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Inkjet printing device and inkjet printing method

Abstract

A technique is provided that reduces the occurrence of a difference in print resolution between an upstream ejector and a downstream ejector due to expansion and contraction of a recording medium. An inkjet printing apparatus includes four heads arranged in a transport direction and four ejection controllers that control the four heads, respectively. Each ejection controller includes an ejection timing generator that generates an ejection timing signal for causing the head that is controlled to eject ink toward a target portion of a recording medium, an expansion/contraction amount estimator that estimates the amount of expansion and contraction in the target portion, and a correction information generator that outputs, to a downstream ejection controller, correction information that includes the ejection timing signal and expansion/contraction amount information indicating the amount of expansion and contraction.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) This application is the U.S. National Phase under 35 U.S.C. § 371 of International Patent Application No. PCT/JP2021/030579, filed on Aug. 20, 2021, which claims the benefits of

Japanese Patent Application No. 2020-143649, filed on Aug. 27, 2020 the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

(2) The present invention relates to an inkjet printing apparatus and an inkjet printing method.

BACKGROUND ART

(3) Inkjet printing apparatuses that eject ink periodically from nozzles to a recording medium that is being transported in a predetermined transport direction may be used in recording an image on the recording medium. The inkjet printing apparatuses are capable of forming an appropriate image by ejecting ink for each timing when a target position of the recording medium to which the ink is to be ejected has shifted to a predetermined reference ejection position in the transport direction, and by thereby causing the ink to land at appropriate intervals in the transport direction

(4) The printing apparatus disclosed in Patent Literature (PTL) 1 eject ink from a plurality of print heads arranged in the transport direction of a recording medium while transporting the recording medium by a roller. Each print head ejects different color ink (black, cyan, magenta, or yellow) in accordance with a detection signal output from an encoder attached to the roller. Thermal expansion of the roller causes a timing difference between detection signals output from different encoders. In that case, the timing of ink ejection from each print head shifts and results in color shifts. Therefore, PTL 1 proposes to reduce the occurrence of color shifts by correcting print data on the basis of the perimeter of the roller.

CITATION LIST

Patent Literature

(5) PTL 1: Japanese Patent Application Laid-Open No. 2016-032927

SUMMARY OF INVENTION

Technical Problem

(6) The recording medium that is being printed on may expand or contract in the transport direction. For example, in the case where the recording medium is paper, the recording medium may expand or contract due to adhesion of the ink to the recording medium or due to drying of the ink adhering to the recording medium. In the case where the recording medium is a film, the recording medium may expand or contract due to the application of heat or tension on the recording medium. The expansion and contraction of the recording medium may cause a difference in print resolution (ink dot pitch) between an upstream ejector and a downstream ejector and accordingly may deteriorate image quality.

(7) It is an object of the present invention to provide a technique for reducing the occurrence of a difference in print resolution between an upstream ejector and a downstream ejector due to the expansion and contraction of a recording medium.

Solution to Problem

(8) To solve the problem described above, a first aspect is an inkjet printing apparatus that includes a transporter that transports a long band-like recording medium in a prescribed transport direction, a first ejector capable of ejecting ink toward the recording medium being transported by the transporter, a first ejection timing generator that generates first ejection timing when the first ejector ejects ink to a target portion of the recording medium, an expansion/contraction amount estimator that estimates an amount of expansion and contraction in the target portion in the transport direction, a second ejector that is capable of ejecting ink toward the recording medium being transported by the transporter, and that is located away from the first ejector on a downstream side in the transport direction, and a second ejection timing generator that generates, in accordance with the amount of expansion and contraction, second ejection timing when the second ejector ejects ink to the target portion.

(9) A second aspect is the inkjet printing apparatus according to the first aspect, in which the expansion/contraction amount estimator estimates the amount of expansion and contraction in accordance an amount of ink that the first ejector ejects to each area obtained by virtually

