



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.01.2010 Bulletin 2010/02

(51) Int Cl.:
B41J 2/01 (2006.01) **B41J 2/175** (2006.01)
B41J 25/304 (2006.01)

(21) Application number: **09251718.4**

(22) Date of filing: **03.07.2009**

(84) Designated Contracting States:
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 SE SI SK SM TR

(30) Priority: **10.07.2008 JP 2008179667**

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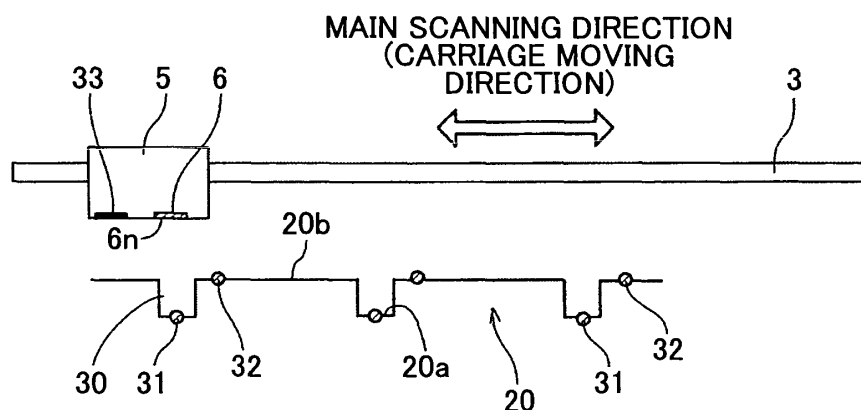
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(54) **Image forming apparatus**

(57) An image forming apparatus includes a carriage (5) which scans in a main scanning direction by being moved and includes a recording head (6) having nozzles for ejecting liquid droplets, a first mark (31) and a second mark (32) disposed at positions facing a nozzle surface (6n) of the recording head (6) by having different heights

from each other, a mark reading sensor (33) attached to the carriage (5) for detecting the first mark (31) and the second mark (32), and a slant angle detecting unit which detects a slant angle of the carriage (5) in a height direction relative to the main scanning direction based on a detection result by the mark reading sensor (33).

FIG.5



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention generally relates to an image forming apparatus having a carriage to which a recording head is attached for ejecting liquid droplets.

2. Description of the Related Art

[0002] Recently, as image forming apparatuses such as a printer, a facsimile machine, a copying machine, a plotter, and a multifunctional apparatus including a printing function, a facsimile transmitting function, a copying function, and a plotting function, an inkjet recording apparatus using a recording head which ejects ink droplets has been well known. The inkjet recording apparatus ejects the ink droplets on a transported recording medium and forms an image on the recording medium. The recording medium includes paper, a sheet, an OHP sheet, and so on onto which the ink droplets can be adhered. The image forming includes image recording, character printing, figure printing, and image transferring. As the inkjet recording apparatus, there are a serial type image forming apparatus which forms an image on a sheet by ejecting ink droplets while moving the recording head in the main scanning direction, and a line type image forming apparatus which forms an image on a sheet by ejecting ink droplets without moving the recording head.

[0003] In the present invention, the image forming apparatus forms an image on a recording medium, for example, paper, thread, fiber, cloth, leather, metal, plastic, glass, wood, ceramics, and so on by ejecting ink droplets on the recording medium. In addition, the image forming means to form not only a significant image, for example, a character, a figure, but also a simple image, for example, a pattern (by merely hitting the ink droplets on a recording medium). Further, ink means liquid by which an image can be formed, for example, recording liquid, fixing treatment liquid, and the like.

[0004] In a serial type inkjet recording apparatus, a carriage to which a recording head is attached is moved in the main scanning direction by being slidably guided by main and sub guiding members. However, the carriage may be slanted in the height direction relative to the sheet transporting surface due to worn out parts of the main and sub guiding members with the passage of time. When the carriage is slanted, distances (gaps) between nozzles disposed in the main scanning direction of the recording head and the sheet surface are different among positions in the main scanning direction. That is, flying distances of the ink droplets from the plural nozzles are different from each other, and ink droplet hitting accuracy on the sheet is decreased and image quality is degraded.

[0005] In order to solve the above problem, in Patent Document 1, a light receiving sensor is secured to the

carriage which moves in the main scanning direction. The light receiving sensor detects two ink ejecting patterns; that is, an ink ejecting pattern (positional information of ink droplets) determined when the inkjet recording apparatus is delivered to a user from a manufacturer, and an ink ejecting pattern at each time of predetermined printed number of sheets which has been determined beforehand in the user in using environment. Then an ink ejection difference (positional shift of the ink droplets) between the two ink ejecting patterns in the total carriage moving range is calculated, and the ejection timing of the ink droplets from the nozzles of the recording head is adjusted based on the calculated difference.

[0006] In patent Document 2, with respect to a gap change between a carriage and a sheet transporting surface, a distance measuring unit is provided for measuring a distance between a printing head and a recording medium at each time of scanning, and liquid droplet ejecting timing is adjusted based on the measured distance. In Patent Document 3, an ink adhering position detecting unit is provided for detecting an adhering position of ink droplets on a recording medium beforehand when the ink droplets are ejected from a recording head at predetermined timing, and the ink droplet ejecting timing is adjusted based on the detected ink droplet adhering position. In Patent Document 4, an optical sensor detects a distance between a sheet and a head when a carriage scans the sheet, and a correction value of a shift amount to be generated is calculated from the detected distance, and the liquid droplet ejecting timing is corrected based on the correction value.

[Patent Document 1] Japanese Unexamined Patent Publication No. 2007-185870

[Patent Document 2] Japanese Unexamined Patent Publication No. 2007-044948

[Patent Document 3] Japanese Unexamined Patent Publication No. 2000-233495

[Patent Document 4] Japanese Unexamined Patent Publication No. 2003-334941

[0007] However, in Patent Document 1, when the carriage has been slanted in the height direction with the passage of time, the light receiving sensor has been also slanted, and the detecting timing of the ink ejecting pattern has been also shifted. Therefore, the ink ejection positional difference between a reference position when the apparatus has been delivered to the user from the manufacturer and an actual ink ejection position when the user uses the apparatus cannot be accurately obtained.

[0008] In addition, since a pattern is printed on a sheet for detecting the slant of the carriage, the sheet is consumed excessively.

SUMMARY OF THE INVENTION

[0009] In a preferred embodiment of the present inven-

tion, there is provided an image forming apparatus in which a slant of a carriage in the height direction relative to a sheet transporting direction can be accurately detected.

[0010] Features and advantages of the present invention are set forth in the description that follows, and in part will become apparent from the description and the accompanying drawings, or may be learned by practice of the invention according to the teachings provided in the description. Features and advantages of the present invention will be realized and attained by an image forming apparatus particularly pointed out in the specification in such full, clear, concise, and exact terms so as to enable a person having ordinary skill in the art to practice the invention.

[0011] To achieve one or more of these and other advantages, according to one aspect of the present invention, there is provided an image forming apparatus. The image forming apparatus includes a carriage which scans in a main scanning direction by being moved and includes a recording head having nozzles for ejecting liquid droplets, a first mark and a second mark disposed at positions facing a nozzle surface of the recording head by having different heights from each other, a detecting unit attached to the carriage for detecting the first mark and the second mark, and a slant angle detecting unit which detects a slant angle of the carriage in a height direction relative to the main scanning direction based on a detection result by the detection unit.

[Effect of the Invention]

[0012] According to an embodiment of the present invention, an image forming apparatus includes a first mark and a second mark facing a nozzle surface of a recording head in which heights of the first and second marks are different from each other, and a slant angle of a carriage in a height direction is detected based on detection results of the first and second marks. Therefore, the slant angle of the carriage in the height direction is accurately detected without consuming a sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Features and advantages of the present invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view of a structure of an image forming apparatus according to an embodiment of the present invention;

FIG. 2 is a schematic diagram showing a part of a mechanism of the image forming apparatus shown in FIG. 1;

FIG. 3 is a perspective view of a part of the mechanism shown in FIG. 2;

FIG. 4 is a plan view of a platen member shown in

FIG. 3;

FIG. 5 is a front view of the platen member shown in FIG. 3;

FIG. 6 is a block diagram showing a controller and a carriage according to the embodiment of the present invention;

FIG. 7 is a diagram showing a slant angle of the carriage shown in FIG. 1;

FIG. 8 is a diagram showing detection of a first mark and second mark formed in the platen member shown in FIG. 4;

FIG. 9 is a diagram showing a relationship between the detection of the first and second marks and a clock frequency of a CPU in a main controlling section shown in FIG. 6;

FIG. 10 is a table showing a relationship between a slant angle of the carriage and a mark detecting time difference based on a count value of an internal clock frequency of the CPU in the main controlling section shown in FIG. 6;

FIG. 11 is a flowchart showing processes for detecting the slant angle of the carriage and for calculating a correction value of liquid droplet ejection timing according to the embodiment of the present invention;

FIG. 12 is a diagram showing gaps between a sheet and nozzle lines of a recording head when the carriage 5 is slanted according to the embodiment of the present invention;

FIG. 13 is a plan view of the platen member in a modified example of the embodiment of the present invention;

FIG. 14 is a front view of the platen member in the modified example of the embodiment of the present invention;

FIG. 15 is a diagram showing a relationship between the first and second marks and first and second reference marks formed in the platen member in the modified example of the embodiment of the present invention;

FIG. 16 is a flowchart showing processes for detecting the slant angle of the carriage and for calculating a correction value of the liquid droplet ejection timing in the modified example of the embodiment of the present invention;

FIG. 17 is a diagram showing the detection of the slant angle of the carriage in a forward route and a return route according to the embodiment of the present invention;

FIG. 18 is a diagram showing a relationship between a liquid droplet hitting positional shift due to the slant angle of the carriage and the correction of the liquid droplet ejection timing according to the embodiment of the present invention; and

FIG. 19 is a table showing a relationship among the slant angle of the carriage, a liquid droplet hitting position difference, and a delay time of the liquid droplet according to the embodiment of the present

invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[Best Mode of Carrying Out the Invention]

[0014] The best mode of carrying out the present invention is described with reference to the accompanying drawings.

