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INKJET RECORDING APPARATUS AND METHOD FOR CONTROLLING INKJET RECORDING APPARATUS

Abstract

Disclosed is an inkjet recording apparatus including: a head that includes a plurality of nozzles configured to eject ink onto a recording medium; a drive waveform generator that generates drive waveforms to drive the respective plurality of nozzles; a reverberation waveform receiver that acquires reverberation waveforms generated in the respective plurality of nozzles to be measured in accordance with the drive waveforms; and a hardware processor that generates a characteristic distribution of the acquired reverberation waveforms and performs, based on the characteristic distribution, an ejection characteristic control process of controlling an ejection characteristic of the plurality of nozzles to be uniform.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present invention claims priority under 35 U.S.C. § 119 to Japanese Application No. 2024-023005 filed Feb. 19, 2024, the entire content of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Technical Field

[0002] The present invention relates to an inkjet recording apparatus and a method for controlling an inkjet recording apparatus.

Description of Related Art

[0003] In an inkjet recording apparatus, an inkjet head forms an image by ejecting ink droplets from a plurality of nozzles. In order to obtain high image quality, it is important to suitably control the ejection characteristics such as the ejection speed and ejected droplet amount of the nozzles. The ejection characteristics of the nozzles vary with the temperature of ink adjacent to the nozzles. Therefore, by stably maintaining the ink temperature, the ink ejection characteristics can be stably maintained. In order to keep the temperature adjacent to the nozzle constant, the ink temperature is generally adjusted by using a temperature sensor and a heater disposed within the inkjet head. As a technique for adjusting the ink temperature inside the inkjet head, a technique described in JP 2004-306529A is disclosed, for example.

[0004] It is described in JP 2004-306529A that residual vibration of a vibration plate is detected. Furthermore, a temperature detection means is described which detects the temperature of a liquid in a cavity of a droplet ejection head based on a vibration pattern of the detected residual vibration of the vibration plate. Furthermore, it is described that the temperature of the liquid in the cavity is adjusted based on the ambient temperature of the droplet ejection head detected by a temperature sensor and a detection value of the temperature detection means.

SUMMARY OF THE INVENTION

[0005] As described above, conventionally, there has been disclosed a technique (JP 2004-306529A) of adjusting the temperature of a liquid in a cavity based on the ambient temperature of a head detected by a temperature sensor and the temperature of the liquid in the cavity detected based on residual vibration of a vibration plate. However, since the ink temperature inside an inkjet head has a temperature difference distribution, the ink temperature adjacent to each nozzle is different. The technology described in JP 2004-306529A does not consider the temperature difference distribution of the ink temperature inside an inkjet head. However, in order to obtain higher image quality, it is necessary to uniformly control the ejection characteristics of each nozzle by adjusting the ink temperature adjacent to each nozzle.

[0006] The present invention has been made in consideration of the above-described situation, and objects of the present invention include uniformly controlling the ejection characteristics of each nozzle of a head.

[0007] To achieve at least one of the abovementioned objects, according to one aspect of the present invention, an inkjet recording apparatus comprises: a head that includes a plurality of nozzles configured to eject ink onto a recording medium; a drive waveform generator that generates drive waveforms to drive the respective plurality of nozzles; a reverberation waveform receiver that acquires reverberation waveforms generated in the respective plurality of nozzles to be measured in accordance with the drive waveforms; and a hardware processor that generates a characteristic distribution of the acquired reverberation waveforms and performs, based on the characteristic distribution, an ejection characteristic control process of controlling an ejection

characteristic of the plurality of nozzles to be uniform.
[0008] To achieve at least one of the abovementioned objects, according to another aspect of the present invention, a method for controlling an inkjet recording apparatus that includes a head including a plurality of nozzles configured to eject ink onto a recording medium comprises: generating drive waveforms to drive the respective plurality of nozzles; acquiring reverberation waveforms generated in the respective plurality of nozzles to be measured in accordance with the drive waveforms; and generating a characteristic distribution of the acquired reverberation waveforms to perform, based on the characteristic distribution, an ejection characteristic control process of controlling an ejection characteristic of the plurality of nozzles to be uniform.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0009] The advantages and features provided by one or more embodiments of the invention will become more fully understood from the detailed description given hereinafter and the appended drawings which are given by way of illustration only, and thus are not intended as a definition of the limits of the present invention, and wherein:
[0010] FIG. **1** is a diagram illustrating an overall configuration of an inkjet recording apparatus according to a first embodiment of the present invention;
[0011] FIG. **2** is a block diagram illustrating a functional configuration of a control system of the inkjet recording apparatus according to the first embodiment of the present invention;
[0012] FIG. **3** is a block diagram illustrating a configuration of a control circuit in the inkjet recording apparatus according to the first embodiment of the present invention;
[0013] FIG. **4** is a block diagram illustrating a configuration of a reverberation waveform measurement circuit in the inkjet recording apparatus according to the first embodiment of the present invention;
[0014] FIG. **5** is a diagram illustrating a reverberation waveform acquired from a nozzle;
[0015] FIG. **6** is a diagram illustrating amplitude distributions of reverberation waveforms;
[0016] FIG. **7** is a diagram illustrating a procedure of an initialization process of the inkjet recording apparatus according to the first embodiment of the present invention;
[0017] FIG. **8** is a diagram illustrating a procedure of an in-printing control process of the inkjet recording apparatus according to the first embodiment of the present invention;
[0018] FIG. **9** is a diagram illustrating a procedure of an ejection characteristic control process of the inkjet recording apparatus according to the first embodiment of the present invention;
[0019] FIG. **10** is a diagram illustrating data of a drive voltage correction table of the inkjet recording apparatus according to a second embodiment of the present invention; and
[0020] FIG. **11** is a diagram illustrating a procedure of an ejection characteristic control process of the inkjet recording apparatus according to the second embodiment of the present invention by drive voltage adjustment.
DETAILED DESCRIPTION
[0021] Hereinafter, one or more embodiments of the present invention will be described with reference to the drawings. However, the scope of the invention is not limited to the disclosed embodiments.
[0022] In the present specification and drawings, constituent elements having substantially the same function or configuration are denoted by the same reference numerals, and redundant descriptions of the constituent elements are omitted.
First Embodiment
[Configuration of Inkjet Recording Apparatus]
[0023] First, a configuration of an inkjet recording apparatus **1** according to a first embodiment of