partitioning a surface of the recording medium at a predetermined interval in the transport direction.
(10) A third aspect is the inkjet printing apparatus according to the first aspect further includes encoder that outputs a pulse signal based on an amount of shift of the recording medium caused by the transporter. The second ejection timing generator generates the second ejection timing in accordance with the pulse signal output from the encoder.
(11) A fourth aspect is the inkjet printing apparatus according to any one of the first to third aspects further includes an expansion/contraction amount measuring part that measures the amount of expansion and contraction of the recording medium. The expansion/contraction amount estimator estimates the amount of expansion and contraction in the target portion in accordance with the amount of expansion and contraction of the recording medium measured by the expansion/contraction amount measuring part.
(12) A fifth aspect is an inkjet printing apparatus that includes a transporter that transports a long band-like recording medium in a prescribed transport direction, a first ejector that is capable of ejecting ink toward the recording medium being transported by the transporter, a first ejection timing generator that generates first ejection timing when the first ejector ejects ink to a target portion of the recording medium, a first expansion/contraction amount estimator that estimates, in accordance with the amount of ink ejected to the target portion by the first ejector, a first expansion/contraction amount that is caused in the target portion in the transport direction by the ink ejected from the first ejector, a second ejector that is capable of ejecting ink toward the recording medium being transported by the transporter and that is located away from the first ejector on a downstream side in the transport direction, a second expansion/contraction amount estimator that estimates, in accordance with the amount of ink ejected to the target portion by the first ejector and the amount of ink ejected to the target portion by the second ejector, a second expansion/contraction amount that is caused in the target potion in the transport direction by the ink ejected from the first ejector and the ink ejected from the second ejector, a third ejector that is capable of ejecting ink toward the recording medium being transported by the transporter and that is spaced away from the second ejector on a downstream side in the transport direction, and a third ejection timing generator that generates, in accordance with the second expansion/contraction amount, third ejection timing when the third ejector ejects ink to the target portion.
(13) A sixth aspect is an inkjet printing method that includes (a) transporting a recording medium in a prescribed transport direction, (b) generating first ejection timing when a first ejector ejects ink to a target portion of the recording medium being transported in the operation (a), (c) estimating an amount of expansion and contraction in the target portion in the transport direction, and (d) generating second ejection timing when a second ejector ejects ink toward the target portion, in accordance with the first ejection timing and the amount of expansion and contraction.
Advantageous Effects of Invention
(14) According to the inkjet printing apparatus of the first aspect, the amount of expansion and contraction in the target portion of the recording medium, to which the first ejector has ejected the ink, is used as a basis to determine the ejection timing when the second ejector ejects ink to the target portion. Accordingly, even if expansion and contraction have occurred in the target portion of the recording medium, it is possible to reduce the occurrence of a difference in the print resolution on the target portion between the first ejector and the second ejector.
(15) According to the inkjet printing apparatus of the second aspect, the ejection timing of the second ejector is determined from the amount of shift of the recording medium.
(16) According to the inkjet printing apparatus of the third aspect, the amount of expansion and contraction is estimated from the amount of the ink ejected from the first ejector.
(17) According to the inkjet printing apparatus of the fourth aspect, the second ejection timing is determined based on the measured value of the amount of expansion and contraction of the recording medium.

(18) According to the inkjet printing apparatus of the fifth aspect, in the case where three ejectors (first to third ejectors) are present in the transport direction of the recording medium, the first expansion/contraction amount estimator estimates the first expansion/contraction amount of the target portion in accordance with the amount of the ink ejected from the first ejector, and the second ejection timing generator generates, in accordance with the first expansion/contraction amount, the second ejection timing when the second ejector ejects the ink to the target portion. The second expansion/contraction amount estimator estimates the second expansion/contraction amount of the target portion in accordance with the amount of the ink ejected from the first ejector and the amount of the ink ejected from the second ejector, and the third ejection timing generator generates, in accordance with the second expansion/contraction amount, the third ejection timing when the third ejector ejects the ink to the target portion. Therefore, according to the inkjet printing apparatus of the fifth aspect, even if expansion or contraction has occurred in the target portion of the recording medium, it is possible to reduce the occurrence of a difference in print resolution on the target portion among the first to third ejectors.

(19) According to the inkjet printing method of the sixth aspect, the amount of expansion and contraction in the target portion of the recording medium, to which the first ejector has ejected the ink, is used as a basis to determine the ejection timing when the second ejector ejects the ink to the target portion. Therefore, even if expansion or contraction has occurred in the target portion of the recording medium, it is possible to reduce the occurrence of a difference in print resolution on the target portion between the first ejector and the second ejector.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is an illustration of a configuration of an inkjet printing apparatus according to a first embodiment;

(2) FIG. **2** is an illustration of an ejection surface of a head;

(3) FIG. **3** is an illustration of a configuration of an ejection controller;

(4) FIG. **4** is a flowchart of processing in which the ejection controller generates an ejection timing signal;

(5) FIG. **5** is a flowchart of processing in which the ejection controller generates correction information;

(6) FIG. **6** is a diagram showing a condition in which the inkjet printing apparatus executes print processing;

(7) FIG. **7** is an illustration of a configuration of an inkjet printing apparatus according to a second embodiment; and

(8) FIG. **8** is an illustration of a configuration of an inkjet printing apparatus according to a third embodiment.

DESCRIPTION OF EMBODIMENTS

(9) Hereinafter, embodiments of the present disclosure will be described with reference to the accompanying drawings. Note that constituent elements described in each embodiment are merely examples, and the scope of the present invention is not intended to be limited thereto. To facilitate understanding of the drawings, the dimensions or numbers of the constituent elements may be illustrated in exaggerated or simplified form as necessary.

