(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 034 308 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.06.2016 Bulletin 2016/25

(51) Int Cl.:
B41J 11/00 *(2006.01)* ***B41J 2/21*** *(2006.01)*
B41J 25/00 *(2006.01)*

(21) Application number: **15191552.7**

(22) Date of filing: **27.10.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

(30) Priority: **30.10.2014 JP 2014221101**

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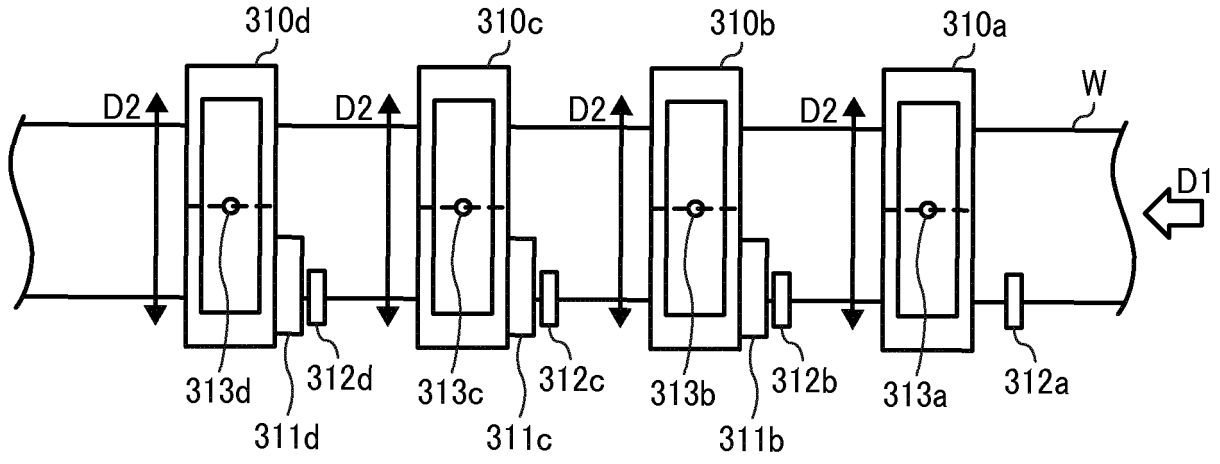
(54) IMAGE FORMING APPARATUS

(57) An image forming apparatus includes a conveyor (201), head units (310a, 310b, 310c, 310d), edge sensors (312a, 312b, 312c, 312d), an actuator (311b, 311c, 311d), a memory (416), and a controller (417). The edge sensors (312a, 312b, 312c, 312d) are arranged in correspondence with at least two sensor-corresponding head units of the head units, to detect edge positions of the recording medium in a direction perpendicular to a conveyance direction of the recording medium. The actuator (311b, 311c, 311d) moves at least one actuator-driven head unit of the sensor-corresponding head units in the direction perpendicular to the conveyance direction. The memory (416) stores reference values generated in advance based on data on the edge positions read by the edge sensors. The controller (417) controls the actuator according to the edge positions read by the edge sensors and the reference values to correct a position of the actuator-driven head unit.

FIG. 3



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Description

BACKGROUND

Technical Field

[0001] Embodiments of this disclosure relate to an image forming apparatus that has a line head composed of a plurality of head units.

Related Art

[0002] Conventionally, there is known an image forming apparatus such as a line-type inkjet printer, for example, that performs printing on a recording medium by discharging ink droplets onto the recording medium from a plurality of head units aligned from upstream to downstream sides in the conveyance direction of the recording medium.

[0003] There is a technique by which to detect data on edge position of a recording medium by edge sensors in the vicinities of a plurality of head units, and correct the positions of the head units according to the edge position data. Specifically, comparison is made between the data on the edge position of the recording medium detected by the edge sensor (upstream edge sensor) arranged in correspondence with the head unit at upstream side of the conveyance direction of the recording medium and the edge sensor (downstream edge sensor) arranged in correspondence with the head unit at the downstream side of the conveyance direction of the recording medium to calculate the relative positional relation between the edge position of the recording medium at the location of the upstream head unit and the edge position of the recording medium at the location of the downstream head unit. Then, according to the relative positional relation, an actuator for moving the head unit at the downstream side of the conveyance direction of the recording medium is controlled to correct the position of the downstream head unit. Accordingly, even when the position of the recording medium varies during its conveyance, the head units can discharge ink droplets to the desired points on the recording medium, thereby suppressing printing failures due to deviation in discharging points of ink droplets.

[0004] Due to apparatus assembly errors and individual differences among the edge sensors, the edge positions of the recording medium detected by the edge sensors may not match the actual edge positions but include a certain degree of error relative to the actual edge positions. According to a technique of JP-2011-136526-A, however, the position of the downstream head unit is corrected on the assumption that the edge positions of the recording medium detected by the upstream edge sensor and the downstream edge sensor match the actual edge positions of the recording medium.

[0005] When the relative positional relation between the edge position of the recording medium at the location of the upstream head unit and the edge position of the recording medium at the location of the downstream head unit is calculated as described in JP-2011-136526-A, the resultant relative positional relation is inaccurate by the error described above. In the technique of JP-2011-136526-A, the position of the head unit is corrected according to the inaccurate relative positional relation by the error, there is the possibility that a printing failure occurs due to deviations in discharging points of ink droplets even after the correction of the position of the head unit.

SUMMARY

[0006] In an aspect of the present disclosure, there is provided an image forming apparatus that includes a conveyor, a plurality of head units, a plurality of edge sensors, an actuator, a memory, and a controller. The conveyor conveys a recording medium. The plurality of head units are arranged side by side with certain spacing therebetween in a conveyance direction of the recording medium. The plurality of head units include discharge ports to discharge droplets on the recording medium. The plurality of edge sensors are arranged in correspondence with at least two sensor-corresponding head units of the plurality of head units, to detect edge positions of the recording medium in a direction perpendicular to the conveyance direction of the recording medium. The actuator moves at least one actuator-driven head unit of the at least two sensor-corresponding head units in the direction perpendicular to the conveyance direction of the recording medium. The memory stores reference values generated in advance based on data on the edge positions of the recording medium read by the plurality of edge sensors. The controller controls the actuator according to the edge positions of the recording medium read by the plurality of edge sensors and the reference values to correct a position of the at least one actuator-driven head unit.

[0007] According to this disclosure, a configuration having a plurality of head units aligned over a recording medium from upstream to downstream sides of the conveyance direction of the recording medium makes it possible to suppress occurrence of color deviation in printing on the recording medium.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0008] The aforementioned and other aspects, features, and advantages of the present disclosure would be better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a diagram illustrating an example of entire configuration of a production printer according to an embodiment;

Fig. 2 is a schematic side cross-sectional view of an

example of an image forming unit in the production printer according to the embodiment;
Fig. 3 is a schematic plan view of an example of the image forming unit in the production printer according to the embodiment;
Fig. 4 is a block diagram illustrating a configuration of a control system that corrects the positions of ink head units at the image forming unit according to the embodiment;
Figs. 5A through 5D are illustrations of an overview of correction of the positions of the ink head units according to the embodiment;
Fig. 6 is a block diagram illustrating a configuration of a control system that performs a reference-value adjustment operation at the correction of the position of the ink head units according to the embodiment;
Fig. 7 is an illustration of a method for determining the stability of conveyance of continuous-form paper W by a K-Y controller in the control system that performs the reference-value adjustment operation according to the embodiment;
Fig. 8 is a flowchart of an example of a reference-value adjustment control in the control system that performs the reference-value adjustment operation according to the embodiment;
Fig. 9 is a flowchart of an example of a process for determining the stability of conveyance of the continuous-form paper W by a K-C controller in the control system that performs the reference-value adjustment operation according to the embodiment; and
Fig. 10 is an illustration of details of determination on whether the conveyance of the continuous-form paper W is stabled at step S37 described in Fig. 9 according to the embodiment.

[0009] The accompanying drawings are intended to depict embodiments of the present disclosure and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted.

DETAILED DESCRIPTION

[0010] In describing embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this patent specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner and achieve similar results.

[0011] Although the embodiments are described with technical limitations with reference to the attached drawings, such description is not intended to limit the scope of the disclosure and all of the components or elements described in the embodiments of this disclosure are not necessarily indispensable.