[0015] FIG. 1 is a perspective view of a structure of an image forming apparatus according to the embodiment of the present invention. FIG. 2 is a schematic diagram showing a part of a mechanism of the image forming apparatus shown in FIG. 1. FIG. 3 is a perspective view of a part of the mechanism shown in FIG. 2. In the embodiment of the present invention, as the image forming apparatus, an inkjet recording apparatus is used.

[0016] Referring to FIGs. 1 through 3, the inkjet recording apparatus is described.

[0017] The inkjet recording apparatus is a serial type inkjet recording apparatus and includes a recording apparatus main body 1 and a table 2 on which the recording apparatus main body 1 is put.

[0018] In the recording apparatus main body 1, a guide rod 3 and a guide rail 4 are hung between side plates (not shown), and a carriage 5 is slidably supported in the arrow direction A by the guide rod 3 and the guide rail 4.

[0019] As shown in FIG. 2, eight recording heads 6k1 and 6k2 for ejecting black ink (K), 6y1 and 6y2 for ejecting yellow ink (Y), 6m1 and 6m2 for ejecting magenta ink (M), and 6c1 and 6c2 for ejecting cyan ink (C) are attached to the carriage 5. When color is not referred to, a recording head 6 represents the eight recording heads. As shown in FIG. 2, in each color, the two recording heads 6 are positioned by being shifted in the main scanning direction and the sub scanning direction (the paper transporting direction) orthogonal to the main scanning direction.

[0020] A main scanning direction mechanism for moving the carriage 5 in the main scanning direction includes a driving motor 11 (main scanning direction motor), a driving pulley 12, a driven pulley 13, and a belt member 14. The driving motor 11 is disposed at one side position in the main scanning direction. The driving pulley 12 is rotated by the driving motor 11. The driven pulley 13 is disposed at the other side position in the main scanning direction. The belt member 14 is wound around the driving pulley 12 and the driven pulley 13. A tension force is applied to the driven pulley 13 by a tension spring 15 in the outside direction (in the direction separating from the driving pulley 12).

[0021] The pulley shaft directions of the driving pulley 12 and the driven pulley 13 are along the ink (liquid) droplet ejecting direction. As shown in FIG. 3, the belt member 14 is formed of two independent timing belts 14A and 14B having rubber cogs. The timing belts 14A and 14B are wound around the driving pulley 12 and the driven pulley 13 with no space between the timing belts 14A

and 14B in the pulley shaft directions. The timing belts 14A and 14B are partially supported at a belt fixing section 7 disposed at the back side of the carriage 5. That is, the timing belts 14A and 14B are disposed at one side of the carriage 5 in the direction orthogonal to the main scanning direction.

[0022] An encoder sheet (linear scale) 21 for detecting a main scanning direction position of the carriage 5 is disposed along the main scanning direction. A value from the encoder sheet 21 is read by an encoder sensor 22 disposed at the carriage 5.

[0023] In a recording region of a main scanning direction region of the carriage 5, a sheet (paper) 10 is intermittently transported by a paper transporting mechanism (not shown) in a direction orthogonal to the main scanning direction of the carriage 5 (the sub scanning direction) shown by the arrow direction B with a guide of a platen member 20. The platen member 20 is disposed along the main scanning direction region of the carriage 5 and faces the recording head 6 in the recording region.

[0024] In addition, a recovering and maintaining mechanism 8 for recovering the recording head 6 from bad conditions and maintaining the recording head 6 in good conditions is disposed at one end side region of the main scanning direction region. Further, main cartridges 9, which store corresponding color ink and supply the color ink to the recording head 6, are disposed under the other end side of the main scanning direction region or at the outside of the carriage moving region in the main scanning direction. The main cartridges 9 are detachably attached to the recording apparatus main body 1.

[0025] In the inkjet recording apparatus, when the carriage 5 is moved in the main scanning direction and liquid droplets (ink droplets) are ejected from the recording head 6 corresponding to image information while intermittently transporting the sheet 10 in the sub scanning direction; an image of the image information is formed on the sheet 10.

[0026] Next, referring to FIGs. 4 and 5, the embodiment of the image forming apparatus is described in detail. FIG. 4 is a plan view of the platen member 20. FIG. 5 is a front view of the platen member 20. In the following, in order to make the description concise, one recording head 6 is used.

[0027] The platen member 20 is disposed along the main scanning direction of the carriage 5 by facing a nozzle surface 6n for ejecting liquid droplets of the recording head 6, and grooves 30 are formed at predetermined positions of the platen member 20. The platen member 20 includes second surfaces 20b (sheet transporting surfaces for guiding the sheet 10) and first surfaces 20a which are bottom surfaces of the grooves 30. The positions of the first surface 20a and the second surface 20b are different from each other in the height direction; that is, the distances from the nozzle surface 6n to the first surface 20a and the second surface 20b are different from each other. The groove 30 also has a function to prevent cockling of the sheet 10 (waviness of the sheet

10) when the liquid droplets hit the sheet 10 (paper), and the depth of the groove 30 is approximately 1 mm.

[0028] A first mark 31 is formed on the first surface 20a and a second mark 32 is formed on the second surface 20b in the platen member 20. In FIGs. 4 and 5, the first and second marks 31 and 32 are shown as circles; however, the shapes of the first and second marks 31 and 32 are not limited to the circles. As shown in FIGs. 4 and 5, the plural first marks 31 and the plural second marks 32 are formed in the platen member 20 in the main scanning direction of the carriage 5. By using the first and second marks 31 and 32, a slant angle of the carriage 5 in the height direction relative to the main scanning direction can be detected. With this, accuracy of correction of the liquid droplet ejection timing can be increased (described below in detail).

[0029] A mark reading sensor 33 (detecting unit) formed of a reflection type photosensor, which detects the first and second marks 31 and 32, is disposed on a surface of the carriage 5 at a side where the recording head 6 is attached (at the side of the nozzle surface 6n).

[0030] Next, referring to FIG. 6, a controller 100 for detecting the slant angle of the carriage 5 is described. FIG. 6 is a block diagram showing the controller 100 and the carriage 5.

[0031] As shown in FIG. 6, the controller 100 includes a main controlling section 101, a head driving controller 102, a driving waveform storage unit 106, a main scanning direction motor driving circuit 107, a sub scanning direction motor driving circuit 108, and a communication circuit 110.

[0032] The main controlling section 101 includes a microcomputer formed of a CPU which controls all elements in the inkjet recording apparatus and works as a slant angle detecting unit of the carriage 5, a ROM, a RAM, an interface (I/F), and so on. The head driving controller 102 controls and drives the recording head 6. The driving waveform storage unit 106 stores driving waveform data to be applied to the recording head 6 by the head driving controller 102. The main scanning direction motor driving circuit 107 drives the main scanning direction motor 11. The sub scanning direction motor driving circuit 108 drives a sub scanning direction motor 16. The communication circuit 110 communicates with an external apparatus.

[0033] The main controlling section 101 receives print data and so on from an external apparatus such as an information processing apparatus, for example, a personal computer, an image reading apparatus, for example, an image scanner, and an image taking apparatus, for example, a digital camera, by using the communication circuit 110 via a cable or a network. In the main controlling section 101, the RAM is used as a buffer and a work memory, and stores data; and the ROM stores control routine software, font data, graphic functions, procedure data, and so on.

[0034] The head driving controller 102 includes a driving signal generating circuit which generates a driving

waveform for driving an actuator unit of the recording head 6 by converting the driving waveform data stored in the driving waveform storage unit 106 into digital data. The head driving controller 102 outputs print data of dot pattern data (bitmap data) sent from the main controlling section 101 and the generated driving waveform to a head driver (not shown) for driving the recording head 6 in the carriage 5.

[0035] The main controlling section 101 detects a position of the carriage 5 in the main scanning direction based on a signal output from the encoder sensor 22 and controls a moving and stopping position of the carriage 5. In addition, the main controlling section 101 obtains position signals (detection signals) of the first and second marks 31 and 32 from the mark reading sensor 33 of the carriage 5, and detects the slant angle of the carriage 5 in the height direction relative to the main scanning direction. Further, the main controlling section 101 controls output timing of the driving waveform data from the driving waveform storage unit 106 based on the detected slant angle of the carriage 5 in the height direction. With this, the correction of the liquid droplet ejection timing from the recording head 6 is controlled.

[0036] Next, referring to the drawings, detecting processes of the slant angle of the carriage 5 in the height direction are described. The position and condition of the carriage 5 correspond to the position and condition of the mark reading sensor 33; therefore, the position and condition of the mark reading sensor 33 are described.

[0037] FIG. 7 is a diagram showing the slant angle of the carriage 5. As described above, in FIG. 7, the slant angle of the mark reading sensor 33 is described.

[0038] In this, the velocity of the carriage 5 is defined as V_{crg} (carriage velocity), the distance between the first and second marks 31 and 32 is defined as L , and the time is defined as " t_1 " between when the mark reading sensor 33 of the carriage 5 moves from a carriage position A where the first mark 31 is detected to a carriage position B where the second mark 32 is detected. As shown in FIG. 7(a), when the carriage 5 is not slanted, $t_1 = L / V_{crg}$. That is, " t_1 " is the time between when the mark reading sensor 33 detects the first mark 31 and the second mark 32.

[0039] However, as shown in FIG. 7(b), when the carriage 5 is slanted by an angle θ in the carriage moving direction in which the front side of the carriage 5 is higher than the back side of the carriage 5 in the carriage moving direction, and a height difference between the first mark 31 and the second mark 32 is Δh ; the mark reading sensor 33 detects the first mark 31 at a carriage position A1 where is a nearer position of a carriage position A0 on a virtual line in the carriage moving direction.

[0040] Consequently, when the time is defined as " t_2 " when the mark reading sensor 33 of the carriage 5 moves from the carriage position A1 where the first mark 31 is detected to a carriage position B1 where the second mark 32 is detected, " t_2 " = $(L + \Delta h \tan \theta) / V_{crg}$.