1. First Embodiment

(10) FIG. **1** is an illustration of a configuration of an inkjet printing apparatus **1** according to a first embodiment. The inkjet printing apparatus **1** transports a long band-like recording medium **9** in a prescribed transport direction by, for example, a roll-to-roll method. The inkjet printing apparatus **1** forms an image on the surface of the recording medium **9** by ejecting ink toward the surface of the

recording medium **9** that is being transported. The recording medium **9** may be paper or film. As illustrated in FIG. **1**, the inkjet printing apparatus **1** includes a transporter **10**, a first encoder **20**, a transport controller **30**, and printer **40**.

(11) The transporter **10** includes a first roller **11**, a second roller **13**, and a transport motor **15**. The first roller **11** and the second roller **13** each have an outer peripheral surface that supports the recording medium **9**. The recording medium **9** is wound on the outer peripheral surface of the second roller **13**. The transport motor **15** is connected to a rotation shaft of the second roller **13**. The transport motor **15** rotates the rotation shaft of the second roller **13** so as to move the recording medium **9** from the first roller **11** to the second roller **13** under a predetermined tension.

(12) The first encoder **20** outputs a pulse signal based on the transport speed of the recording medium **9** transported by the transporter **10**. The first encoder **20** may be mounted on, for example, the transport motor **15**. The first encoder **20** outputs a pulse signal each time the transport motor **15** rotates a predetermined angle. Note that the first encoder **20** may detect the rotation of the second roller **13**.

(13) The transport controller **30** controls the transport speed of the recording medium **9** transported by the transporter **10**, by controlling the transport motor **15** on the basis of the pulse signal output from the first encoder **20**.

(14) The printer **40** includes four ejection controllers **41** and four heads **43**. As illustrated in FIG. **1**, the heads **43** each have an ejection surface **45** that faces the upper surface (print target surface) of the recording medium **9** transported by the transporter **10**. As illustrated in FIG. **1**, the ejection surface **45** is approximately parallel to the upper surface of the recording medium **9**. The four heads **43** are arranged at regular intervals in the transport direction. That is, the four heads **43** are arranged with a fixed pitch (head-to-head distance D**1**). However, it is not an absolute necessity to arrange the four heads **43** at regular intervals.

(15) FIG. **2** is an illustration of the ejection surface **45** of one head **43**. As illustrated in FIG. **2**, the ejection surface **45** has an approximately rectangular shape extending in a width direction orthogonal to the transport direction. The ejection surface **45** has a plurality of nozzles **47** (ejection outlets) from which ink is ejected. The nozzles **47** are arranged at regular intervals in the width direction. The nozzles **47** arranged in the width direction form a plurality of lines (in the present example, two lines) in the transport direction. The nozzles **47** on the first line (on the upstream side in the transport direction) are displaced in the width direction from the nozzles **47** on the second line (on the downstream side in the transport direction).

(16) The heads **43** form an image corresponding to image data on the upper surface of the recording medium **9** by ejecting ink from each nozzle **47** toward the recording medium **9** transported by the transporter **10**. The heads **43** each include a plurality of inkjet elements **49** (see FIG. **1**) that each correspond respectively to each nozzle **47**. The inkjet elements **49** jet ink from the nozzles **47**. For example, the inkjet elements **49** each may be configured of an ink room in which ink is stored, and a piezoelectric element that configures the wall surface of the ink room. When voltage is applied, the piezoelectric element applies pressure to the ink stored in the ink room. When pressure is applied to the ink, the ink is ejected from the nozzle **47** that communicates with the ink room. The nozzle **47** and the inkjet element **49** are one example of an ejector.

(17) As illustrated in FIG. **1**, the four heads **43** are arranged at intervals in the transport direction. For example, each of the four heads **43** may eject ink corresponding to one of four colors including black (K), cyan (C), magenta (M), and yellow (Y). Note that the colors ejected from the heads **43** are not limited to K, C, M, and Y. The number of heads **43** is also not limited to four, and may be in the range of one to three, or five or more.

(18) The ejection controllers **41** each control the ejection of ink from each nozzle **47** of the corresponding head **43**. In the following description, when a specific head **43** is focused on, the head **43** that is located adjacent to the upstream side of the specific head **43** may be simply referred to as the “upstream head **43**,” and the head **43** that is located adjacent to the downstream side of the

specific head **43** may be simply referred to as the "downstream head **43**." Moreover, the ejection controller **41** corresponding to the upstream head **43** may be simply referred to as the "upstream ejection controller **41**," and the ejection controller **41** corresponding to the downstream head **43** may be simply referred to as the "downstream ejection controller **41**."