[0012] Referring now to the drawings, embodiments of the present disclosure are described below. In the drawings for explaining the following embodiments, the same reference codes are allocated to elements (members or components) having the same function or shape and redundant descriptions thereof are omitted below.

[0013] Fig. 1 is a diagram illustrating an example of entire configuration of a production printer 110 as an image forming apparatus according to an embodiment. The production printer 110 is a high-speed printer for use in high-volume printing of 100 pages or more per minute, for example, and is capable of applying ink on a continuous-form recording medium such as continuous-form paper W. The continuous-form paper W is conveyed by one or more feed rollers 130 in the direction of arrow D1 in Fig. 1 and fed to the outside of the production printer 110. During the printing operation, the feed roller 130 performs positioning and tension adjustment of the continuous-form paper W.

[0014] An image forming unit of the production printer 110 is an inkjet type that does printing on the recording medium by discharging ink droplets from ink heads of a plurality of ink head units according to image data. Fig. 2 is a schematic side cross-sectional view of an example of an image forming unit in the production printer 110. As illustrated in Fig. 2, the image forming unit of the production printer 110 is provided with a conveyor 201 that holds and conveys the continuous-form paper W to be printed, and a printing unit 202 that executes printing on the continuous-form paper W held and conveyed by the conveyor 201.

[0015] The conveyor 201 is composed of a first drive roller 232, a second drive roller 233, guide rollers 234, and the like. At least one of the first drive roller 232 and the second drive roller 233 is driven for rotation by a drive source such as a motor not illustrated. The tension of the continuous-form paper W is adjusted between the first drive roller 232 and the second drive roller 233.

[0016] The printing unit 202 includes a first head unit 310a, a second head unit 310b, a third head unit 310c, and a fourth head unit 310d that discharge ink droplets.

[0017] Fig. 3 is a schematic plan view of an example of the image forming unit in the production printer 110. As illustrated in Fig. 3, the image forming unit has the first head unit 310a, the second head unit 310b, the third head unit 310c, and the fourth head unit 310d aligned at certain spacing between them in this order from the upstream side of the conveyance direction of the continuous-form paper W (shown by arrow D1 in Fig. 3). There is no particular limitation on the kinds of ink droplets used in the ink head units. For example, ink droplets of black (K), cyan (C), magenta (M), and yellow (Y) may be used in the individual ink head units. There is also no limitation on which color of ink droplets to be used at which of the ink head units. For example, ink droplets of black (K) may be used at the first head unit 310a, ink droplets of cyan (C) at the ink head unit 310b, ink droplets of magenta (M) at the ink head unit 310c, and ink droplets of yellow (Y) at the ink head unit 310d.

[0018] The first head unit 310a, the second head unit

310b, the third head unit 310c, and the fourth head unit 310d have ink discharge nozzles 313a, 313b, 313c, and 313d, respectively, as discharge ports for discharging ink droplets. In addition, the ink head units 310b, 310c, and 310d have actuators 311b, 311c, and 311d for moving the ink head units 310b, 310c, and 310d in a direction (shown by arrows D2 in Fig. 3) perpendicular to the conveyance direction of the continuous-form paper W. In this embodiment, the ink head unit 310a at the most upstream side of the conveyance direction of the continuous-form paper W is set as a reference ink head unit, and the position of the ink head unit 310a in the direction perpendicular to the conveyance direction of the continuous-form paper W is fixed. Accordingly, the ink head unit 310a is not provided with an actuator. Alternatively, as the other ink head units, the ink head unit 310a may be provided with an actuator to move the position of the ink head unit 310a in the direction perpendicular to the conveyance direction of the continuous-form paper W.

[0019] In the vicinities of the ink head units 310a, 310b, 310c, and 310d at the upstream side of the conveyance direction of the continuous-form paper W (shown by arrow D1 in Fig. 3), edge sensors 312a, 312b, 312c, and 312d are arranged, respectively, to detect the edge position of the continuous-form paper W perpendicular to the conveyance direction of the continuous-form paper W. Using the data on the edge positions of the continuous-form paper W detected by the edge sensors 312a, 312b, 312c, and 312d, the positions of the ink head units 310b, 310c, and 310d are corrected. The correction of the positions of the ink head units will be described later in detail.

[0020] Fig. 4 is a block diagram illustrating a configuration of a control system that corrects the positions of the ink head units. A read controller 410 detects output values from the edge sensors 312a, 312b, 312c, and 312d at every sampling cycle, and converts the same into data from which unnecessary frequency components are removed by filtering (hereinafter, referred to as sensor readings). These sensor readings are saved in a memory 416. The sensor reading from the edge sensor 312a is held in the memory 416 until the edge position of the continuous-form paper W read by the edge sensor 312a passes through the edge sensor 312d. The readings from the edge sensors except for the edge sensor 312a are overwritten as needed. A recording-position correction controller 417 performs necessary arithmetic operations on the data saved in the memory 416, and controls the actuators 311b, 311 c, and 311d based on the results of the arithmetic operations.

[0021] Figs. 5A through 5D are illustrations of an overview of correction of the positions of the ink head units. The following description will be given with reference to Fig. 4 as appropriate. As illustrated in Fig. 5A, for example, no color deviation occurs in printing on the continuous-form paper W when a line linking the ink discharge nozzles 313a, 313b, 313c, and 313d is parallel to a line formed by the edge of the continuous-form paper W. The line formed by the edge of the continuous-form paper W in the ideal state with no occurrence of color deviation in printing as described above will be designated as a reference line L. In addition, in this state, the sensor readings of the edge positions of the continuous-form paper W detected by the edge sensors 312a, 312b, 312c, and 312d will be designated as reference values r1, r2, r3, and r4. The reference values r1, r2, r3, and r4 vary among the apparatuses and the edge sensors depending on apparatus assembly errors, individual differences among the sensors, and the like. Accordingly, at the time of installation of an apparatus or replacement of edge sensors, it is necessary to make a reference value adjustment for determining reference values described later.

[0022] As illustrated in Fig. 5B, if the line formed by the edge of the continuous-form paper W deviates from the reference line L, the line linking the ink discharge nozzles 313a, 313b, 313c, and 313d is no longer parallel to the reference line L, thereby causing a color deviation in printing on the continuous-form paper W. To suppress occurrence of a color deviation, the positions of the ink head units need corrections.

[0023] Referring to Figs. 5C and 5D, a specific method for correcting the positions of the ink head units will be described taking the ink head unit 310b as an example. As illustrated in Fig. 5C, the sensor reading on the edge sensor 312a when a certain section of the continuous-form paper W (shaded section S in Fig. 5C) passes through the edge sensor 312a will be designated as p1. The recording-position correction controller 417 calculates the difference (deviation d1) between the sensor reading p1 and the reference value r1 on the edge sensor 312a. As illustrated in Fig. 5D, the sensor reading on the edge sensor 312b when the certain section of the continuous-form paper W (shaded section S in Fig. 5D) passes through the edge sensor 312b will be designated as p2. The recording-position correction controller 417 calculates the difference (deviation d2) between the sensor reading p2 and the reference value r2 on the edge sensor 312b.

[0024] The edge positions of the recording medium detected by the edge sensors include errors relative to the actual edge positions. The sensor reading p1 and the reference value r1 on the edge sensor 312a are both the values detected by the edge sensor 312a and thus include errors of the same magnitude. Accordingly, the errors are canceled out by taking the difference (deviation d1) between the sensor reading p1 and the reference value r1 on the edge sensor 312a. Similarly, the errors are canceled out by taking the difference (deviation d2) between the sensor reading p2 and the reference value r2 on the edge sensor 312b.

[0025] The read controller 410 determines a relative deviation value D1 by calculating the difference between the positional deviation d1 and the positional deviation d2. The relative deviation value D1 represents the relative positional relation between the edge position of the continuous-form paper W at the location of the ink head

unit 310b and the edge position of the continuous-form paper W at the location of the ink head unit 310a. As described above, the errors are canceled out by taking the positional deviation d1 and the positional deviation d2, and thus no error is included in the relative deviation value D1 calculated by the difference between the positional deviation d1 and the positional deviation d2. The recording-position correction controller 417 controls the actuator 311b according to the relative deviation value D1 to correct the position of the ink head unit 310b.