[0041] That is, as shown in FIG. 8, a mark detection

time difference is generated between the time "t1" when the carriage 5 is not slanted (normal operation) and the time "t2" when the carriage 5 is slanted. The mark detection time difference $\Delta t = (t2 - t1) = \Delta h \tan \theta / V_{crg}$. FIG. 8 (a) shows the time "t1" in the normal operation, and FIG. 8(b) shows the time "t2" when the carriage 5 is slanted. In FIG. 8, "ta" is detection timing of the first mark 31 in the normal operation, "tb" is detection timing of the second mark 32 in the normal operation, and "ta1" is detection timing of the first mark 31 when the carriage 5 is slanted.

[0042] Therefore, when the time "t1" in a predetermined carriage velocity at the normal operation (for example, when the apparatus is delivered from a manufacturer to a user) is stored in a storage unit of the main controlling section 101, and the time "t2" is obtained by reading the first and second mark 31 and 32 while moving the carriage 5 at a predetermined velocity before printing an image; the mark detection time difference Δt can be obtained. Then the angle θ is obtained from the mark detection time difference Δt , and the liquid droplet ejection timing is corrected by using the angle θ . With this, a liquid droplet hitting position shift on the sheet 10 due to the slant of the carriage 5 in the carriage moving direction can be decreased.

[0043] The time "t1" and the time "t2" can be calculated by counting an internal clock of the CPU of the main controlling section 101. For example, as shown in FIG. 9, by counting clocks of the frequency "f", a count value "n1" (normal operation) and a count value "n2" (when the carriage 5 is slanted) between detection of the first mark 31 and detection of the second mark 32 are obtained, then the mark detection time difference Δt between the time $(n2 / f)$ and the time $(n1 / f)$ is obtained. That is, $\Delta t = (n2 - n1) / f$ is obtained, and the slant angle θ of the carriage 5 is obtained from the equation $\Delta t = \Delta h \tan \theta / V_{crg}$. FIG. 9 is a diagram showing a relationship between the detection of the first and second marks 31 and 32 and a clock frequency of the CPU in the main controlling section 101.

[0044] As an example, when the height difference $\Delta h = 1$ mm, the carriage velocity $V_{crg} = 1.185$ mm/sec, and the internal clock frequency "f" = 80 MHz; a relationship between the slant angle θ of the carriage 5 and the mark detecting time difference Δt is shown in FIG. 10. That is, FIG. 10 is a table showing the relationship between the slant angle θ of the carriage 5 and the mark detecting time difference Δt based on the count value of the internal clock frequency. As shown in FIG. 10, for example, when the slant angle θ is 0.01° , and the internal clock frequency is 80 MHz; the count value is 12. When the relationship is formed in a table as shown in FIG. 10, the slant angle θ of the carriage 5 can be obtained from a count value of the internal clock frequency.

[0045] Next, referring to FIG. 11, an example of processes for detecting the slant angle θ of the carriage 5 in the height direction relative to the carriage moving direction by using the count value of the internal clock fre-

quency is described. FIG. 11 is a flowchart showing the processes for detecting the slant angle θ of the carriage 5 and for calculating a correction value of the liquid droplet ejection timing.

5 [0046] First, mark detection scanning is started in which the mark reading sensor 33 detects the first and second marks 31 and 32 by moving the carriage 5 in the main scanning direction (S1). Then the mark reading sensor 33 detects the first and second marks 31 and 32 (S2).

10 [0047] Next the count value "n2" between detection of the first mark 31 and detection of the second mark 32 is obtained by counting the number of clocks (S3). Then a difference $(n2 - n1)$ between the count value "n2" and the count value "n1" at the apparatus delivering time from the manufacturer stored beforehand is obtained (S4), and the slant angle θ of the carriage 5 is obtained from the difference $(n2 - n1)$ (S5).

15 [0048] Next, it is determined whether the slant angle $\theta = 0$ (S6). When the slant angle $\theta = 0$ (YES in S6), since the carriage 5 is not slanted, printing is started. When the slant angle θ is not 0 (NO in S6), it is determined whether the slant angle $\theta > 0$ (S7).

20 [0049] When the slant angle $\theta > 0$ (YES in S7), the carriage 5 is slanted by the slant angle θ in which the front side is higher than the back side in the carriage moving direction (S8). When the slant angle $\theta < 0$ (NO in S7), the carriage 5 is slanted by the slant angle θ in which the back side is higher than the front side in the carriage moving direction (S10).

25 [0050] After the processes in S8 and S10, a correction value for correcting the liquid droplet ejection timing from the nozzles of the recording head 6 is calculated and the correction value is stored in a storage unit (register) of the main controlling section 101 (S9 and S11).

30 [0051] As shown in FIG. 12, for example, in a case where liquid droplets are ejected from two nozzle lines 6Na and 6Nb arrayed in the main scanning direction of the recording head 6, when the carriage 5 is slanted in which the front side is higher than the back side of the carriage 5 in the carriage moving direction (the main scanning direction), a gap G1 between the nozzle line 6Na and the sheet 10 is smaller than a gap when the carriage 5 is not slanted, and a gap G2 between the nozzle line 6Nb and the sheet 10 is greater than the gap when the carriage 5 is not slanted. FIG. 12 is a diagram showing the gaps G1 and G2 between the sheet 10 and the nozzle lines 6Na and 6Nb of the recording head 6 when the carriage 5 is slanted. In this case, the liquid droplet ejection timing from the nozzle line 6Na is corrected to be slower than a case where the carriage 5 is not slanted, and the liquid droplet ejection timing from the nozzle line 6Nb is corrected to be faster than the case where the carriage 5 is not slanted.

35 [0052] In addition, the liquid droplet ejection timing from the nozzle line 6Nb can be corrected by determining that the liquid droplet ejection timing from the nozzle line 6Na is a reference, and vice versa. Further, the liquid droplet ejection timing among the plural recording heads

6 can be similarly corrected.

[0053] In the above, the carriage moving direction is described as one direction; however, since the carriage 5 can be moved in the other direction, when the carriage moving direction is the other direction, the detection order of the first and second marks 31 and 32 are reversed. Then, the slant angle θ of the carriage 5 can be detected in the other direction.

[0054] As described above, in the present embodiment, the platen member 20 provides the first mark 31 and the second mark 32 whose distances to the nozzle surface 6n are different from each other, and the slant angle θ of the carriage 5 is detected from the detected results of the first and second mark 31 and 32 by the mark reading sensor 33. Therefore, the slant angle θ of the carriage 5 in the height direction relative to the carriage moving direction can be surely detected without consuming the sheet 10.

[0055] Next, referring to FIGs. 13 and 14, a modified example of the embodiment of the present invention is described.

[0056] FIG. 13 is a plan view of the platen member 20 in the modified example of the embodiment of the present invention. FIG. 14 is a front view of the platen member 20 in the modified example of the embodiment of the present invention.

[0057] As shown in FIGs. 13 and 14, in the modified example of the embodiment of the present invention, a first reference mark 41 and a second reference mark 42 are newly provided on the second surface 20b of the platen member 20. A distance L between the first and second reference marks 41 and 42 is the same as the distance L between the first and second mark 31 and 32. The first and second reference marks 41 and 42 can be disposed on the first surface 20a of the platen member 20. That is, a height difference does not exist between the first and second reference marks 41 and 42.

[0058] Referring to FIG. 15, a method for detecting the slant angle θ of the carriage 5 is described in the modified example of the embodiment of the present invention.

[0059] As shown in FIG. 15 (b), in the first and second reference marks 41 and 42 disposed on the same level surface (the second surface 20b), when the carriage 5 is slanted or not, the time (the count value of the clock frequency) between the detection of the first reference mark 41 and the detection of the second reference mark 42 is a constant.

[0060] However, as shown in FIG. 15 (a), in the first mark 31 disposed on the first surface 20a and the second marks 32 disposed on the second surface 20b, when the carriage 5 is slanted, the time (the count value of the clock frequency) between the detection of the first mark 31 and the detection of the second mark 32 is changed corresponding to the slant angle θ . When the carriage 5 is slanted by the angle θ , the distance between the first and second marks 31 and 32 detected by the mark reading sensor 33 becomes $(L + \Delta h \tan \theta)$.

[0061] In a case where the distance L between the first

and second reference marks 41 and 42 is compared with the distance $(L + \Delta h \tan \theta)$ between the first and second marks 31 and 32 when the carriage 5 is slanted, even if a default value at delivering the apparatus to a user is not stored or is erased, the slant angle θ of the carriage 5 can be obtained by the comparison. FIG. 15 is a diagram showing a relationship between the first and second marks 31 and 32 and the first and second reference marks 41 and 42.

[0062] Next, referring to FIG. 16, an example of processes for detecting the slant angle θ of the carriage 5 in the height direction relative to the carriage moving direction in the modified example of the embodiment of the present invention is described. FIG. 16 is a flowchart showing the processes for detecting the slant angle θ of the carriage 5 and for calculating a correction value of the liquid droplet ejection timing in the modified example of the embodiment of the present invention.

[0063] First, mark detection scanning is started in which the mark reading sensor 33 detects the first and second marks 31 and 32 and the first and second reference marks 41 and 42 by moving the carriage 5 in the main scanning direction (S21).

[0064] Then the mark reading sensor 33 detects the first and second marks 31 and 32 whose heights are different from each other (S22), and the count value "n2" between detection of the first mark 31 and detection of the second mark 32 is obtained by counting the number of clocks (S23).

[0065] Next, the mark reading sensor 33 detects the first and second reference marks 41 and 42 whose heights are not different from each other (S24), and the count value "n1" between detection of the first reference mark 41 and detection of the second reference mark 42 is obtained by counting the number of clocks (S25).

[0066] Then a difference $(n2 - n1)$ between the count value "n2" and the count value "n1" is obtained (S26), and the slant angle θ of the carriage 5 is obtained from the difference $(n2 - n1)$ (S27).

[0067] Next, it is determined whether the slant angle $\theta = 0$ (S28). When the slant angle $\theta = 0$ (YES in S28), since the carriage 5 is not slanted, printing is started. When the slant angle θ is not 0 (NO in S28), it is determined whether the slant angle $\theta > 0$ (S29).