(19) FIG. **3** is an illustration of the configuration of one ejection controller **41**. The ejection controller **41** includes an ejection timing generator **51**, a print-data processing part **53**, a printing-ratio calculator **55**, an expansion/contraction amount estimator **57**, and a correction information generator **59**. The ejection controller **41** may be configured as a dedicated circuit such as an application specific integrated circuit (ASIC). Alternatively, the ejection controller **41** may be configured as a general-purpose computer that includes, for example, a processor such as a CPU and a RAM electrically connected to the processor. Each function of the ejection controller **41** may be realized by the processor operating in accordance with a program.

(20) The ejection timing generator **51** generates an ejection timing signal TS on the basis of a pulse signal EP output from the first encoder **20**. The ejection timing generators **51** of the second to fourth ejection controllers **41** from the upstream side each acquire correction information CD that is output from the correction information generator **59** of the upstream ejection controller **41**. These ejection timing generators **51** generate the ejection timing signal TS on the basis of the pulse signal EP and the acquired correction information CD. The ejection timing generator **51** of the ejection controller **41** that corresponds to the first head **43** from the upstream side generates the ejection timing signal TS on the basis of only the pulse signal EP.

(21) Each ejection timing generator **51** outputs the generated ejection timing signal TS to the head **43**, the print-data processing part **53**, and the correction information generator **59**. The ejection timing signal TS serves as a trigger for the inkjet elements **49** of the head **43** to eject ink from the nozzles **47**. The processing in which the ejection timing generator **51** generates the ejection timing signal TS corresponds to processing for generating the timing when the ejector ejects ink.

(22) Upon acquisition of the ejection timing signal TS, the print-data processing part **53** outputs a print data signal PS based on the print data. The print data is data for forming characters or images on the recording medium **9**. The print-data processing part **53** outputs the generated print data signal PS to the head **43** and the printing-ratio calculator **55**. The print data signal PS is a control signal for selectively ejecting ink from each nozzle **47** with the timing indicated by the ejection timing signal TS. The head **43** selectively ejects ink from each nozzle **47** on the basis of the ejection timing signal TS and the print data signal PS.

(23) The printing-ratio calculator **55** calculates a printing ratio on the basis of the print data signal PS. The printing ratio refers to information that indicates the amount of ink to be ejected to each target area, the target area being obtained by virtually dividing the surface of the recording medium **9** at fixed intervals in the transport direction into a plurality of areas. The printing-ratio calculator **55** outputs printing-ratio information PD that indicates the calculated printing ratio, to the expansion/contraction amount estimator **57**.

(24) The expansion/contraction amount estimator **57** estimates, on the basis of the printing-ratio information PD, the magnitude of expansion or contraction (the amount of expansion or contraction) in the transport direction that may occur in a target portion to which the head **43** to be controlled has ejected ink. The expansion/contraction amount estimator **57** outputs expansion/contraction amount information ED that indicates the estimated amount of expansion and contraction of the recording medium **9**, to the correction information generator **59**. The expansion/contraction amount estimator **57** may estimate the amount of expansion and contraction, using an expansion/contraction amount table that prescribes the relationship between the printing ratio and the amount of expansion and contraction. The ejection controller **41** may further include a storage that stores the expansion/contraction amount table. The expansion/contraction amount table may be prepared for each ink color. For example, in the case where the amount of expansion and contraction of the recording medium **9** varies depending on the ink color, it is preferable that the