[0026] The recording positions of the ink head units 310c and 310d are also corrected by the same method as that for the correction of the recording position of the ink head unit 310b described above. Specifically, the recording-position correction controller 417 calculates relative deviation values D2 and D3 of the edge positions of the continuous-form paper W at the locations of the ink head units 310c and 310d from the edge position of the continuous-form paper W at the location of the ink head unit 310a. Then, the recording-position correction controller 417 controls the actuators 311c and 311d according to the relative deviation values D2 and D3 to correct the positions of the ink head units 310c and 310d.

[0027] When the position of the ink head unit 310a is movable in the direction perpendicular to the conveyance direction of the continuous-form paper W, the amount of movement of the ink head unit 310a is added to the relative deviation values D1, D2, and D3.

[0028] Reference value adjustment will be described in outline. It has been experimentally confirmed that, while the continuous-form paper W is stably conveyed, the line linking the ink discharge nozzles 313a, 313b, 313c, and 313d is parallel to the line formed by the edge of the continuous-form paper W and no color deviation occurs in printing on the continuous-form paper W. That is, it can be determined whether the line linking the ink discharge nozzles 313a, 313b, 313c, and 313d is parallel to the line formed by the edge of the continuous-form paper W by determining whether the continuous-form paper W is stably conveyed.

[0029] When it is determined that the continuous-form paper W is stably conveyed, the sensor readings of the edge positions of the continuous-form paper W detected by the edge sensors 312a, 312b, 312c, and 312d are to be the reference values r1, r2, r3, and r4. It can be automatically determined whether the continuous-form paper W is stably conveyed as described below. Therefore, according to this embodiment, reference value adjustment can be automatically made.

[0030] Fig. 6 is a block diagram illustrating a configuration of a control system that performs a reference-value adjustment operation. A reference-value adjustment controller 411 has individual controllers, that is, a K-C controller 412, a K-M controller 413, and a K-Y controller 414, and a general controller 415 that collectively controls the individual controllers. The K-C controller 412 reads from the memory 416 the reading p1 on the edge sensor 312a and the reading p2 on the edge sensor 312b, and calculates the difference between these readings to determine whether the continuous-form paper W is stably conveyed. The K-C controller 412 determines that the continuous-form paper W is stably conveyed when the calculated difference falls within a prescribed range for a certain period of time. When it is determined that the continuous-form paper W is stably conveyed, the general controller 415 calculates the reference values r1, r2, r3, and r4 from the sensor readings of the edge positions of the continuous-form paper W detected by the edge sensors 312a, 312b, 312c, and 312d, respectively. These reference values r1, r2, r3, and r4 are saved in the memory 416.

[0031] The K-M controller 413 and the K-Y controller 414 determine whether the continuous-form paper W is stably conveyed as the K-C controller 412 does. The K-M controller 413 determines whether the continuous-form paper W is stably conveyed by the difference between the reading p1 on the edge sensor 312a and the reading p3 on the edge sensor 312c. The K-Y controller 414 determines whether the continuous-form paper W is stably conveyed by the difference between the reading p1 and the reading p4 on the edge sensor 312d.

[0032] Fig. 7 is an illustration of a method for determining the stability of conveyance of continuous-form paper W by the K-Y controller 414. Referring to Fig. 7, the horizontal axis indicates the time and the vertical axis the readings. Curves K and Y in Fig. 7 are plots of readings on the edge sensors 312a and 312d, respectively. A curve K_Deviation deviates from the curve K by the time determined by dividing the distance between the edge sensor 312a and the edge sensor 312d by the conveyance speed of the continuous-form paper W. This allows the comparison between the readings p1 and p4 of the edge positions detected by the edge sensors 312a and 312d in the same section of the continuous-form paper W. By comparing the readings of the edge positions in the same section of the continuous-form paper W, it is possible to determine whether the continuous-form paper W is stably conveyed in a more accurate manner.

[0033] A curve Y-K_Deviation constitutes the difference between the curve Y and the curve K_Deviation. By the curve Y-K_Deviation, it is possible to determine the degree of variations in the edge position of the continuous-form paper W between the edge sensor 312a and the edge sensor 312d in the direction perpendicular to the conveyance direction of the continuous-form paper W. That is, it can be said that, when the variations in the curve Y-K_Deviation are large, the continuous-form paper W is unstably conveyed between the edge sensor 312a and the edge sensor 312d. In contrast, it can be said that, when the variations in the curve Y-K_Deviation are small, the continuous-form paper W is stably conveyed between the edge sensor 312a and the edge sensor 312d.

[0034] During the period of time between P and Q in Fig. 7, the variations in the curve Y-K_Deviation fall within a predetermined range $\pm \alpha$ over a predetermined certain

time T. Accordingly, the K-Y controller 414 determines that the continuous-form paper W is stably conveyed for the period of time indicated by P and Q. Hereinafter, the curve such as the curve Y-K_Deviation in Fig. 7 will be referred to as "variation curve." In addition, the period of time during which the individual controller determines that the continuous-form paper W is stably conveyed such as the period of time T indicated by P and Q in Fig. 7 will be referred to as "individual stable period."

[0035] The methods for determining the stability of conveyance of the continuous-form paper W by the K-C controller 412 and the K-M controller 413 are the same as the foregoing method for determining the stability of conveyance of the continuous-form paper W by the K-Y controller 414. Specifically, each of the K-C controller 412 and the K-M controller 413 determines that the continuous-form paper W is stably conveyed when the variations in the variation curve fall within a certain range $\pm \alpha$ over the certain time T.

[0036] The general controller 415 illustrated in Fig. 6 determines that the continuous-form paper W is stably conveyed when all of the K-C controller 412, the K-M controller 413, and the K-Y controller 414 have determined that the continuous-form paper W is stably conveyed. That is, the general controller 415 determines that the continuous-form paper W is stably conveyed when all of the individual stable periods at the K-C controller 412, the K-M controller 413, and the K-Y controller 414 overlap. Hereinafter, the overlapped individual stable periods will be referred to as "overall stable period." The general controller 415 calculates the reference values on the edge sensors based on the sensor readings on the edge sensors during the overall stable period.

[0037] The determinations on the stability of conveyance of the continuous-form paper W by the individual controllers relate to the times required for conveyance of the continuous-form paper W between the edge sensor 312a as a reference and the edge sensors other than the edge sensor 312a. Accordingly, the individual controllers do not provide the results of determination at the same timing on whether the continuous-form paper W is stably conveyed. In this embodiment, the K-Y controller 414 provides at the latest timing the result of determination on whether the continuous-form paper W is stably conveyed between the edge sensor 312a as a reference and the edge sensor 312d. Therefore, at the timing when the K-Y controller 414 has provided the determination result, the general controller 415 determines whether the continuous-form paper W is stably conveyed.

[0038] When the general controller 415 provides the determination result indicating that the continuous-form paper W is not stably conveyed, the individual controllers continue to monitor the stability of conveyance of the continuous-form paper W. In case that the general controller 415 provides the determination result indicating that the conveyance is not stable, the K-C controller 412 and the K-M controller 413 start to monitor the next cycle on completion of the previous cycle even while the K-Y controller 414 continues to monitor the previous cycle. When the general controller 415 provides the determination result indicating that the conveyance of the continuous-form paper W is not stable after an elapse of a predetermined time, the controller may instructs displaying an error message.

[0039] The reference values can be calculated as described below, for example. The reference value r1 on the edge sensor 312a is calculated by averaging the sensor readings on the edge sensor 312a for the overall stable period. Each of the reference values on the edge sensors 312b, 312c, and 312d is calculated by averaging plot values in the differential curve for the overall stable period and adding the reference value r1 on the edge sensor 312a to the averaged value.

[0040] Fig. 8 is a flowchart of an example of a reference-value adjustment control in the control system that performs the reference-value adjustment operation. At step S1, the conveyance of the continuous-form paper W is started. At step S2, each of the edge sensors starts to read the edge position of the continuous-form paper W At step S3, each of the individual controllers monitors the stability of conveyance of the continuous-form paper W based on the readings on the edge sensors saved in the memory 416. The details of step S3 will be described later.