[0068] When the slant angle $\theta > 0$ (YES in S30), the carriage 5 is slanted by the angle θ in which the front side is higher than the back side in the carriage moving direction (S30). When the slant angle $\theta < 0$ (NO in S29), the carriage 5 is slanted by the angle θ in which the back side is higher than the front side in the carriage moving direction (S32).

[0069] After the processes in S30 and S32, a correction value for correcting the liquid droplet ejection timing from the nozzles of the recording head 6 is calculated and the correction value is stored in a storage unit (register) of the main controlling section 101 (S31 and S33).

[0070] When the carriage moving direction is the opposite direction, since the second reference mark 42 is

first detected by the mark reading sensor 33, the count value "n1" is firstly obtained and the count value "n2" is secondarily obtained.

[0071] Next, referring to FIG. 17, the detection of the first and second marks 31 and 32 in a forward route and a return route of the carriage 5 in the carriage moving direction is described. In FIG. 17, the first mark 31 on a virtual line (dotted line) is positioned on the same level as the position of the second mark 32, and the mark reading sensor 33 shown by an alternate two-dot broken line is positioned to read the mark 31 on the virtual line.

[0072] As shown in FIG. 17(a), in the forward route of the carriage 5, when the carriage 5 is slanted by an angle θ in the carriage moving direction in which the front side of the carriage 5 is higher than the back side of the carriage 5 in the carriage moving direction, and a height difference between the first mark 31 and the second mark 32 is Δh ; the mark reading sensor 33 detects the first mark 31 and the second mark 32 in this order and detects the first mark at faster timing than the timing when the carriage is not slanted. Therefore, a distance corresponding to the time between the detection of the first mark 31 and the detection of the second mark 32 becomes $(L + \Delta h \tan \theta)$ (L is the distance between the first and second marks 31 and 32 when the carriage 5 is not slanted).

[0073] However, as shown in FIG. 17(b), in the return route of the carriage 5, when the carriage 5 is slanted by an angle θ in the carriage moving direction in which the back side of the carriage 5 is higher than the front side of the carriage 5 in the carriage moving direction, the mark reading sensor 33 detects the second mark 32 and the first mark 31 in this order and detects the first mark 31 at faster timing than the timing when the carriage is not slanted. Therefore, a distance corresponding to the time between the detection of the second mark 32 and the detection of the first mark 31 becomes $(L - \Delta h \tan \theta)$.

[0074] Since the mark detection time difference Δt can be obtained from $(\Delta h \tan \theta / V_{crg})$, the slant angle θ of the carriage 5 can be obtained.

[0075] Therefore, even if the carriage 5 bidirectionally scans the sheet 10, the slant angle θ of the carriage 5 can be individually obtained in the forward direction and the return direction of the carriage 5, and the liquid droplet ejection timing from the recording head 6 can be corrected.

[0076] Next, referring to FIG. 18, the correction of the liquid droplet ejection timing is described. FIG. 18 is a diagram showing a relationship between a liquid droplet hitting positional shift due to a slant angle θ of the carriage 5 and the correction of the liquid droplet ejection timing.

[0077] When an ink velocity (liquid droplet velocity) is defined as V_{jet} , a gap between the recording head 6 and the sheet 10 is defined as " h ", a liquid droplet flying time is defined as " $T1$ " when the carriage 5 is not slanted ($\theta = 0$), and a liquid droplet flying time is defined as " $T2$ " when the carriage 5 is slanted by θ ($\theta > 0$); when the carriage 5 is slanted by an angle θ , as shown in FIG. 18 (c), the velocity V_{jet} becomes $V_{jet} \sin \theta$ in the horizontal

direction, and the liquid droplet flying distance is increased.

[0078] That is, when the carriage 5 is not slanted, $h = V_{jet} \times T1$, and a hitting position $x1 = V_{crg} \times T1$. Then $x1 = V_{crg} / V_{jet} \times h$. When the carriage 5 is slanted by θ , $h = V_{jet} \cos \theta \times T2$, and a hitting position $x2 = (V_{crg} \sin \theta + V_{crg}) \times T2$. Then $x2 = (V_{crg} \sin \theta + V_{crg}) \times V_{jet} \cos \theta / h$.

[0079] Therefore, even if the liquid droplet is ejected at the same position when the carriage 5 is not slanted as shown in FIG. 18(a) and when the carriage 5 is slanted by the angle θ as shown in FIG. 18(b), a hitting position difference $\Delta x = x2 - x1 = h \{ \tan \theta + V_{crg} / V_{jet} (1 / \cos \theta - 1) \}$ is generated.

[0080] Therefore, when the carriage 5 is slanted, the liquid droplet ejection timing is made to be faster by $\Delta x / V_{crg}$ than when the carriage 5 is not slanted. With this, the liquid droplet hitting position is made to the same position as that when the carriage 5 is not slanted.

[0081] For example, when the gap between the recording head 6 and the sheet 10 " h " = 1.13 mm, the carriage velocity $V_{crg} = 1,185$ mm/sec, the liquid droplet velocity $V_{jet} = 8,000$ mm/sec; a relationship among the slant angle θ of the carriage 5, the liquid droplet hitting position difference Δx , and the delay time of the liquid droplet is shown in FIG. 19.

[0082] When the relationship is formed in a table, the delay time can be obtained from the slant angle θ .

[0083] When the slant angle θ of the carriage 5 is detected before printing an image on the sheet 10, the liquid droplet ejection timing can be accurately corrected, and the image quality can be increased.

In addition, when the slant angle θ of the carriage 5 is detected at predetermined timing or in each apparatus, the image quality can be made high.

[0084] Further, the present invention is not limited to the specifically disclosed embodiment, and variations and modifications may be made without departing from the scope of the present invention.

[0085] The present invention is based on Japanese Priority Patent Application No. 2008-179667, filed on July 10, 2008, with the Japanese Patent Office, the entire contents of which are hereby incorporated herein by reference.

Claims

1. An image forming apparatus characterized by:

a carriage (5) which scans in a main scanning direction by being moved and includes a recording head (6) having nozzles for ejecting liquid droplets;
a first mark (31) and a second mark (32) disposed at positions facing a nozzle surface (6n) of the recording head (6) by having different

heights from each other;

a detecting unit (33) attached to the carriage (5) for detecting the first mark (31) and the second mark (32); and

a slant angle detecting unit which detects a slant angle of the carriage (5) in a height direction relative to the main scanning direction based on a detection result by the detection unit (33). 5

2. The image forming apparatus as claimed in claim 1, **characterized in that** 10

the slant angle of the carriage (5) in the height direction relative to the main scanning direction is detected by a detection time of the first mark (31) and a detection time of the second mark (32) by the detecting unit (33). 15

3. The image forming apparatus as claimed in claim 1 or 2, **characterized in that** 20
a plurality of the first marks (31) and a plurality of the second marks (32) are disposed in the main scanning direction of the carriage (5).

4. The image forming apparatus as claimed in any one of claims 1 through 3 further **characterized by:** 25

two reference marks (41 and 42) disposed on a same level surface by having the same distance between the reference marks (41 and 42) as the distance between the first mark (31) and the second mark (32). 30

5. The image forming apparatus as claimed in any one of claims 1 through 4, **characterized in that** 35
the slant angle of the carriage (5) in the height direction relative to the main scanning direction is detected by detecting the first mark (31) and the second mark (32) before printing an image on a sheet (10). 40

6. The image forming apparatus as claimed in any one of claims 1 through 5, **characterized in that** 45
liquid droplet ejection timing of the liquid droplets from the recording head (6) is corrected based on the detection result of the slant angle of the carriage (5) in the height direction relative to the main scanning direction. 50