expansion/contraction amount table may be prepared for each color.
(25) In the case where the printing ratio is the same but the amount of expansion and contraction of the recording medium **9** varies depending on a transport speed range of the recording medium **9**, it is preferable that a different expansion/contraction amount table may be prepared for each transport speed range. This allows accurate printing during adjustable speed printing.
(26) Similarly, in the case where the printing ratio is the same but the amount of expansion and contraction of the recording medium **9** varies depending on the magnitude of the tension applied to the recording medium **9**, it is preferable that a different expansion/contraction amount table may be prepared for each tension range. This allows accurate printing even in the case where the tension applied to the recording medium **9** varies during printing (e.g., the transport speed is increased or reduced).
(27) The correction information generator **59** generates correction information CD on the basis of the expansion/contraction amount information ED and the ejection timing signal TS. The correction information generator **59** outputs the generated correction information CD to the downstream ejection controller **41**. The correction information CD refers to information for allowing the downstream ejection controller **41** to correct the ejection timing. The correction information CD includes the ejection timing signal TS and the expansion/contraction amount information ED corresponding to the ejection timing signal TS. The ejection timing indicated by the ejection timing signal TS is information that indicates the position of the target portion of the recording medium **9** to which the head **43** has ejected ink.
(28) Note that the ejection controller **41** of the head **43** that is located on the most downstream side may not include the printing-ratio calculator **55**, the expansion/contraction amount estimator **57**, and the correction information generator **59**.
(29) FIG. **4** is a flowchart of the processing in which one ejection controller **41** generates the ejection timing signal TS. As illustrated in FIG. **4**, the ejection timing generator **51** of the ejection controller **41** acquires the correction information CD generated by the correction information generator **59** of the upstream ejection controller **41** (correction-information acquisition processing S**11**). Upon acquisition of the correction information CD, the ejection timing generator **51** acquires the pulse signal EP from the first encoder **20** (pulse-signal acquisition processing S**12**). The ejection timing generator **51** determines, on the basis of the correction information CD and the pulse signal EP, whether the target portion of the recording medium **9** to which the upstream head **43** has ejected ink has reached a position (ejection position) at which ink is to be ejected from the head **43** to be controlled (determination processing S**13**). Specifically, in the determination processing S**13**, the ejection timing generator **51** determines whether a moving distance of the recording medium **9** from the timing indicated by the ejection timing signal TS included in the correction information CD output from the upstream ejection controller **41** (i.e., the ejection timing when the upstream head **43** has ejected ink to the target portion) has exceeded a corrected distance that is obtained by correcting the head-to-head distance D**1**, using the amount of expansion and contraction.
(30) If it is determined in the determination processing S**13** that the target position has not reached the ejection position (i.e., moving distance<corrected distance) (in the case of No), the ejection timing generator **51** executes the pulse-signal acquisition processing S**12** again. If it is determined in the determination processing S**13** that the target position has reached the ejection position (i.e., moving distance≥corrected distance) (in the case of Yes), the ejection timing generator **51** generates the ejection timing signal TS (ejection-timing generation processing S**14**).
(31) FIG. **5** is a flowchart of processing in which one ejection controller **41** generates the correction information CD. As illustrated in FIG. **5**, the printing-ratio calculator **55** of the ejection controller **41** calculates, on the basis of the print data signal PS, the printing ratio of the target portion of the recording medium **9** that corresponds to the ejection timing (printing-ratio calculation processing S**21**). The expansion/contraction amount estimator **57** estimates, on the basis of the printing-ratio

information PD indicating the printing ratio calculated by the printing-ratio calculation processing S**21**, the amount of expansion and contraction that may occur in the target portion of the recording medium **9** (expansion/contraction-amount estimation processing S**22**). The target portion of the recording medium **9** refers to a portion of the recording medium **9** to which ink is to be ejected from the head **43** with the ejection timing generated by the ejection-timing generation processing S**14**. The correction information generator **59** generates the correction information CD that includes the expansion/contraction amount estimated by the expansion/contraction-amount estimation processing S**22** and the ejection timing signal TS generated by the ejection-timing generation processing S**14** (correction-information generation processing S**23**). The correction information generator **59** outputs the generated correction information CD to the downstream ejection controller **41** (correction-information output processing S**24**).

(32) FIG. **6** is a diagram showing a condition in which the inkjet printing apparatus **1** executes print processing. In the following description, the four heads **43** are respectively referred to as a first head **43**K, a second head **43**C, a third head **43**M, and a fourth head **43**Y in order from the upstream side in the transport direction. The four ejection controllers **41** are also respectively referred to as a first ejection controller **41**K, a second ejection controller **41**C, a third ejection controller **41**M, and a fourth ejection controller **41**Y in order from the upstream side. In the example illustrated in FIG. **6**, it is assumed that the recording medium **9** is virtually partitioned into a plurality of areas A**1** to A**5** in the transport direction and the ratio of expansion and contraction in each of the areas A**1** to A**5** is estimated based on the average value of the printing ratios of the areas A**1** to A**5**.

(33) First, a description is given of print control of the first to fourth heads **43**K to **43**Y for the area A**1**. The first head **43**K ejects the K ink to the area A**1** at an average printing ratio of 30% during a period T**0**-T**1** from time T**0** when the downstream end of the area A**1** in the transport direction reaches immediately under the first head **43**K to time T**1** when the upstream end of the area A**1** in the transport direction reaches immediately under the first head **43**K. The first ejection controller **41**K outputs, to the second ejection controller **41**C, the amount of expansion and contraction in the area A**1** that corresponds to the average K-ink printing ratio of 30%.