[0041] At step S4, the general controller 415 determines whether the continuous-form paper W is stably conveyed according to the results of monitoring for the stability of conveyance of the continuous-form paper W by the individual controllers. When the continuous-form paper W is not stably conveyed (NO at S4), the general controller 415 returns to step S3. When the continuous-form paper W is stably conveyed (YES at S4), the general controller 415 moves to step S5. At step S5, the reference values on the edge sensors are calculated. At step S6, the reference values calculated at step S5 are saved in the memory 416.

[0042] The operation at step S3 in Fig. 8 will be described taking an example of the operation in the K-C controller 412 as an example. The K-M controller 413 and the K-Y controller 414 perform basically the same operation as that of the K-C controller 412. Fig. 9 is a flowchart of an example of a process for determining the stability of conveyance of the continuous-form paper W by the K-C controller 412. At step S30, the K-C controller 412 determines whether an end instruction is received from the general controller 415. When an end instruction is received (YES at S30), the process is terminated. When no end instruction is received (NO at S30), the K-C controller 412 moves to step S31. At step S31, the K-C controller 412 acquires from the memory 416 the latest sensor reading on the edge sensor 312b and the sensor reading on the edge sensor 312a preceding by the time obtained by dividing the distance between the edge sensor 312a and the edge sensor 312b by the conveyance speed. At step S32, the K-C controller 412 calculates the difference between the two sensor readings acquired at

step S31. At step S33, the K-C controller 412 adds the value of the difference calculated at step S32 to a summation variable SUM (initial value is 0) and increments a difference data count k (initial value is 0) by 1.

[0043] At step S34, the K-C controller 412 determines whether the difference data count k is a threshold number or greater. When the difference data count k is smaller than the threshold number (NO at S34), the K-C controller 412 returns to step S30. When the difference data count k is the threshold number or greater (YES at S34), the K-C controller 412 moves to step S35. At step S35, the K-C controller 412 divides the summation variable SUM by the difference data count k to calculate the average of the differences between the two sensor readings acquired at step S31, and sets the difference data count k to the initial value of 0, and then increments an average data count n (initial value is 0) by 1.

[0044] At step S36, the K-C controller 412 determines whether the average data count n is a threshold number or greater. When the average data count n is smaller than the threshold number (NO at S36), the K-C controller 412 returns to step S30. When the average data count n is the threshold number (YES at S36), the K-C controller 412 moves to step S37. At step S37, the K-C controller 412 uses the average data determined at step S35 to determine whether the continuous-form paper W is stably conveyed. The details of the determination will be described later. When not determining that the conveyance is stable at step S37 (NO at S37), the K-C controller 412 moves to step S38. When determining that the conveyance of the continuous-form paper W is stable at step S37 (YES at S37), the K-C controller 412 moves to step S39. At step S38, the K-C controller 412 deletes the oldest one of the average values calculated at step S35, and decrements the average data count n by 1, and then returns to step S30. At step S39, the K-C controller 412 sets the average data count n to 0 and moves to step S4 in Fig. 8.

[0045] Fig. 10 is a diagram describing the details of the determination at step S37 described in Fig. 9 on whether the continuous-form paper W is stably conveyed. Referring to Fig. 10, the vertical axis indicates the average values determined at step S35, and the horizontal axis indicates the cycle numbers of the average values (corresponding to the average data counts n). A cycle number of 1 is assigned to the oldest average value, and the following cycle numbers are assigned to the next older average values in order of increasing. In this embodiment, the number of the average values for use in determination on the stability of conveyance of the continuous-form paper W is five and a threshold range is $\pm 5\mu m$. The threshold range is determined based on an allowable deviation range from an average value when color deviations from the average value fall within the range of $\pm 3\sigma$. When the average value with the cycle number 1 is set as a reference value and all of the differences between the average values with the following cycle numbers 2, 3, and 4 and the reference value fall within the range of $\pm 5\ \mu m$, it is determined that the continuous-form paper W is stably conveyed.

[0046] The method for reference value adjustment described above is a mere example, and the reference value adjustment may not be made by determining whether the continuous-form paper W is stably conveyed with reference to the reading p1 on the edge sensor 312a. Alternatively, the stability of the conveyance of the continuous-form paper W may be determined with reference to the reading on the edge sensor other than the edge sensor 312a. In addition, in this embodiment, four ink head units are provided and thus the three individual controllers are used. When the number of the ink head units is increased or decreased, the individual controllers may also be increased or decreased accordingly. In this case, the method for reference value adjustment is basically the same as the method described above. At the reference value adjustment, conditions are desirably set such the continuous-form paper W travels stably (the kind of the continuous-form paper W, the conveyance speed of the same, and others).

[0047] The embodiment described above is a mere example, and the present disclosure produces specific advantages in the following aspects:

(Aspect A)

[0048] An image forming apparatus includes: a plurality of head units such as the ink head units 310a, 310b, 310c, and 310d that are arranged side by side with certain spacing therebetween in a conveyance direction of a recording medium and have discharge ports such as the ink discharge nozzles 313a, 313b, 313c, and 313d to discharge droplets, such as ink droplets, on the recording medium; a plurality of edge sensors such as the edge sensors 312a, 312b, 312c, and 312d that are arranged in correspondence with at least two sensor-corresponding head units of the plurality of head units and detect edge positions of the recording medium in a direction perpendicular to the conveyance direction of the recording medium; at least one actuator such as the actuators 311b, 311 c, and 311d to move at least one actuator-driven head unit of the sensor-corresponding head units in the direction perpendicular to the conveyance direction of the recording medium; and a controller such as the recording position correction controller 417 to control the at least one actuator. The image forming apparatus further includes a memory such as the memory 416 to store data on the edge positions of the recording medium read by the plurality of edge sensors. The memory stores in advance reference values on the plurality of edge sensors as readings on the edge sensors of the edge positions of the recording medium as a reference. The controller calculates the differences between the edge positions of the recording medium read by the plurality of edge sensors and the reference values on the edge sensors, and uses the differences to control the actuators and correct the positions of the head units having the

actuators. The edge positions of the recording medium read by the edge sensors include errors resulting from apparatus assembly and individual differences among the edge sensors. The edge position of the recording medium read by one edge sensor and the reference value on the edge sensor are values read by the same edge sensor, and thus include an error of the same size. Accordingly, the foregoing error can be canceled out by taking the difference between the edge position of the recording medium read by the one edge sensor and the reference value on the edge sensor. By taking the difference between the difference in an edge sensor arranged in correspondence with one head unit having an actuator and the difference in an edge sensor arranged in correspondence with another head unit, it is possible to determine correctly the relative positional relation between the edge position of the recording medium at the location of the former head unit and the edge position of the recording medium at the location of the latter head unit. By correcting the position of the former head unit according to the relative positional relation, it is possible to raise correction accuracy and suppress occurrence of a color deviation in printing on the recording medium.

(Aspect B)

[0049] In the aspect A, when the sensor-corresponding head units include at least one actuator-less heat unit not having the actuator, the controller sets one of the at least one actuator-less head unit to a reference head unit, and when all of the at least two sensor-corresponding head units are actuator-driven head units having the actuator, the controller sets one of the at least two sensor-corresponding head units to the reference head unit. The controller determines whether the recording medium is stably conveyed by calculating a difference between an edge position of the recording medium read by at least one of the edge sensors arranged in correspondence with non-reference head units of the actuator-driven head units and an edge position of the recording medium read by an edge sensor of the edge sensors arranged in correspondence with the reference head unit, and determining whether variations in the difference fall within a predetermined threshold value over a predetermined period of time. The controller sets the edge position of the recording medium when the recording medium is stably conveyed as the reference edge position of the recording medium. Accordingly, the controller can automatically determine whether the recording medium is stably conveyed by determining whether variations in the difference fall within the predetermined threshold range over a predetermined period of time. It has been experimentally confirmed that, when the recording medium is stably conveyed, no color deviation occurs in printing on the recording medium. By setting the edge position of the recording medium when the recording medium is stably conveyed as a reference edge position of the recording medium, the reference edge position of the recording medium can be automatically determined. Accordingly, the reference values on the head units can also be automatically set. Such a configuration prevents the user from having to set the reference values when, after the replacement of edge sensors, the reference value is to be re-set on the new head unit.