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FIG.1

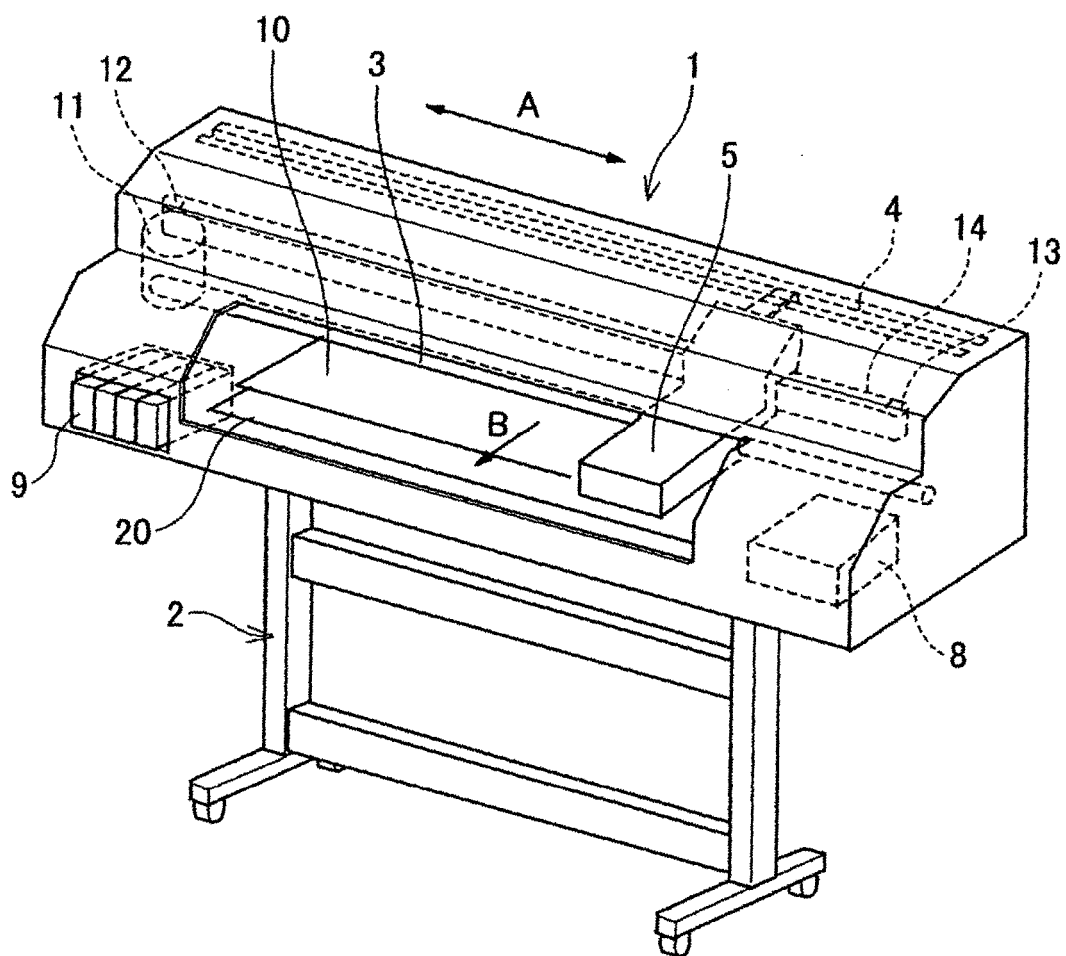


FIG.2

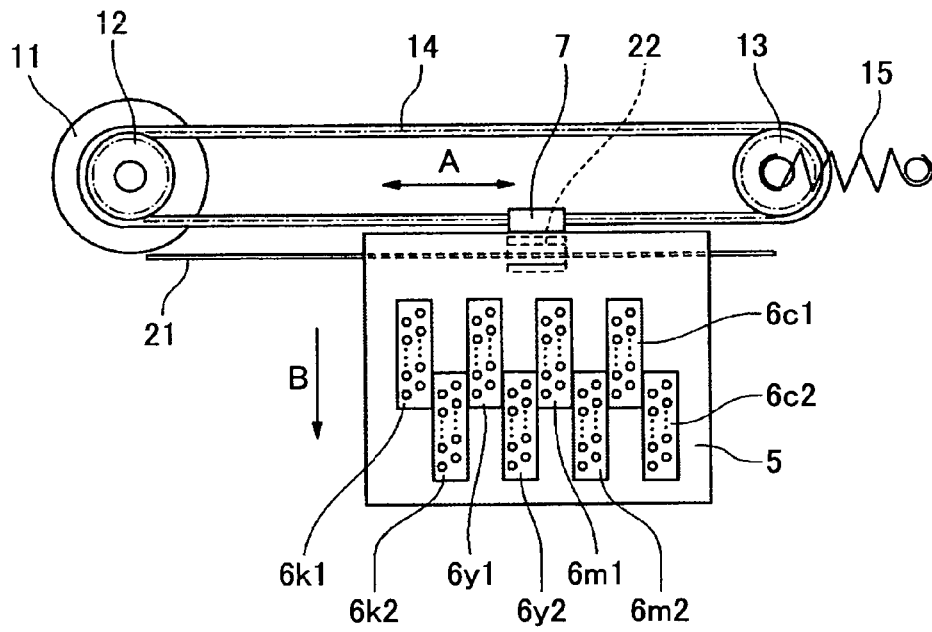


FIG.3

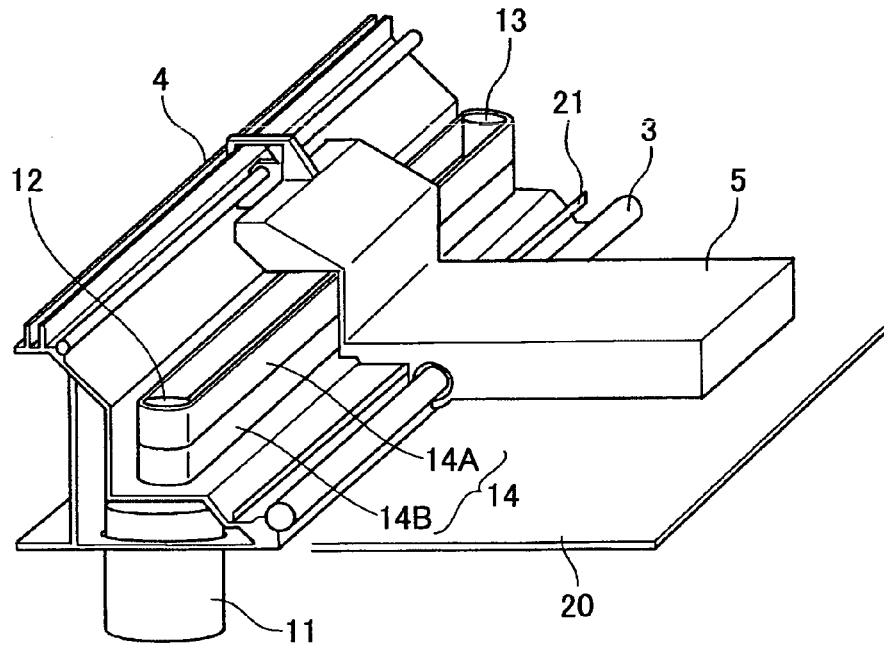


FIG.4

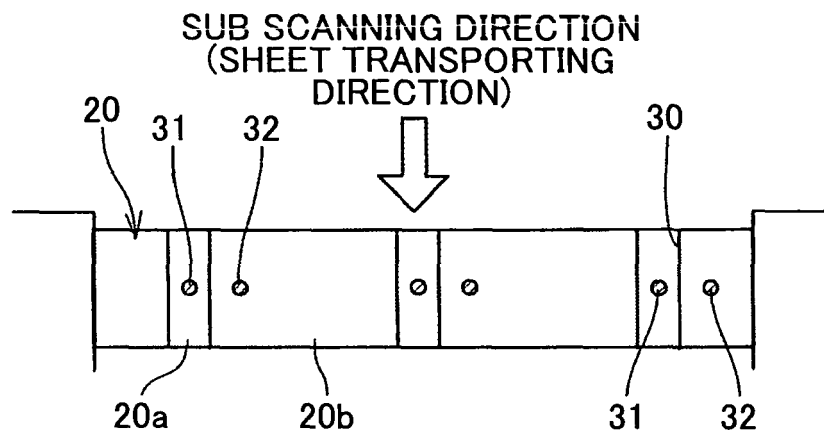


FIG.5

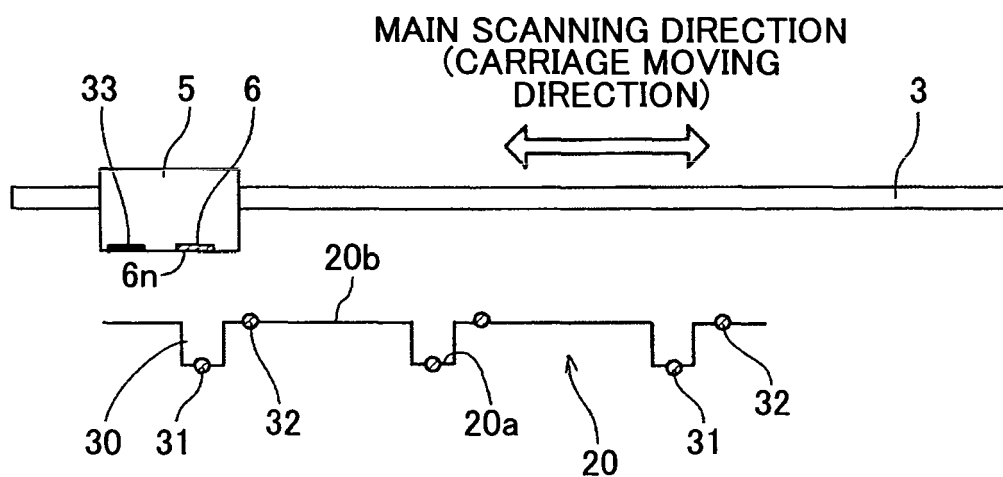


FIG.6

