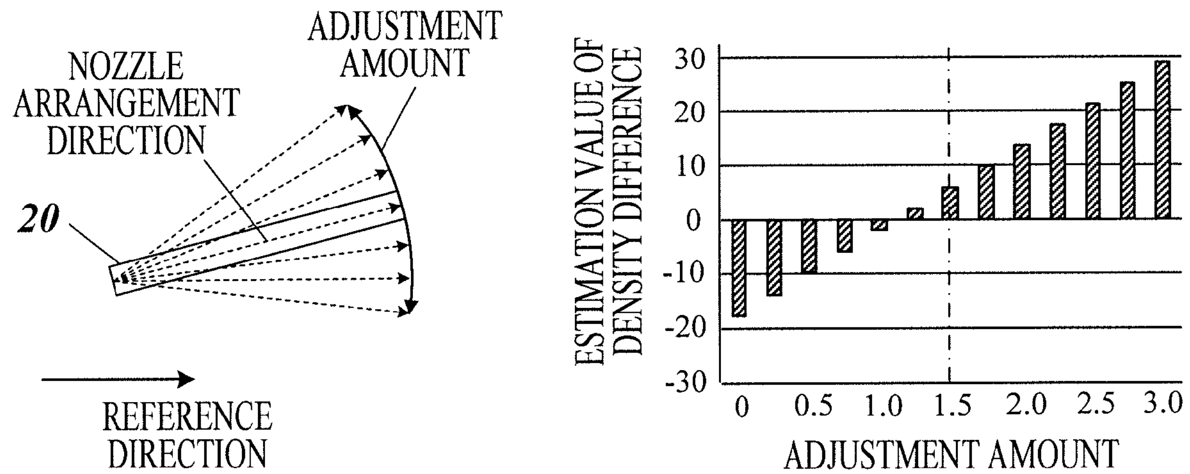


FIG.8C

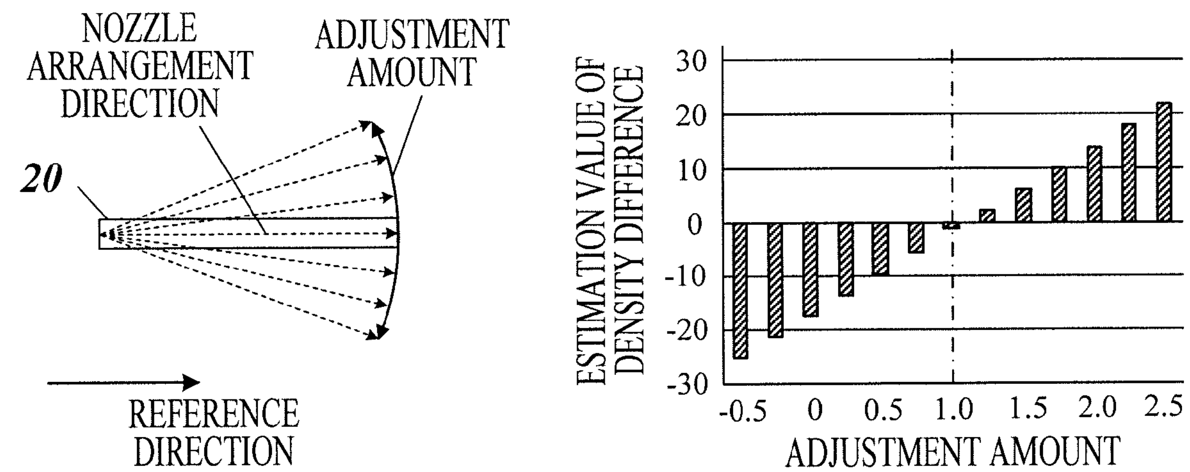


FIG.9

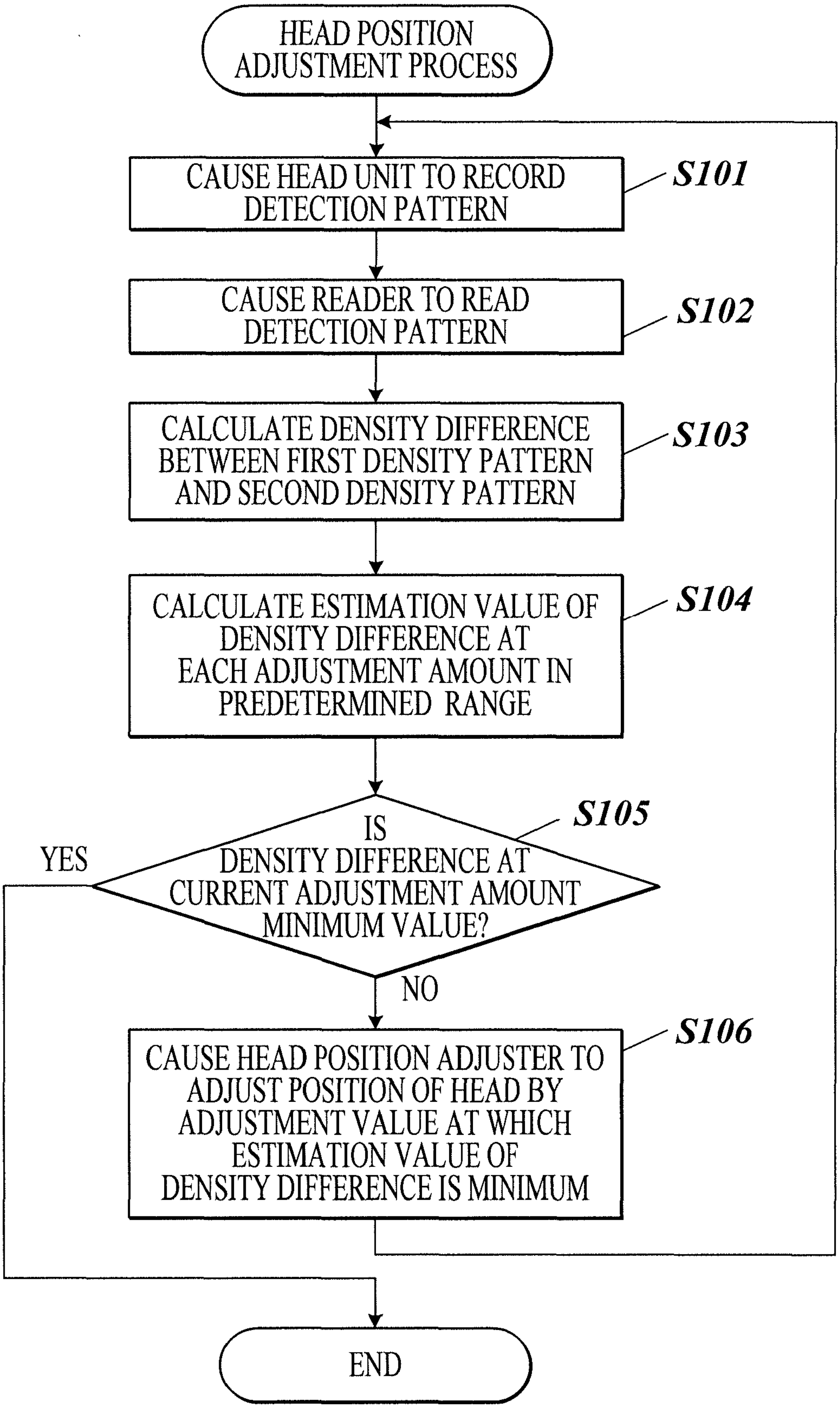

HEAD POSITION ADJUSTMENT PROCESS
CAUSE HEAD UNIT TO RECORD DETECTION PATTERN
S101
CAUSE READER TO READ DETECTION PATTERN
S102
CALCULATE DENSITY DIFFERENCE BETWEEN FIRST DENSITY PATTERN AND SECOND DENSITY PATTERN
S103
CALCULATE ESTIMATION VALUE OF DENSITY DIFFERENCE AT EACH ADJUSTMENT AMOUNT IN PREDETERMINED RANGE
S104
IS DENSITY DIFFERENCE AT CURRENT ADJUSTMENT AMOUNT MINIMUM VALUE?
S105
YES
NO
CAUSE HEAD POSITION ADJUSTER TO ADJUST POSITION OF HEAD BY ADJUSTMENT VALUE AT WHICH ESTIMATION VALUE OF DENSITY DIFFERENCE IS MINIMUM
S106
END