(Aspect C)

[0050] In the aspect A or B, the edge sensors are arranged upstream from the sensor-corresponding head units in the conveyance direction of the recording medium.

(Aspect D)

[0051] In any one of the aspects A to C, when, on determination of whether the variations in the difference fall within the predetermined threshold range over the predetermined period of time, a determination result indicating that the recording medium is stably conveyed is not obtained after an elapse of a predetermined determination period, an error message is displayed. Accordingly, in the event of occurrence of any abnormality in the recording medium conveyance system, it is possible to prevent the determination on the parallelism from being continued for an unnecessarily long time.

(Aspect E)

[0052] In any one of the aspects A to D, the threshold range is determined by an allowable deviation amount from an average value of the difference set so that deviations from the average value between colors fall within a range of $\pm 3\sigma$.

Claims

1. An image forming apparatus, comprising:

a conveyor (201) to convey a recording medium;
a plurality of head units (310a, 310b, 310c, 310d) arranged side by side with certain spacing therebetween in a conveyance direction of the recording medium, the plurality of head units including discharge ports (313a, 313b, 313c, 313d) to discharge droplets on the recording medium;
a plurality of edge sensors (312a, 312b, 312c, 312d) arranged in correspondence with at least two sensor-corresponding head units of the plurality of head units, to detect edge positions of the recording medium in a direction perpendicular to the conveyance direction of the recording medium;
an actuator (311b, 311c, 311d) to move at least one actuator-driven head unit of the at least two

sensor-corresponding head units in the direction perpendicular to the conveyance direction of the recording medium;

a memory (416) to store reference values generated in advance based on data on the edge positions of the recording medium read by the plurality of edge sensors; and

a controller (417) to control the actuator according to the edge positions of the recording medium read by the plurality of edge sensors and the reference values to correct a position of the at least one actuator-driven head unit.

2. The image forming apparatus according to claim 1, wherein when the at least two sensor-corresponding head units include at least one actuator-less heat unit not having the actuator, the controller sets one of the at least one actuator-less head unit to a reference head unit,

wherein, when all of the at least two sensor-corresponding head units are actuator-driven head units having the actuator, the controller sets one of the at least two sensor-corresponding head units to the reference head unit, and

wherein the controller determines whether the recording medium is stably conveyed by calculating a difference between an edge position of the recording medium read by at least one edge sensor of the plurality of edge sensors arranged in correspondence with at least one non-reference head unit of the actuator-driven head units and an edge position of the recording medium read by an edge sensor of the plurality of edge sensors arranged in correspondence with the reference head unit, and determining whether variations in the difference fall within a predetermined threshold range over a predetermined period of time, and

the controller sets the edge positions of the recording medium read when the recording medium is stably conveyed, to reference edge positions of the recording medium.

3. The image forming apparatus according to claim 1 or 2, wherein the plurality of edge sensors are arranged upstream from the at least two sensor-corresponding head units in the conveyance direction of the recording medium.

4. The image forming apparatus according to any one of claims 1 to 3, wherein, when on determination of whether variations in the difference fall within a predetermined threshold range over a predetermined period of time, a determination result indicating that the recording medium is stably conveyed is not obtained after an elapse of a predetermined determination period, the controller instructs displaying an error message.

5. The image forming apparatus according to any one of claims 1 to 4, wherein the threshold range is determined based on an allowable deviation amount from an average value of the difference set so that deviations from the average value fall within a range of $\pm 3\sigma$.

FIG. 1

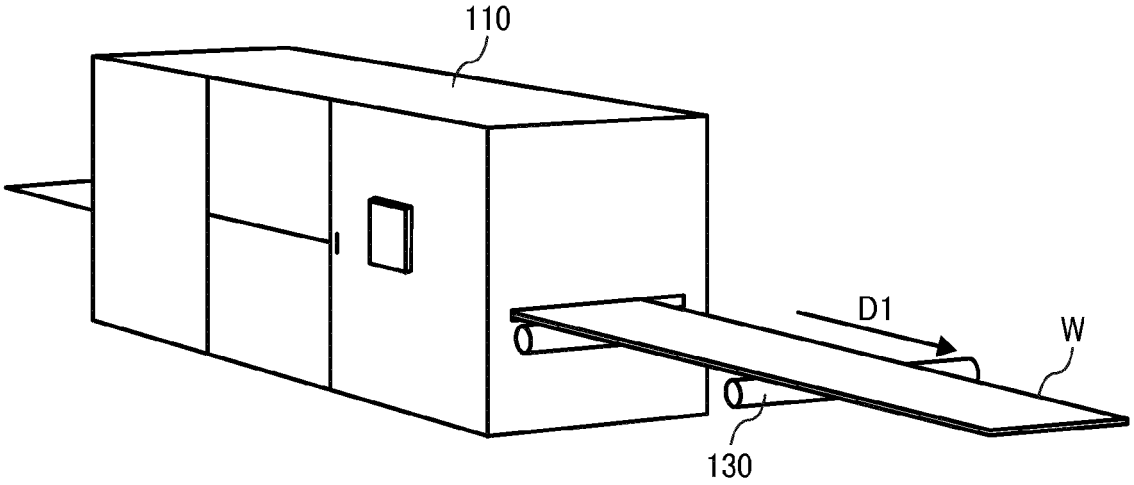


FIG. 2

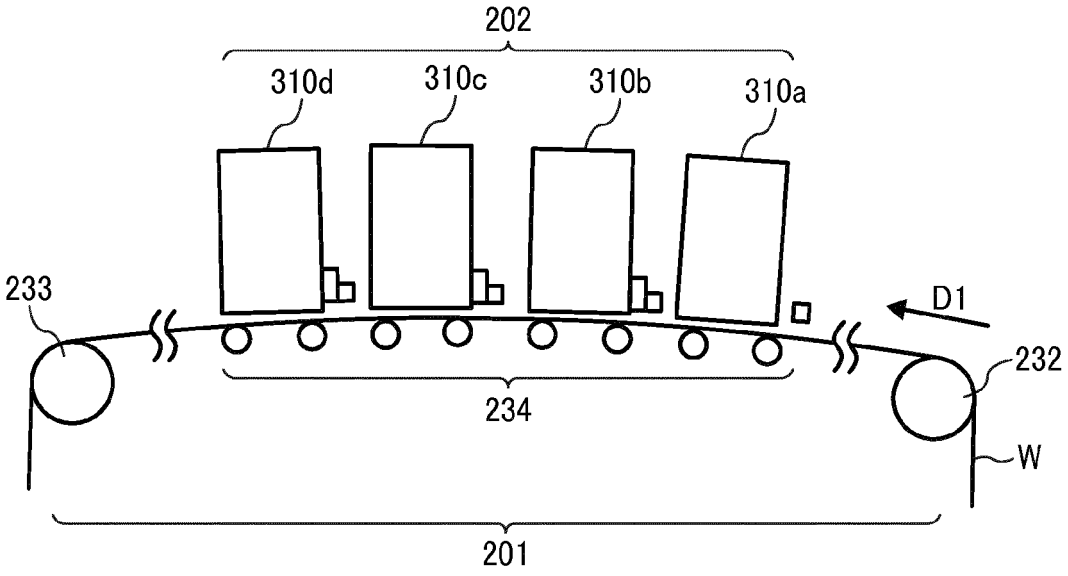


FIG. 3

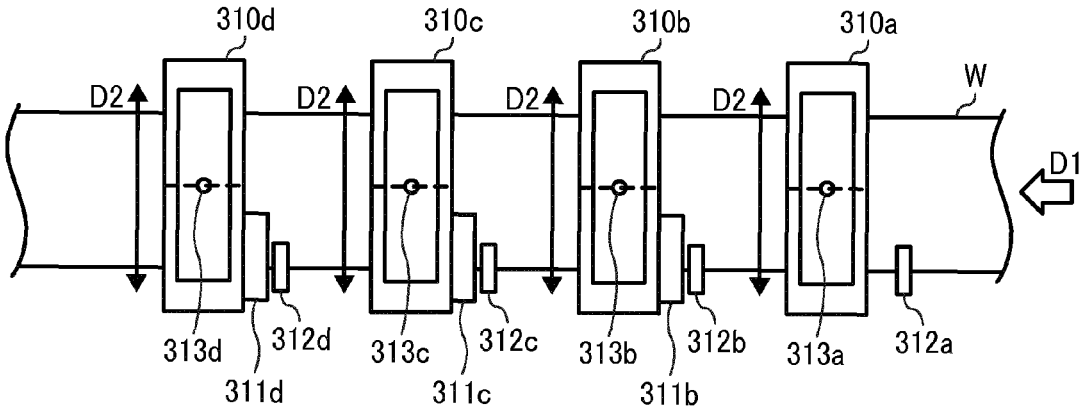

310d
310c
310b
310a
W
D2
D2
D2
D2
D1
313d
312d
311d
313c
312c
311c
313b
312b
311b
313a
312a