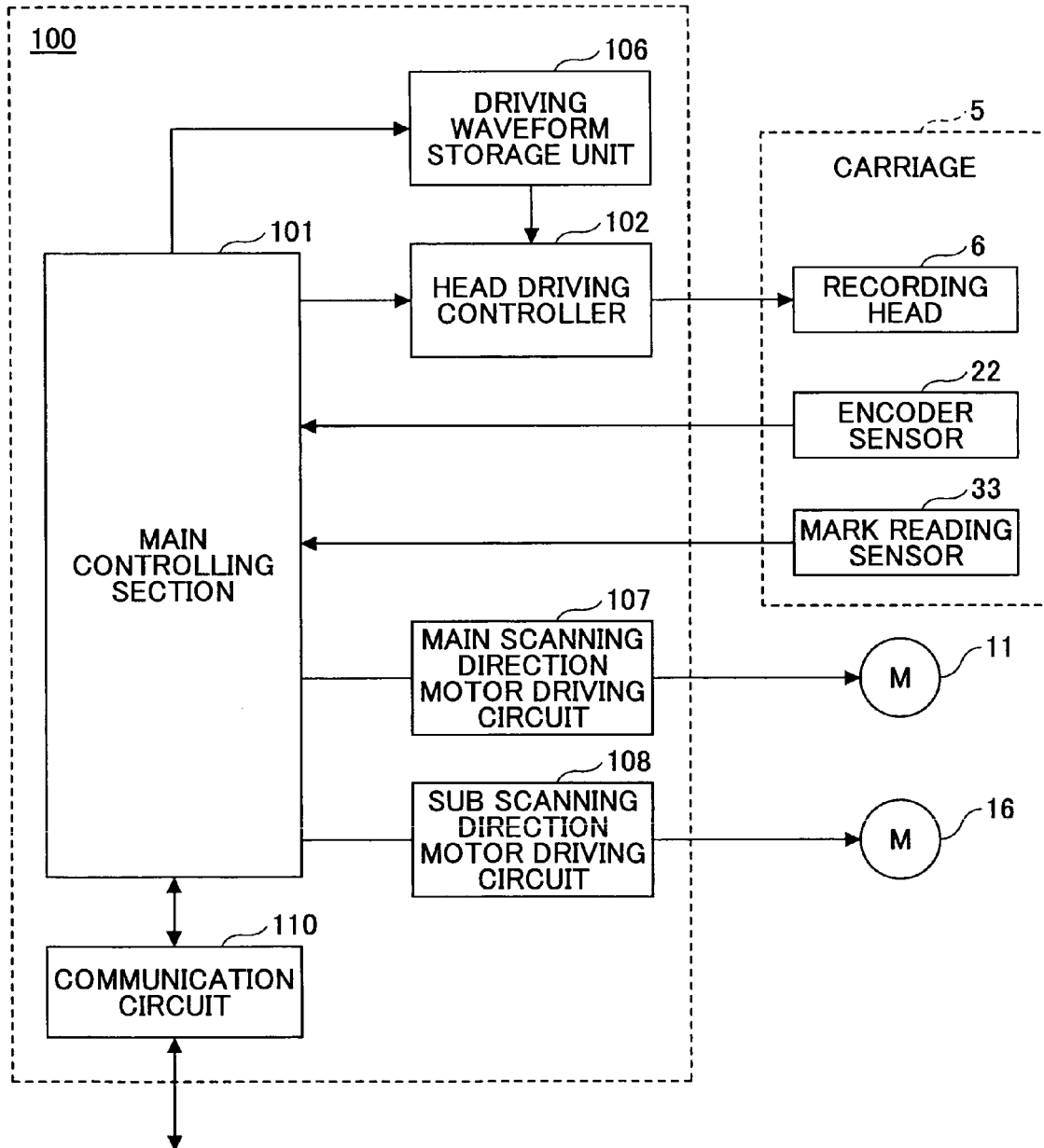


FIG. 7

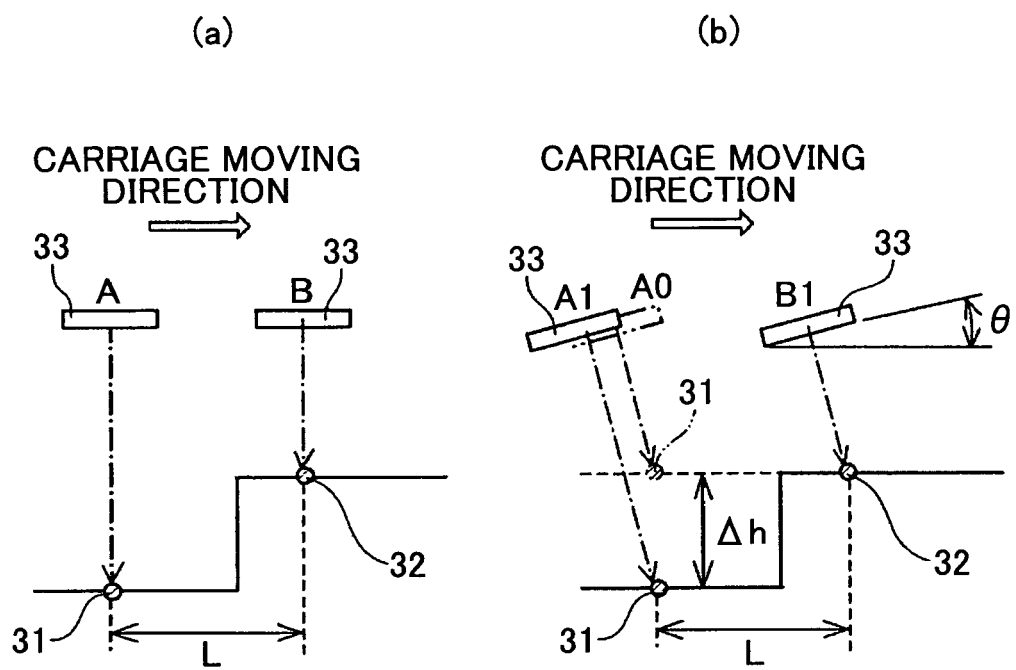


FIG.8

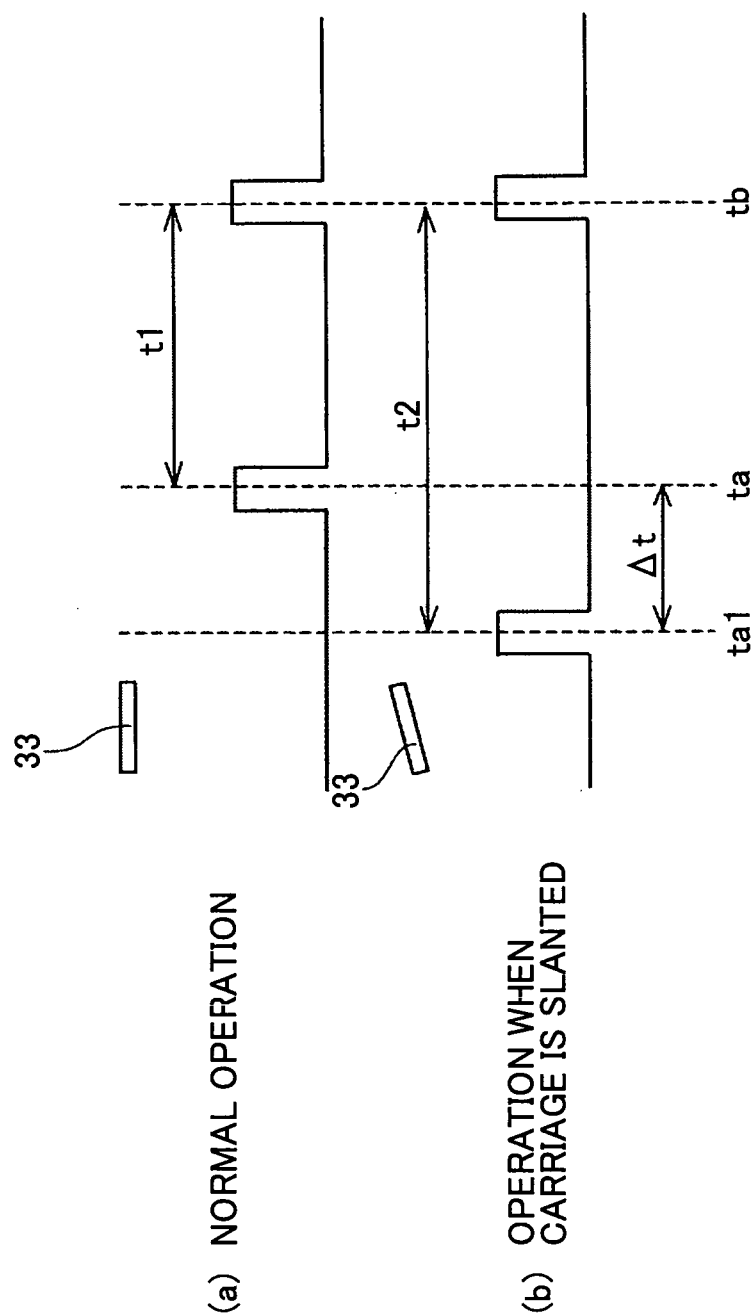


FIG.9

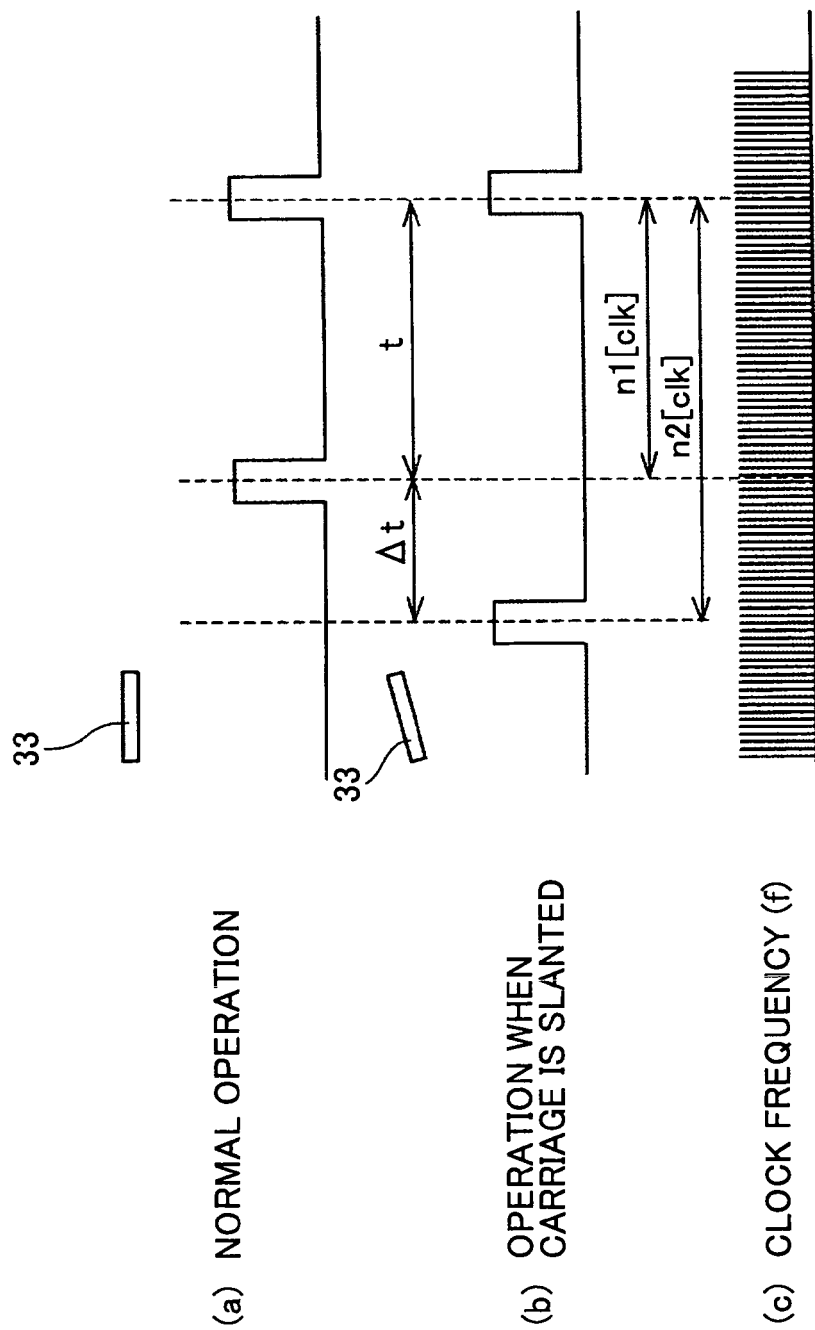


FIG.10

SLANT ANGLE θ (°)	Δt (nsec)	COUNT VALUE (clk)
0.01	0.15	12
0.05	0.7	56
0.1	1.5	120
0.5	7.4	592
1	14.7	1176