(34) The downstream end of the area A**1** in the transport direction reaches immediately under the second head **43**C at time T**2**. This time T**2** is adjusted for the amount of expansion and contraction caused in the area A**1** by the K ink ejected from the first head **43**K. The second head **43**C ejects the C ink to the area A**1** at an average printing ratio of 30% during a period from time T**2** to time T**3** when the upstream end of the area A**1** in the transport direction reaches immediately under the second head **43**C. At this time, the second ejection controller **41**C generates ejection timing that is adjusted by a time quantity depending on the amount of expansion and contraction in the area A**1** (the amount of expansion and contraction in the area A**1** that corresponds to the average K-ink printing ratio of 30%) output from the first ejection controller **41**K. Accordingly, the print resolution (ink dot pitch) offered for the area A**1** by the second head **43**C matches with the print resolution offered for the area A**1** by the first head **43**K. The second ejection controller **41**C outputs, to the third ejection controller **41**M, the amount of expansion and contraction in the area A**1** that corresponds to the average K-ink printing ratio of 30% and the average C-ink printing ratio of 30%.

(35) The downstream end of the area A**1** in the transport direction reaches immediately under the third head **43**M at time T**4**. This time T**4** is adjusted for the amount of expansion and contraction caused in the area A**1** by the K ink ejected from the first head **43**K and the C ink ejected from the second head **43**C. The third head **43**M ejects the M ink to the area A**1** at an average printing ratio of 30% during a period from time T**4** to the time when the upstream end of the area A**1** in the transport direction reaches immediately under the third head **43**M. At this time, the third ejection controller **41**M generates ejection timing that is adjusted by a time quantity depending on the amount of expansion and contraction in the area A**1** output from the second ejection controller **41**C (the amount of expansion and contraction in the area A**1** that corresponds to the average K-ink

printing ratio of 30% and the average C-ink printing ratio of 30%). Accordingly, the print resolution offered for the area A**1** by the third head **43**M matches with the print resolution offered for the area A**1** by the first head **43**K and the print resolution offered for the area A**1** by the second head **43**C. The third ejection controller **41**M outputs, to the fourth ejection controller **41**Y, the amount of expansion and contraction in the area A**1** that corresponds to the average K-ink printing ratio of 30%, the average C-ink printing ratio of 30%, and the average M-ink printing ratio of 30%.

(36) The fourth ejection controller **41**Y generates ejection timing that is adjusted by a time quantity depending on the amount of expansion and contraction in the area A**1** output from the third ejection controller **41**M (the average K-ink printing ratio of 30%, the average C-ink printing ratio of 30%, and the average M-ink printing ratio of 30%). Accordingly, the print resolution offered for the area A**1** by the fourth head **43**Y matches with the print resolution offered for the area A**1** by the first head **43**K, the print resolution offered for the area A**1** by the second head **43**C, and the print resolution offered for the area A**1** by the third head **43**M.

(37) As described above, the heads **43**K, **43**C, **43**M, and **43**Y sequentially perform recording on the area A**1**, and each head **43** is capable of ejecting ink with the ejection timing that reflects the amount of expansion and contraction in the area A**1**, the amount of expansion and contraction reflecting the average printing ratios of all the heads **43** that are located upstream of the head **43** concerned. Accordingly, it is possible to reduce the occurrence of a difference in print resolution among the ink images recorded on the area A**1**.

(38) Next, the area A**2** that is the continuous area following the area A**1** is focused on. The first head **43**K does not eject ink to the area A**2**. Thus, the first ejection controller **41**K outputs, to the second ejection controller **41**C, the ratio of expansion and contraction in the area A**2** that corresponds to an average K-ink printing ratio of 0% (i.e., the ratio of expansion and contraction of 0%).

(39) Therefore, the second head **43**C ejects the C ink to the area A**2** at an average printing ratio of 30% without correcting the ejection timing during the period from time T**3** to time T**4**. The second ejection controller **41**C outputs, to the third ejection controller **41**M, the ratio of expansion and contraction in the area A**2** that corresponds to the average C-ink printing ratio of 30%. Descriptions of the areas A**3** to A**5** shall be omitted.

(40) As described above, the ejection controller **41** generates the ejection timing for the target portion on the basis of the amount of expansion and contraction occurring in the target portion (areas A**1** to A**5**) to which the upstream head **43** has ejected ink. This reduces the occurrence of a difference in print resolution for the target portion among the different heads **43**.

2. Second Embodiment

(41) FIG. **7** is an illustration of a configuration of an inkjet printing apparatus **1***a* according to a second embodiment. The inkjet printing apparatus **1***a* includes a second encoder **22** and an expansion/contraction amount measuring part **61**. The second encoder **22** is mounted on the first roller **11** to detect the rotation of the first roller **11**. Specifically, the second encoder outputs a pulse signal each time the first roller **11** rotates a predetermined angle.

(42) The expansion/contraction amount measuring part **61** measures a total amount of expansion and contraction of the recording medium **9** between the first roller **11** and the second roller **13**, on the basis of a shift between the pulse signal output from the first encoder **20** and the pulse signal output from the second encoder **22**.