FIG. 4

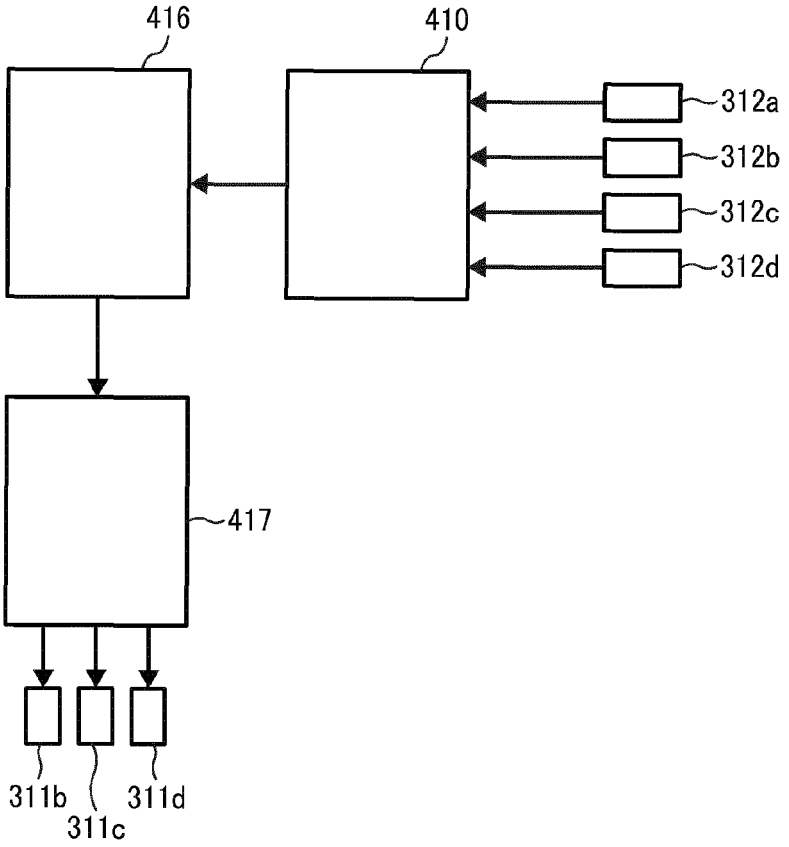

416
410
312a
312b
312c
312d
417
311b
311c
311d

FIG. 5A

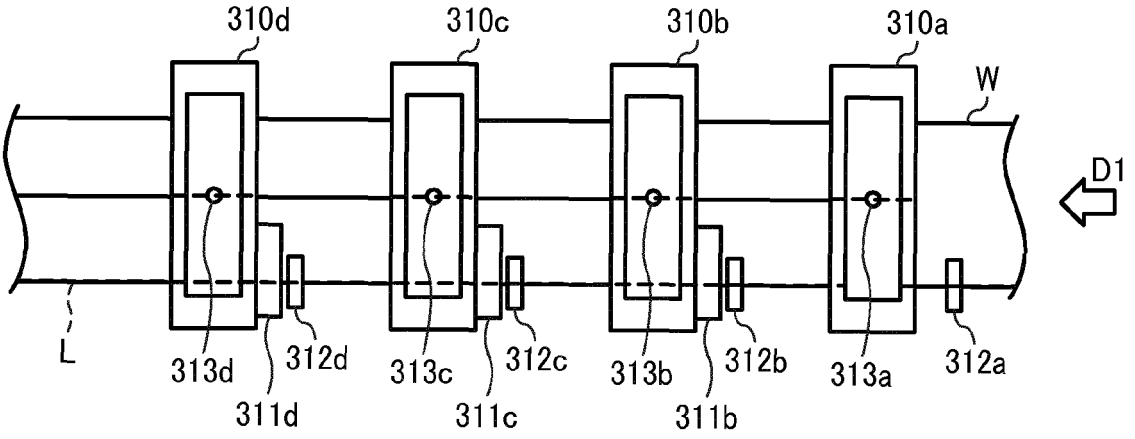

310d
310c
310b
310a
W
D1
L
313d
312d
311d
313c
312c
311c
313b
312b
311b
313a
312a

FIG. 5B

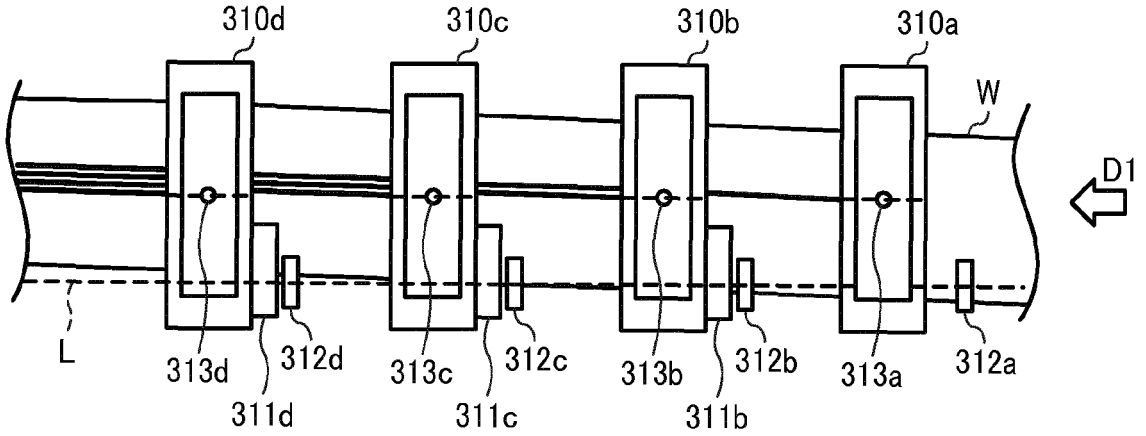

310d
310c
310b
310a
W
D1
L
313d
312d
311d
313c
312c
311c
313b
312b
311b
313a
312a