FIG.10A

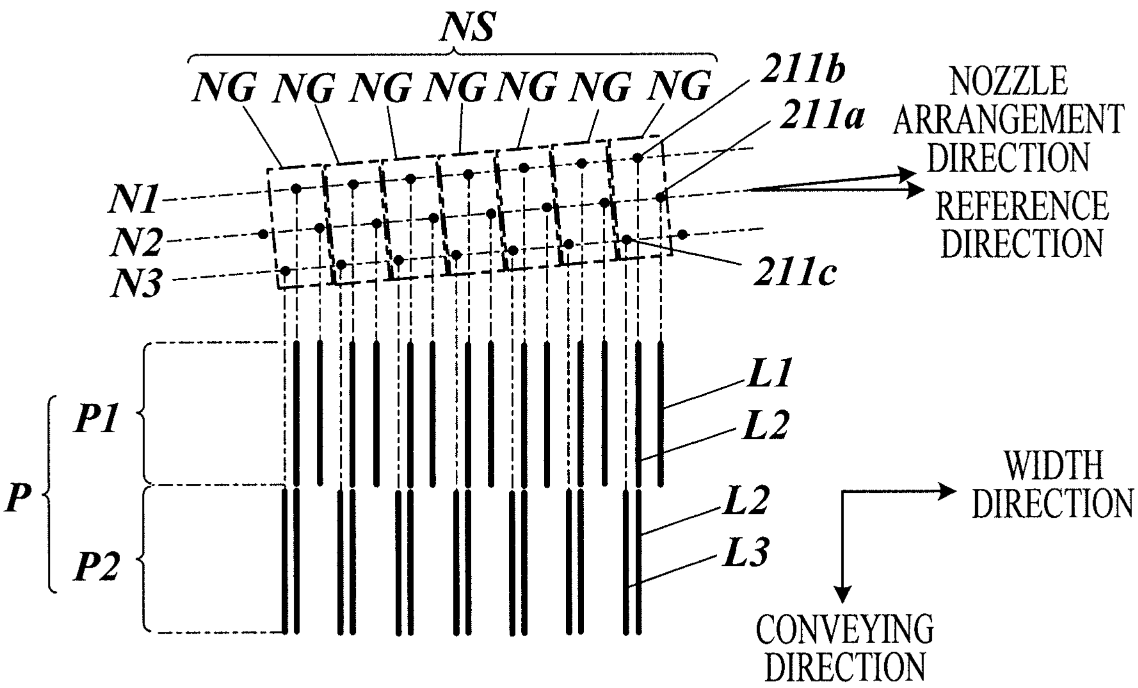


FIG.10B

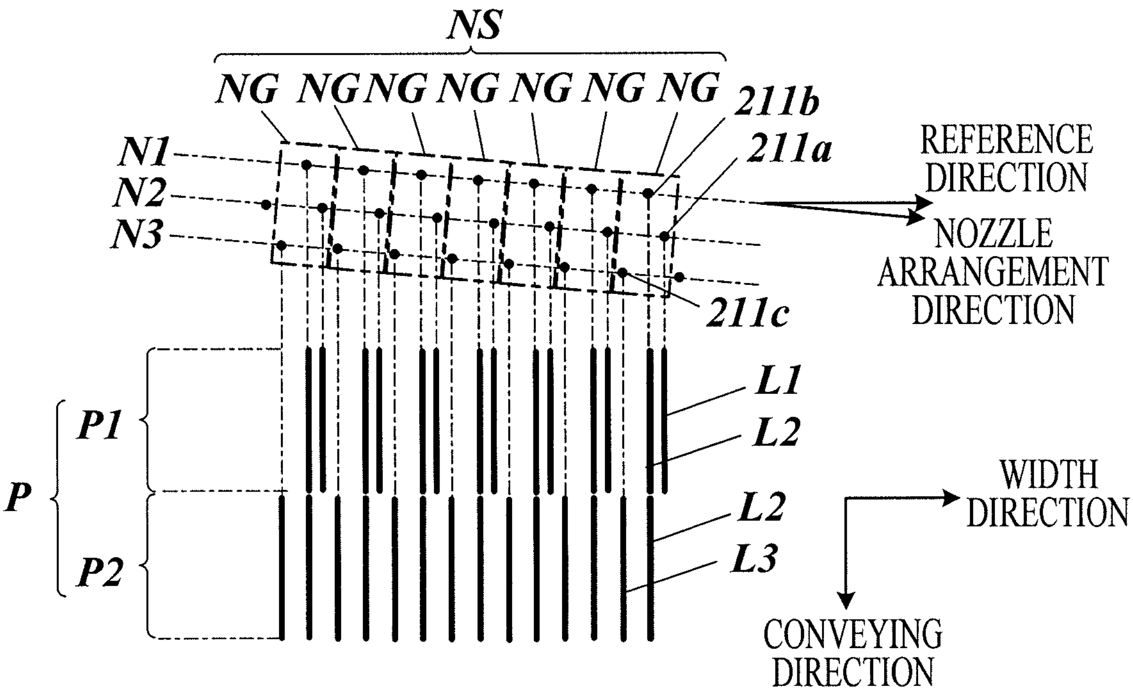


FIG.11A

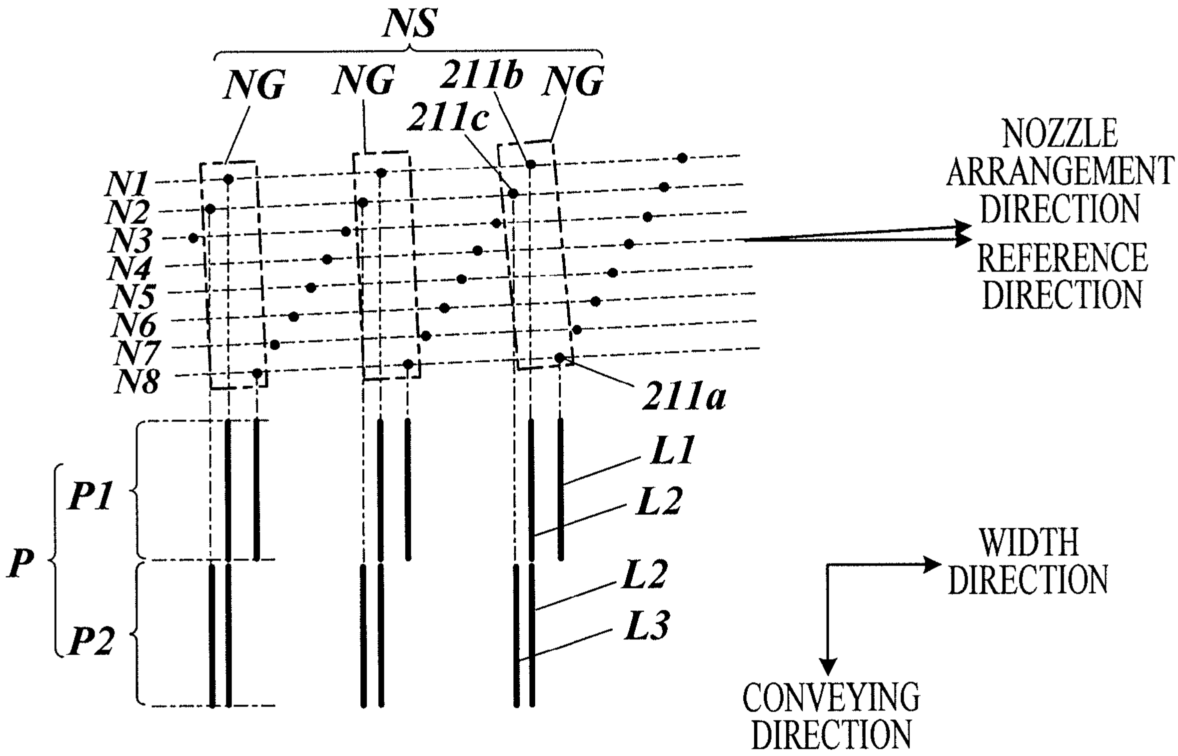


FIG.11B

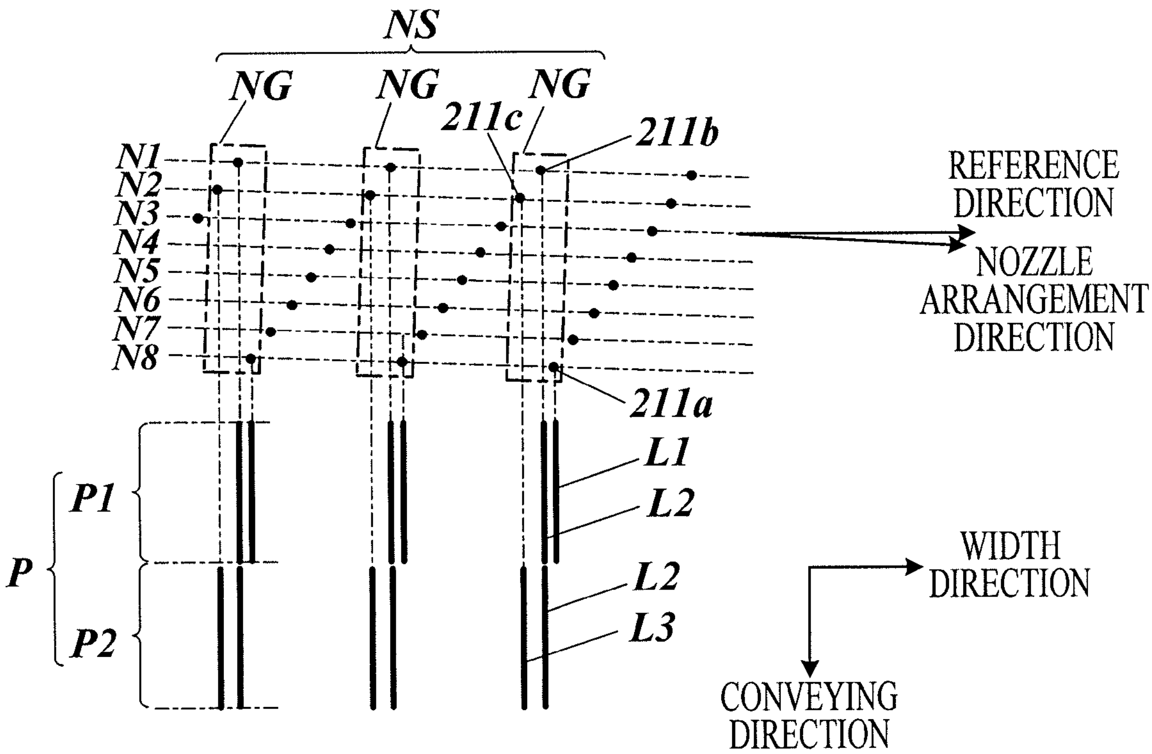


FIG.12A

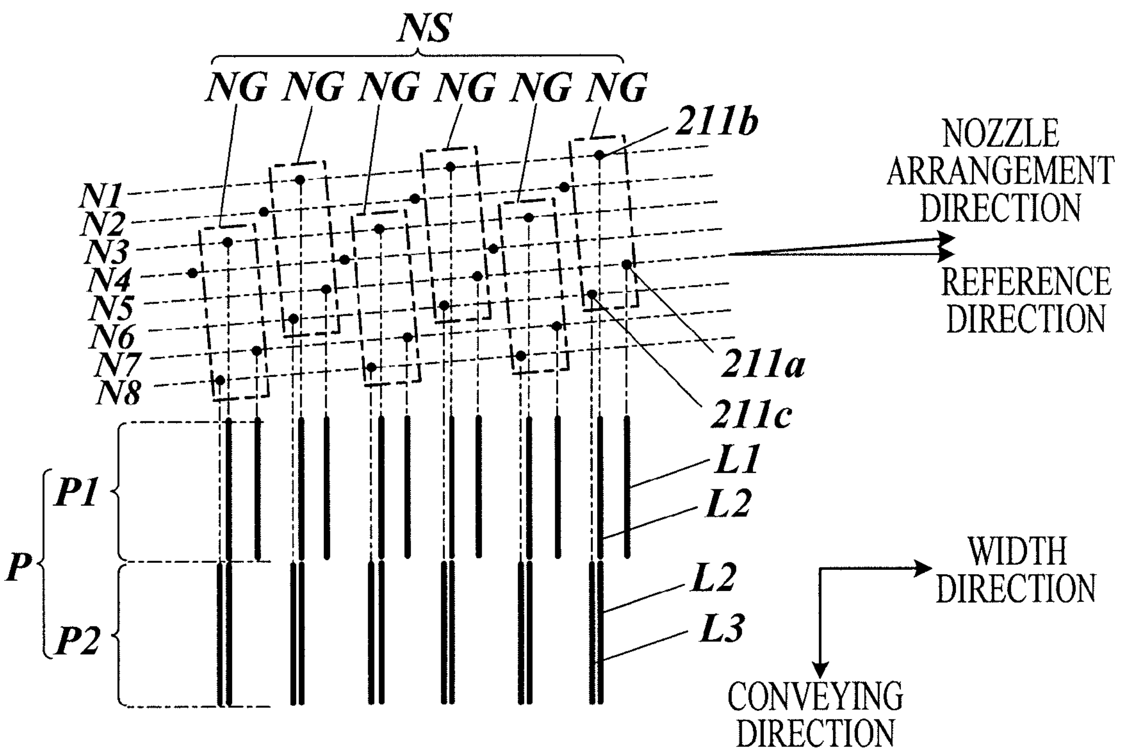
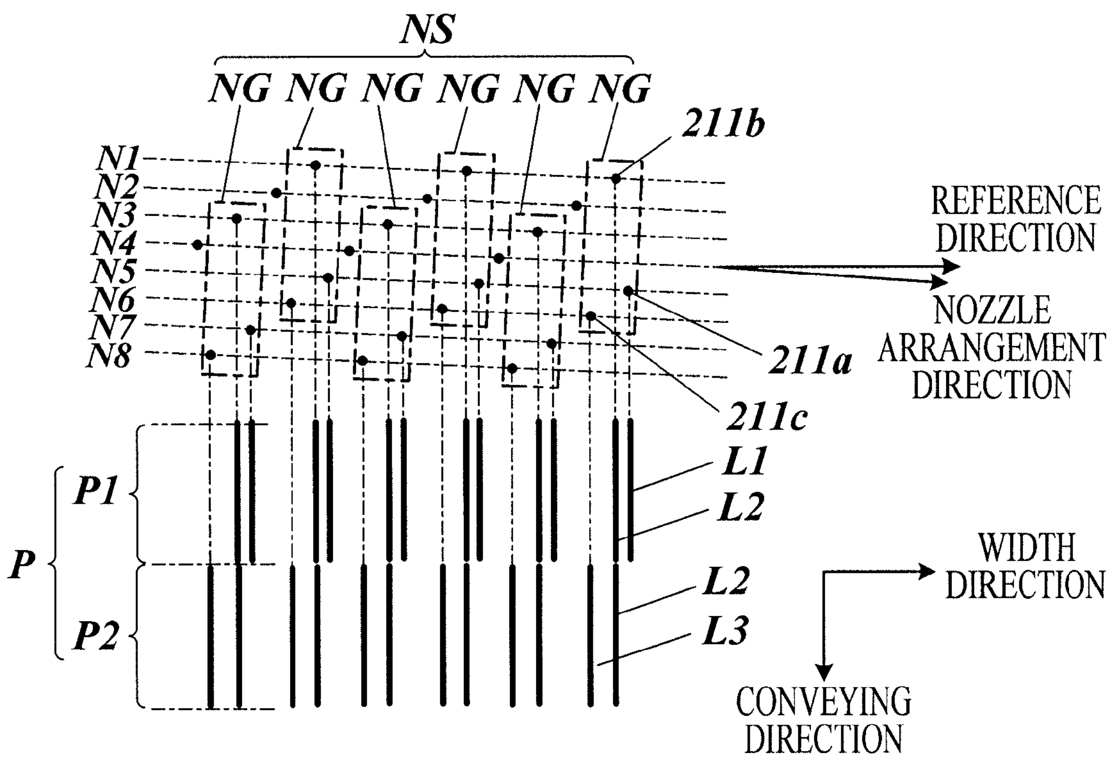


FIG.12B



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EUROPEAN SEARCH REPORT

Application Number
EP 19 16 0592

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2010/026747 A1 (MIYAMOTO TORU [JP] ET AL) 4 February 2010 (2010-02-04) * the whole document * -----	1-12	INV. B41J2/21 B41J2/155 B41J25/00
A	US 2010/039466 A1 (TAKAHASHI TORU [JP] ET AL) 18 February 2010 (2010-02-18) * 119: serial <-> line; the whole document * -----	1,11,12	
A	JP 2014 226911 A (BROTHER IND LTD) 8 December 2014 (2014-12-08) * the whole document * -----	1,11,12	
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TECHNICAL FIELDS SEARCHED (IPC)

B41J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	9 July 2019	Hartmann, Mathias

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09-07-2019

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		US 2010026747 A1	04-02-2010
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Patent documents cited in the description

- JP 2009137015 A **[0004]**