(43) The expansion/contraction amount estimator **57** of each ejection controller **41** estimates, on the basis of the total amount of expansion and contraction, the amount of expansion and contraction of the recording medium **9** at the position of the head **43** to be controlled. At this time, the total amount of expansion and contraction may be allocated according to the position of each head **43**. In the case where the amount of expansion and contraction of the recording medium **9** increases with increasing amount of ink ejection, the amount of expansion and contraction at the position of each head **43** may be set to increase gradually toward the downstream side.

(44) According to the inkjet printing apparatus **1***a*, the total amount of expansion and contraction of the recording medium **9** can be actually measured by the expansion/contraction amount measuring part **61**. This allows each ejection controller **41** to effectively estimate the amount of expansion and contraction at each position, and accordingly it is possible to generate the ejection timing that depends on the expansion and contraction of the recording medium **9**.

3. Third Embodiment

(45) FIG. **8** is an illustration of a configuration of an inkjet printing apparatus **1***b* according to a third embodiment. The inkjet printing apparatus **1***b* includes a mark sensor **24** and an expansion/contraction amount measuring part **61***a*. For example, the mark sensor **24** may be configured as a camera. The mark sensor **24** detects marks that are formed on the surface of the recording medium **9** at predetermined intervals. The marks may be originally formed on the recording medium **9**, or may be formed by ink ejected from one head **43**. The expansion/contraction amount measuring part **61***a* measures a total amount of expansion and contraction of the recording medium **9** on the basis of timing when the mark sensor **24** detects the marks. The expansion/contraction amount estimator **57** of each ejection controller **41** estimates the amount of expansion and contraction at the position of each head **43** on the basis of the total amount of expansion and contraction measured by the expansion/contraction amount measuring part **61***a*.

(46) According to the inkjet printing apparatus **1***b*, the total amount of expansion and contraction of the recording medium **9** can be measured by the expansion/contraction amount measuring part **61***a*. This allows each ejection controller **41** to effectively estimate the amount of expansion and contraction of the recording medium **9**, and accordingly it is possible to generate ejection timing that depends on the expansion and contraction of the recording medium **9**.

4. Variations

(47) While the embodiments have been described thus far, the present invention is not intended to be limited to the embodiments described above, and may be modified in various ways.

(48) For example, the expansion/contraction amount estimator **57** may estimate the amount of expansion and contraction in the target portion of the recording medium **9** on the basis of the temperature of the recording medium **9** or the temperature around the recording medium **9**. In this case, the inkjet printing apparatuses **1**, **1***a*, and **1***b* may further include a thermometer (not shown) that measures the temperature of the recording medium **9** or the temperature around the recording medium **9**. The expansion/contraction amount estimator **57** may also use the transport speed of the recording medium **9** as a basis to estimate the amount of expansion and contraction of the target portion of the recording medium **9**.

(49) Each ejection controller **41** estimates the amount of expansion and contraction in the target portion to which the head **43** to be controlled has ejected ink, and outputs the estimated amount of expansion and contraction to the downstream ejection controller **41**. However, the downstream ejection controller **41** may estimate the amount of expansion and contraction in the target portion. That is, the ejection controller **41** may estimate the amount of expansion and contraction in the target portion of the recording medium **9** to which the upstream head **43** has ejected ink.

(50) In the embodiments described above, each ejection controller **41** generates the ejection timing of the head **43** in accordance with the amount of expansion and contraction of the recording medium **9** and thereby reduces the occurrence of a difference in print resolution between the head **43** to be controlled and the upstream head **43**. Alternatively, it is also possible to reduce the occurrence of a difference in print resolution among the nozzles **47** located at different positions in the transport direction within one head **43**. That is, the ejection timing (first ejection timing) when the upstream nozzle **47** (first ejector) ejects ink to the target portion and the amount of expansion and contraction in the target portion may be used as a basis to generate the ejection timing (second ejection timing) for the downstream nozzle **47** (second ejector).

(51) While the invention has been shown and described in detail, the foregoing description is in all

aspects illustrative and not restrictive. It is therefore understood that numerous modifications and variations that are not described above can be devised without departing from the scope of the invention. The configurations in the embodiment and variations described above may be appropriately combined or omitted as long as there are no mutual inconsistencies.