FIG. 5C

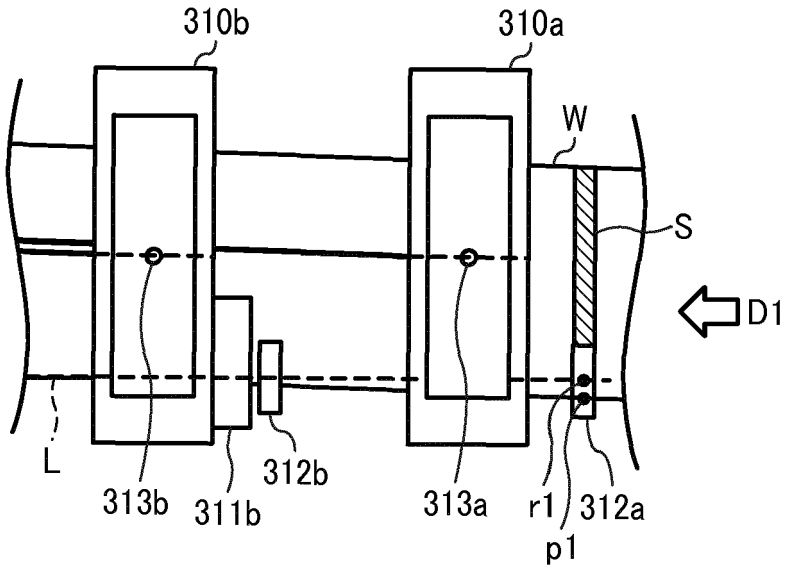

310b
310a
W
S
D1
L
313b
311b
312b
313a
r1
p1
312a

FIG. 5D

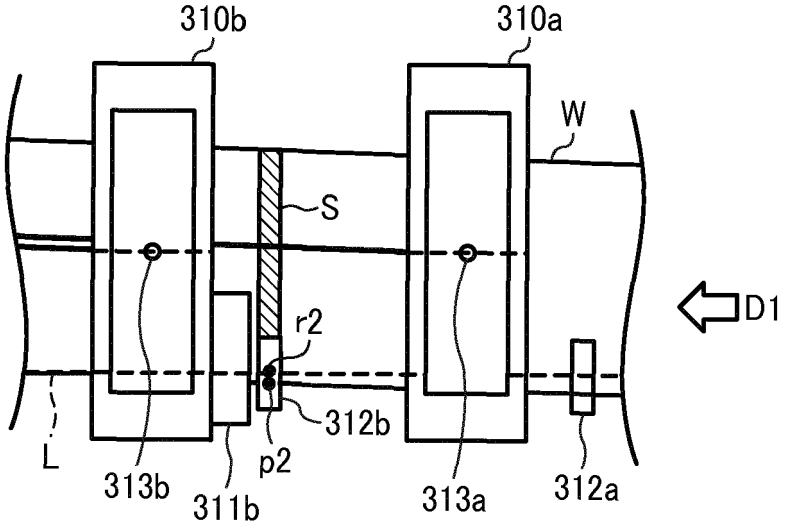

310b
310a
W
S
D1
r2
L
313b
311b
p2
312b
313a
312a

FIG. 6

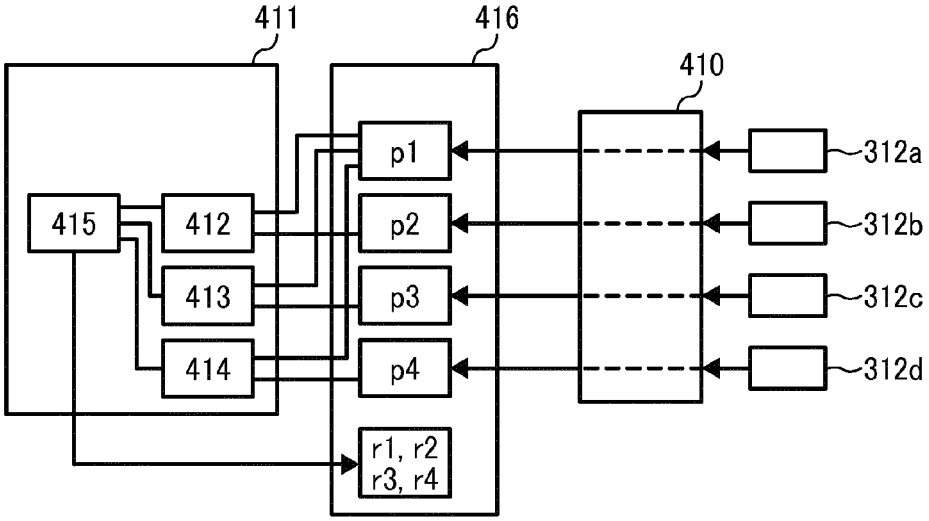

411
416
410
p1
p2
p3
p4
415
412
413
414
r1, r2
r3, r4
312a
312b
312c
312d

FIG. 7

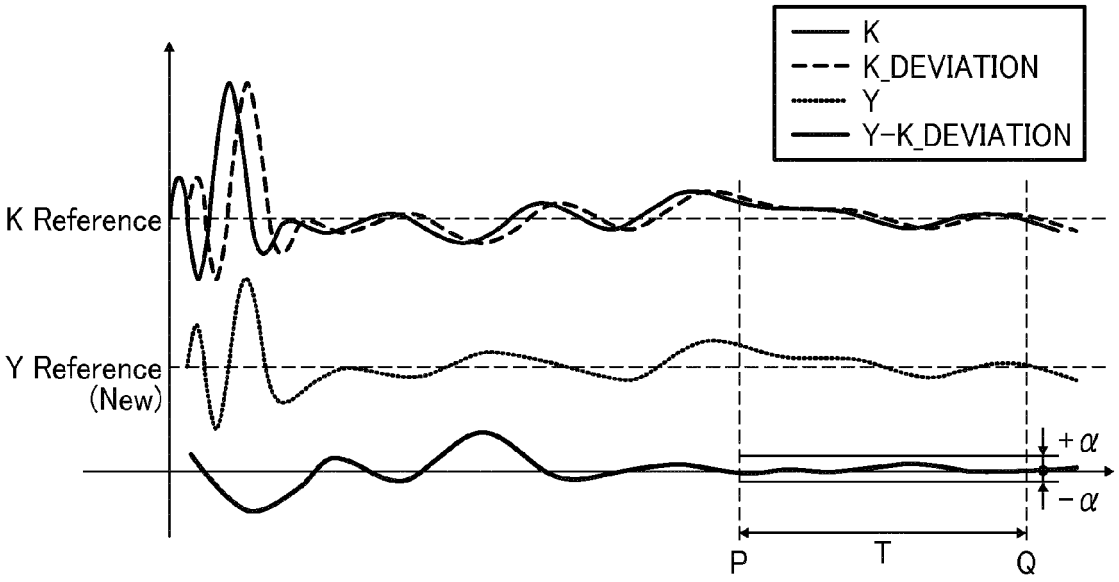

K
K_DEVIATION
Y
Y-K_DEVIATION
K Reference
Y Reference
(New)
+α
−α
P
T
Q

FIG. 8

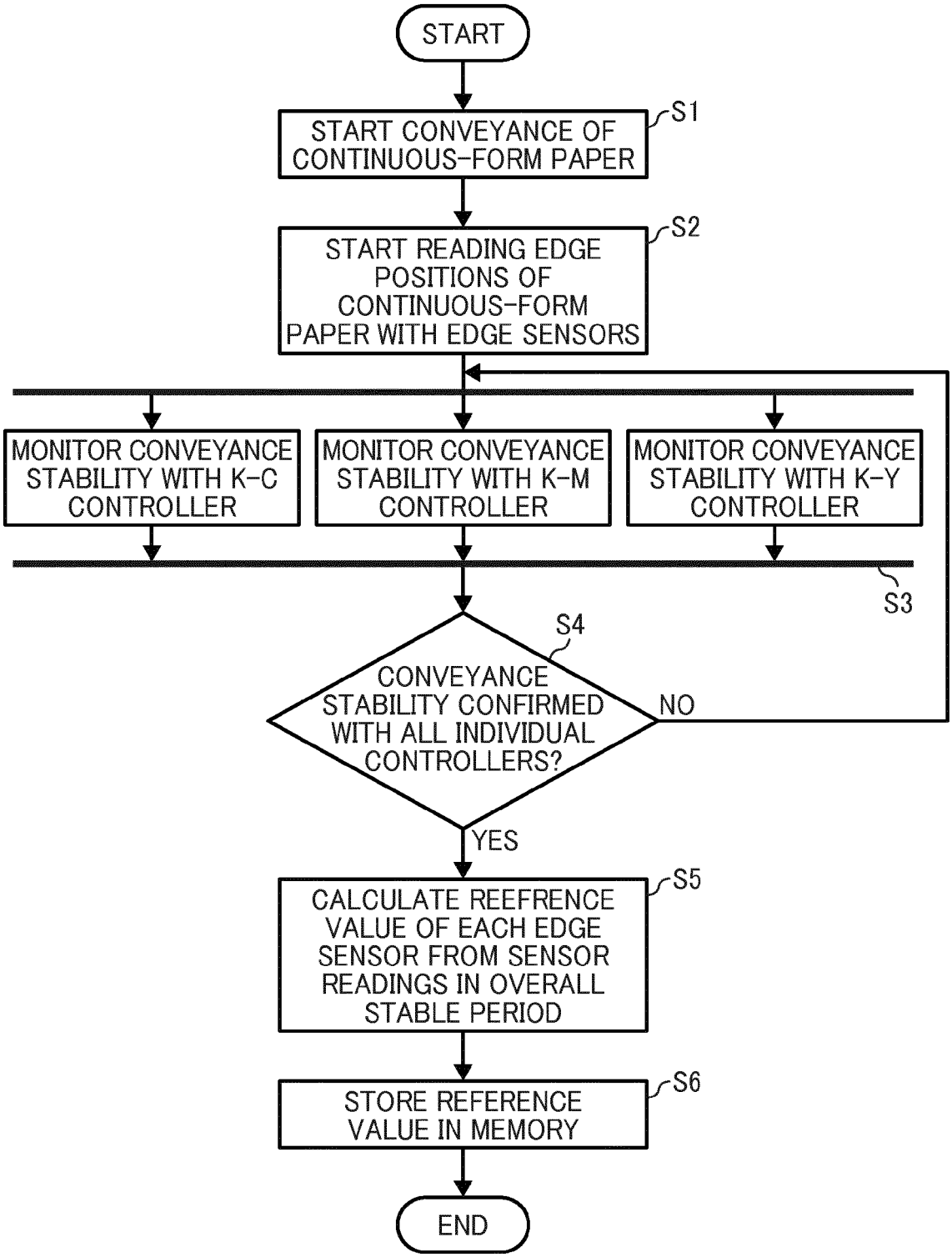

START
START CONVEYANCE OF CONTINUOUS-FORM PAPER
S1
START READING EDGE POSITIONS OF CONTINUOUS-FORM PAPER WITH EDGE SENSORS
S2
MONITOR CONVEYANCE STABILITY WITH K-C CONTROLLER
MONITOR CONVEYANCE STABILITY WITH K-M CONTROLLER
MONITOR CONVEYANCE STABILITY WITH K-Y CONTROLLER
S3
S4
CONVEYANCE STABILITY CONFIRMED WITH ALL INDIVIDUAL CONTROLLERS?
NO
YES