FIG.11

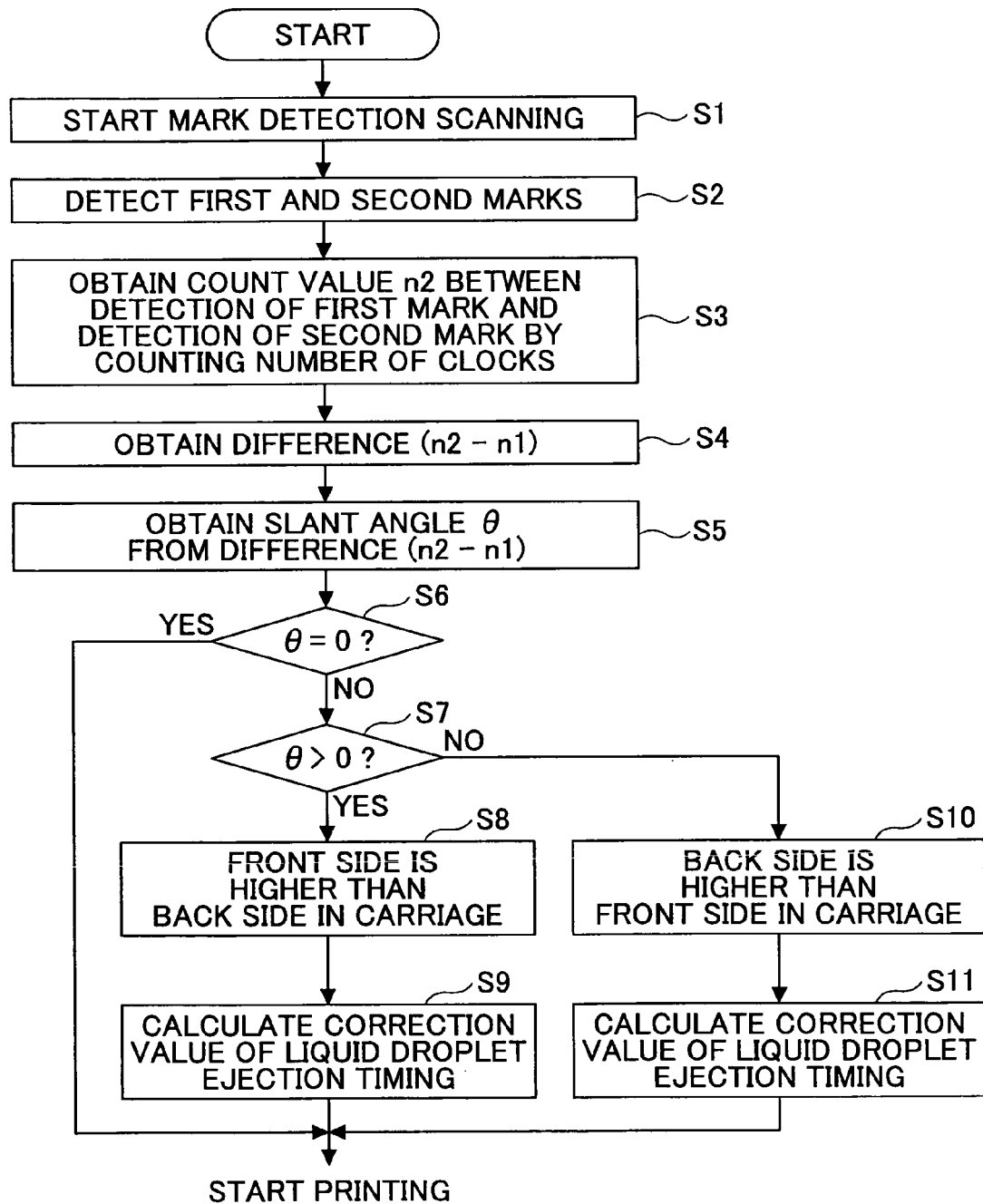


FIG.12

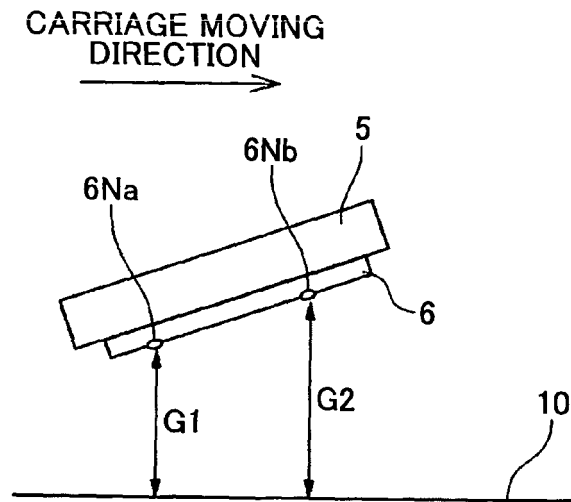


FIG.13

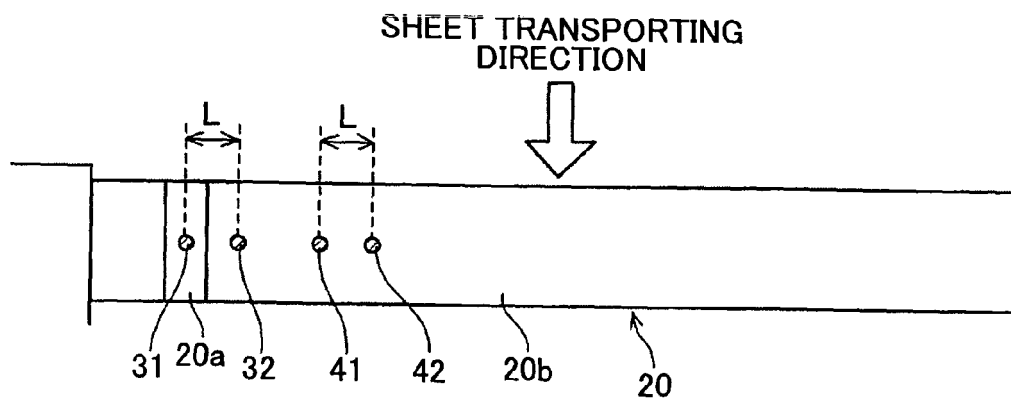


FIG.14

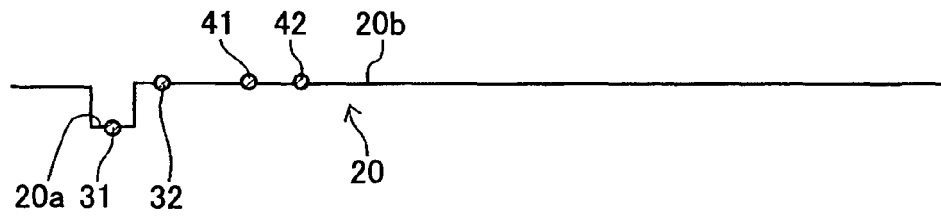


FIG.15

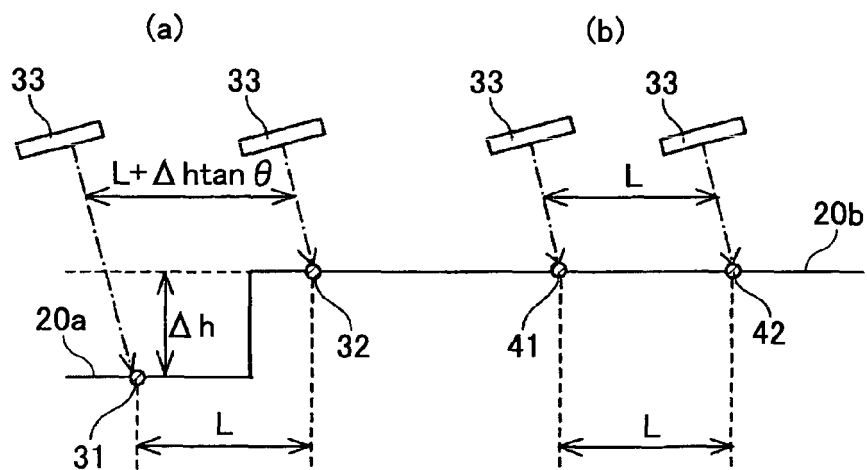


FIG.16

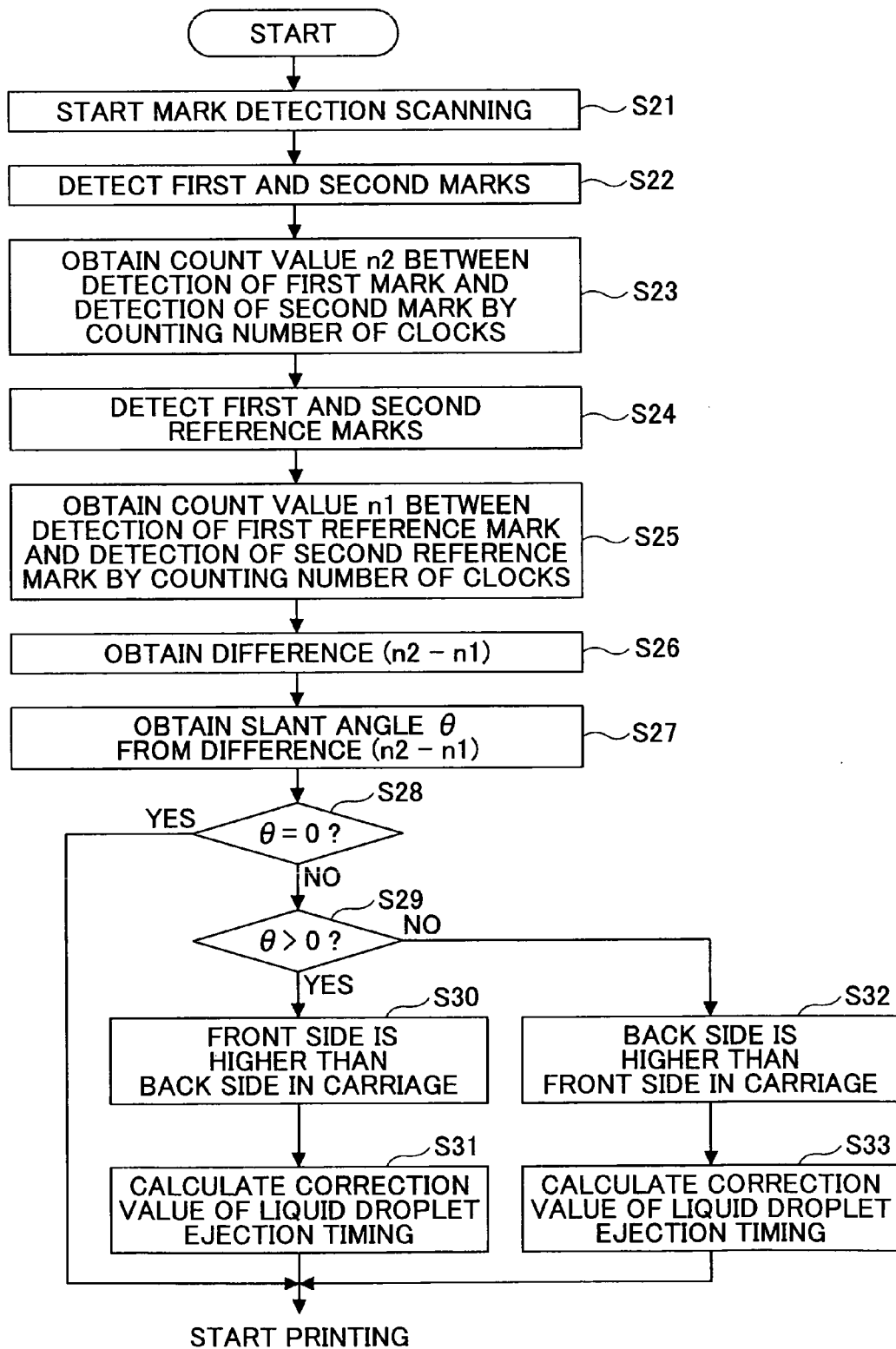


FIG.17

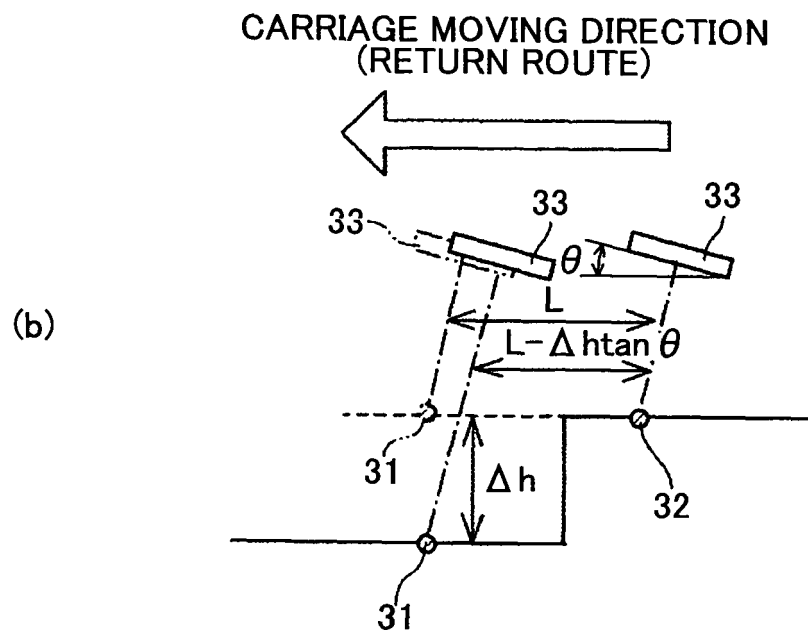
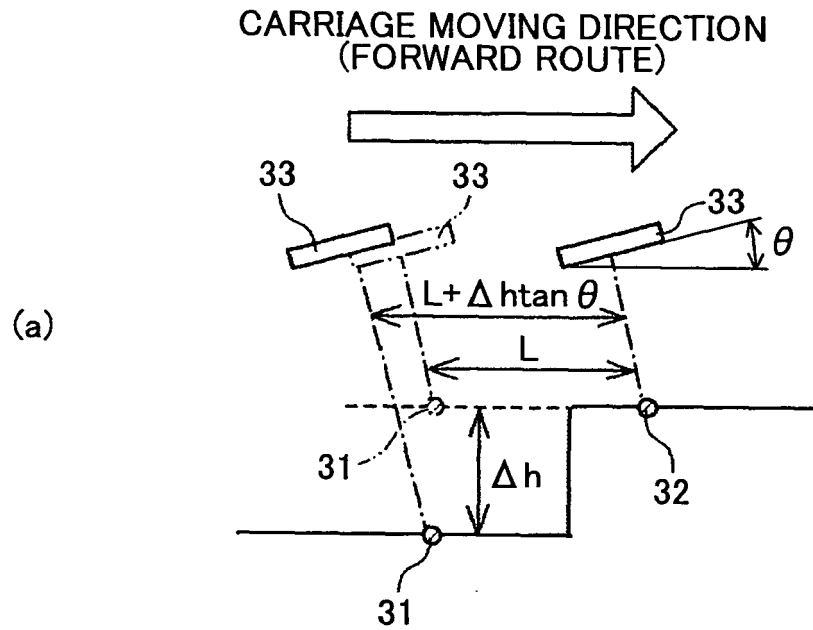


FIG.18

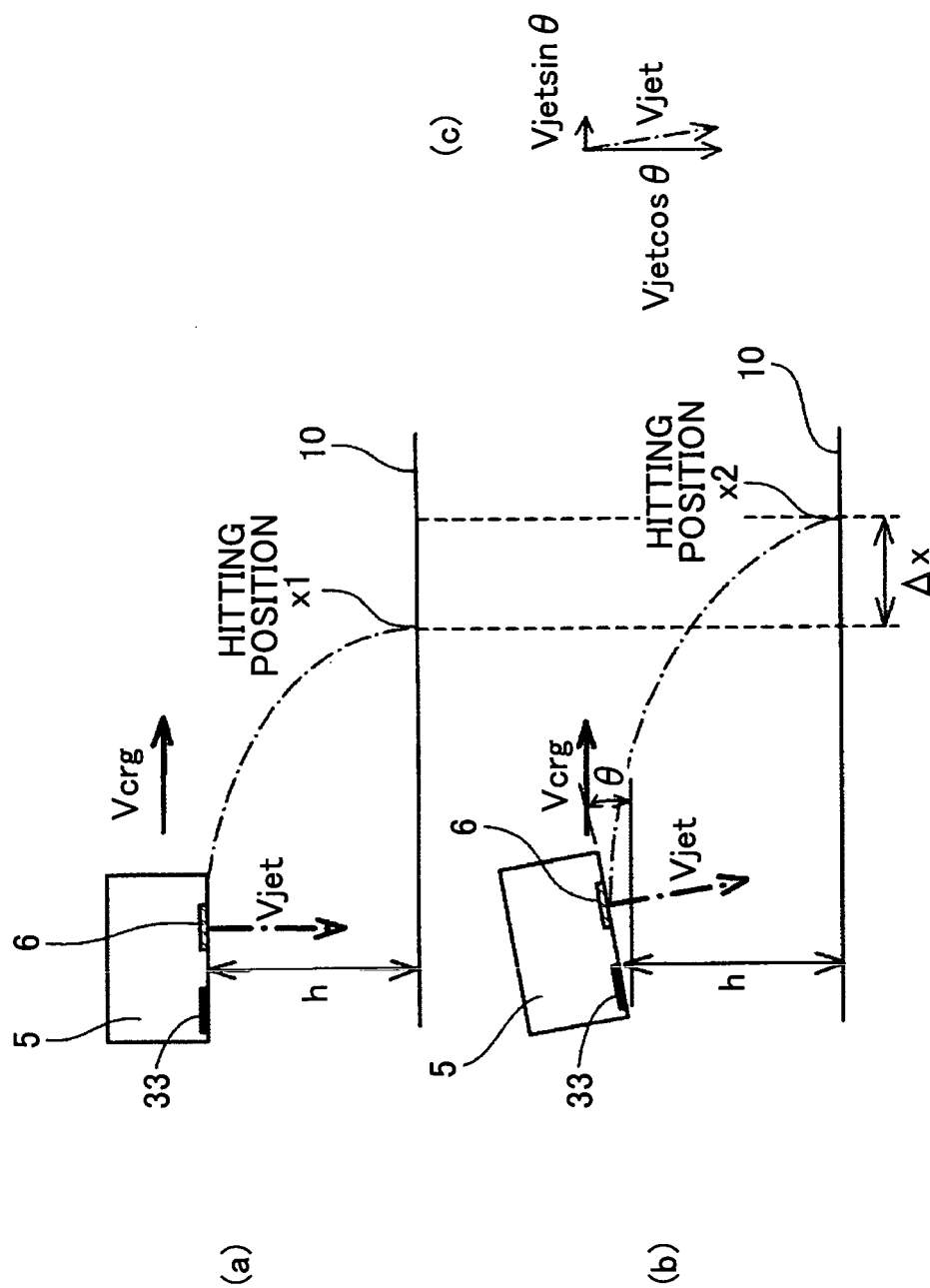


FIG.19

SLANT ANGLE θ (°)	Δx (nm)	DELAY TIME (ns)
0.01	0.2	0.17
0.05	1	0.84
0.1	2	1.69
0.5	9.9	8.35
1	19.8	16.71



EUROPEAN SEARCH REPORT

Application Number
EP 09 25 1718

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	JP 2007 276264 A (CANON KK) 25 October 2007 (2007-10-25) * the whole document *	1-6	INV. B41J2/01 B41J2/175 B41J25/304
D,A	JP 2007 044948 A (CANON KK) 22 February 2007 (2007-02-22) * the whole document *	1-6	
			TECHNICAL FIELDS SEARCHED (IPC)
			B41J
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 15 October 2009	Examiner Axters, Michael
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EP 09 25 1718

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15-10-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2007276264 A	25-10-2007	NONE	

JP 2007044948 A	22-02-2007	NONE	

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