REFERENCE SIGNS LIST

(52) **1**, **1***a*, **1***b* inkjet printing apparatus **10** transporter **20** first encoder **30** transport controller **41** ejection controller **43** head **47** nozzle **51** ejection timing generator **55** printing-ratio calculator **57** expansion/contraction amount estimator **61**, **61***a* expansion/contraction amount measuring part **9** recording medium

Claims

1. An inkjet printing apparatus comprising: a transporter configured to transport a long band-like recording medium in a prescribed transport direction; an encoder configured to output a pulse signal based on an amount of shift of the recording medium caused by the transporter; a first head configured to eject ink toward the recording medium being transported by the transporter; a second head positioned most downstream in the transport direction and configured to eject ink toward the recording medium being transported by the transporter, wherein the second head is positioned downstream in the transport direction of the first head and separated from the first head by a head-to-head distance; a first ejection controller configured to control ink ejection from the first head; and a second ejection controller configured to control ink ejection from the second head, wherein the first ejection controller includes: a first ejection timing signal generator configured to generate a first ejection timing signal based on the pulse signal and output the first ejection timing signal to the first head; a printing-ratio calculator configured to calculate printing-ratio information based on print data for forming characters or images on the recording medium; an expansion/contraction amount estimator configured to estimate an amount of expansion and contraction of a target portion in the transport direction based on the printing-ratio information; and a correction information generator configured to generate correction information including the amount of expansion and contraction based on the amount of expansion and contraction and the first ejection timing signal, and wherein the second ejection controller includes a second ejection timing signal generator configured to: acquire the pulse signal and the correction information; determine whether a moving distance of the recording medium from an ejection timing of the first head for the target portion has exceeded a corrected distance that is obtained by correcting the head-to-head distance using the amount of expansion and contraction, based on the pulse signal and the amount of expansion and contraction included in the correction information; and when determining that the moving distance has exceeded the corrected distance, generate a second ejection timing signal by adjusting the pulse signal by a time quantity corresponding to the amount of expansion and contraction in the target portion, and output the second ejection timing signal to the second head.

2. The inkjet printing apparatus according to claim 1, wherein the expansion/contraction amount estimator estimates the amount of expansion and contraction in accordance with an amount of ink that the first head ejects to each area obtained by virtually partitioning a surface of the recording medium at a predetermined interval in the transport direction.

3. The inkjet printing apparatus according to claim 1, further comprising: an expansion/contraction amount measuring part that measures the amount of expansion and contraction of the recording medium, wherein the expansion/contraction amount estimator estimates the amount of expansion and contraction in the target portion in accordance with the amount of expansion and contraction of the recording medium measured by the expansion/contraction amount measuring part.

4. The inkjet printing apparatus according to claim 1, further comprising a storage that stores an expansion/contraction amount table that prescribes a relationship between a printing ratio and an amount of expansion and contraction, wherein the expansion/contraction amount table is prepared

for each ink color, and wherein the expansion/contraction amount estimator of the first ejection controller is further configured to estimate the amount of expansion and contraction using the expansion/contraction amount table.

5. The inkjet printing apparatus according to claim 1, further comprising a storage that stores expansion/contraction amount tables that prescribe a relationship between a printing ratio and an amount of expansion and contraction, wherein a different expansion/contraction amount table is stored for each transport speed, wherein the expansion/contraction amount estimator is further configured to estimate the amount of expansion and contraction using the expansion/contraction amount tables.

6. The inkjet printing apparatus according to claim 1, further comprising a storage that stores an expansion/contraction amount table that prescribes a relationship between a printing ratio and an amount of expansion and contraction, wherein different expansion/contraction amount tables are stored for each tension range, and wherein the expansion/contraction amount estimator is further configured to estimate the amount of expansion and contraction using the expansion/contraction amount table.

7. An inkjet printing method comprising: transporting a recording medium in a prescribed transport direction; outputting from an encoder a pulse signal based on an amount of shift of the recording medium caused by the transporter; generating a first ejection timing signal indicating first ejection timing when a first head ejects ink to a target portion of the recording medium being transported based on the pulse signal, and outputting the first ejection timing signal to the first head; calculating printing-ratio information based on print data for forming characters or images on the recording medium; estimating an amount of expansion and contraction occurring in the target portion in the transport direction based on the printing-ratio information; generating correction information including the amount of expansion and contraction based on the amount of expansion and contraction and the first ejection timing signal; and generating a second ejection timing signal indicating second ejection timing when a second head ejects ink toward the target portion; wherein the second head is positioned most downstream in the transport direction and located away from the first head by a head-to-head distance on a downstream side in the transport direction, and wherein generating the second ejection timing signal includes: acquiring the pulse signal and the correction information; determining whether a moving distance of the recording medium from the ejection timing of the first head for the target portion has exceeded a corrected distance that is obtained by correcting the head-to-head distance using the amount of expansion and contraction, based on the pulse signal and the amount of expansion and contraction included in the correction information; and when determining that the moving distance has exceeded the corrected distance, generating a second ejection timing signal by adjusting the pulse signal by a time quantity corresponding to the amount of expansion and contraction in the target portion, and outputting the second ejection timing signal to the second head.