CALCULATE REEFRENCE VALUE OF EACH EDGE SENSOR FROM SENSOR READINGS IN OVERALL STABLE PERIOD
S5
STORE REFERENCE VALUE IN MEMORY
S6
END

FIG. 9

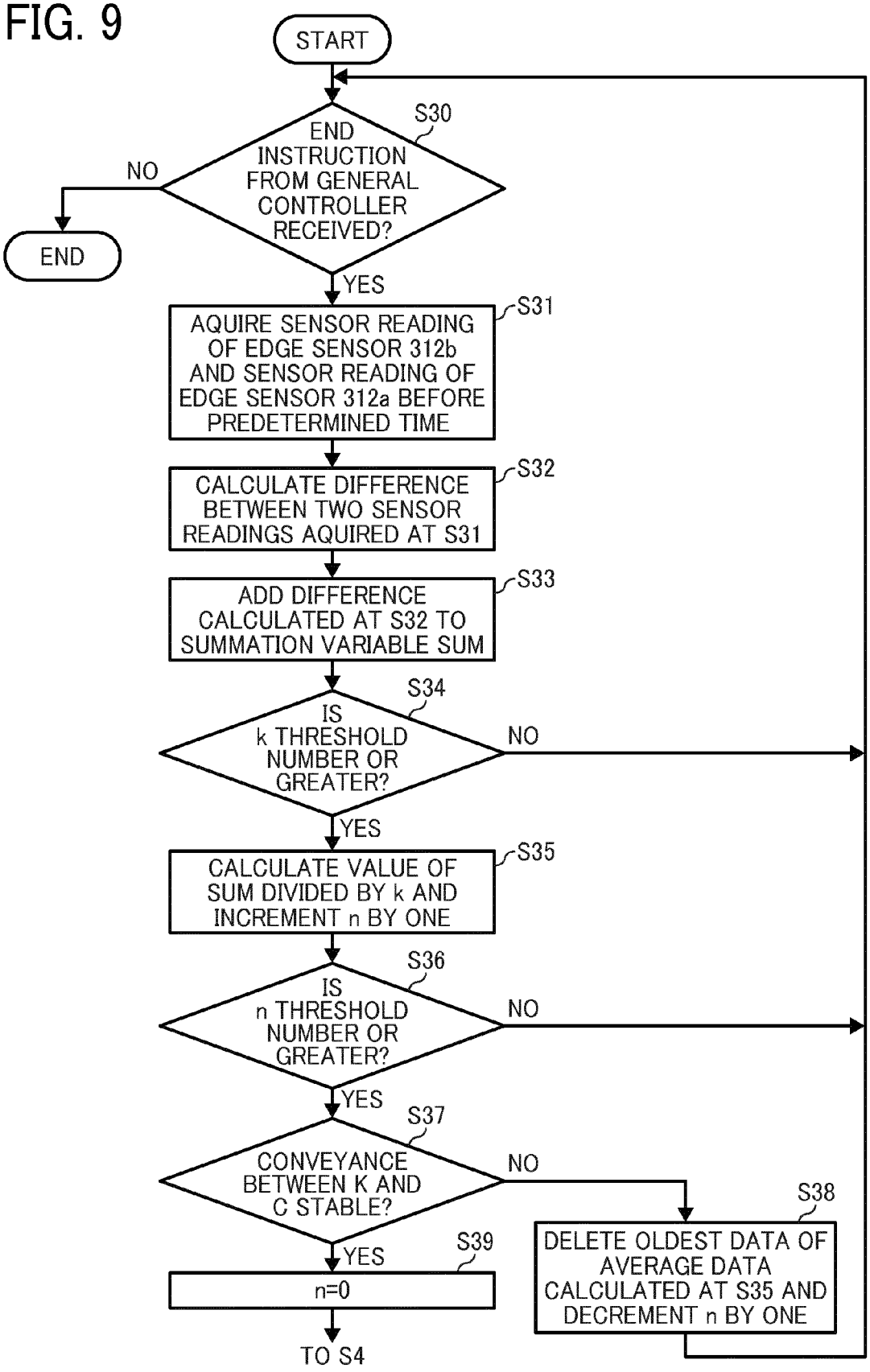
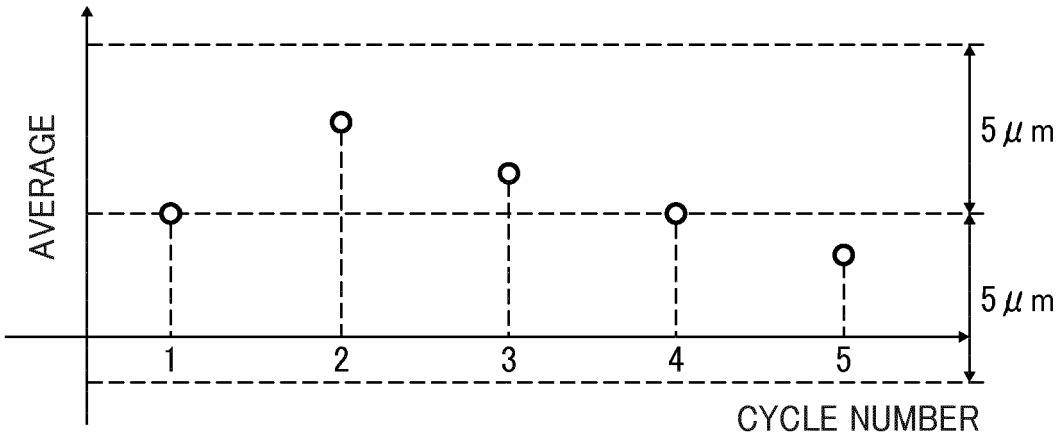

START
S30
END INSTRUCTION FROM GENERAL CONTROLLER RECEIVED?
NO
END
YES
S31
AQUIRE SENSOR READING OF EDGE SENSOR 312b AND SENSOR READING OF EDGE SENSOR 312a BEFORE PREDETERMINED TIME
S32
CALCULATE DIFFERENCE BETWEEN TWO SENSOR READINGS AQUIRED AT S31
S33
ADD DIFFERENCE CALCULATED AT S32 TO SUMMATION VARIABLE SUM
S34
IS k THRESHOLD NUMBER OR GREATER?
NO
YES
S35
CALCULATE VALUE OF SUM DIVIDED BY k AND INCREMENT n BY ONE
S36
IS n THRESHOLD NUMBER OR GREATER?
NO
YES
S37
CONVEYANCE BETWEEN K AND C STABLE?
NO
S38
DELETE OLDEST DATA OF AVERAGE DATA CALCULATED AT S35 AND DECREMENT n BY ONE
YES
S39
n=0
TO S4

FIG. 10



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2011136526 A **[0004] [0005]**