the present invention will be described. FIG. **1** is a diagram illustrating an overall configuration of an inkjet recording apparatus **1** according to the present embodiment. As illustrated in FIG. **1**, the inkjet recording apparatus **1** includes a medium supplier **10**, an image forming section **20**, a medium ejector **30**, and an ink supplier **40**. The inkjet recording apparatus **1** conveys a recording medium P stored in the medium supplier **10** to the image forming section **20** under control of a controller **60** described later. The inkjet recording apparatus **1** also forms (prints) an image on the recording medium P in the image forming section **20** and ejects the recording medium P having the image printed thereon to the medium ejector **30**.

(1) Medium Supplier

[0024] The medium supplier **10** includes a supply tray **11** that stores the recording medium P and a conveyer **12** that conveys the recording medium P from the supply tray **11** to the image forming section **20**. Note that various media that can be held curved on the outer peripheral surface of an image forming drum **21** described later are used as the recording medium P. As the recording medium P, printing sheet (paper), a cell, a film, a textile, or the like can be used, for example. Hereinafter, the recording medium P may be referred to as “sheet”.

[0025] The supply tray **11** is a plate-shaped member on which one or a plurality of recording media P can be placed. The supply tray **11** is disposed so as to move up and down in accordance with the amount of the recording media P placed on the supply tray **11**. The supply tray **11** holds the uppermost recording medium P in the up-down direction at a position to be conveyed by the conveyer **12**.

[0026] The conveyer **12** includes a plurality of rollers, for example, a roller **121** and a roller **122**, and a belt **123**. Furthermore, the conveyer **12** includes a conveyance mechanism (not illustrated) and a supplier (not illustrated). The circular belt **123** is a circular belt stretched by the roller **121** and the roller **122**. The conveyance mechanism drives the belt **123** to convey the recording medium P on the belt **123**. The supplier passes the uppermost recording medium P placed on the supply tray **11** onto the belt **123**. The conveyer **12** conveys the recording medium P passed by the supplier onto the belt **123** in a direction from the roller **121** to the roller **122**.

(2) Image Forming Section

[0027] The image forming section **20** includes an image forming drum **21**, a passing unit **22**, a medium heater **23**, a plurality of head units **24**, an irradiator **25**, and a delivery unit **26**.

[0028] The image forming drum **21** is formed of a cylindrical member and rotates counterclockwise in the drawing by a drive motor (not illustrated). The image forming drum **21** holds the recording medium P along its cylindrical outer peripheral surface and rotates to convey the recording medium P. The medium heater **23**, the plurality of head units **24**, and the irradiator **25** are disposed on the conveyance surface of the image forming drum **21**. The medium heater **23**, the head units **24**, and the irradiator **25** perform an image formation process on the recording medium P conveyed by the image forming drum **21**.

[0029] As illustrated in FIG. **1**, the passing unit **22** is disposed between the conveyer **12** of the medium supplier **10** and the image forming drum **21**. The passing unit **22** includes a claw **221** that holds one end of the recording medium P conveyed by the conveyer **12**. Furthermore, the passing unit **22** includes a cylindrical passing drum **222** that guides the recording medium P held by the claw **221** to the image forming drum **21**. The claw **221** picks up the recording medium P, guides the recording medium P along the outer peripheral surface of the passing drum **222** to pass the recording medium P to the image forming drum **21**.

[0030] The medium heater **23** includes, for example, an electric heating wire and generates heat in response to energization. The medium heater **23** is disposed adjacent to the outer peripheral surface of the image forming drum **21** and upstream of the head units **24** in a conveyance direction of the recording medium P. The medium heater **23** heats the recording medium P, which is held by the image forming drum **21** and passes adjacent to the medium heater **23**, to a predetermined temperature.

[0031] Each of the head units **24** includes a plurality of inkjet heads (not shown). Each inkjet head has a plurality of nozzles for ejecting ink onto the recording medium P. The head unit **24** causes the nozzles to eject ink droplets onto the recording surface of the recording medium P at appropriate timings, thereby forming an image on the recording surface of the recording medium P. Hereinafter, the inkjet head is abbreviated as a "head".

[0032] The irradiator **25** irradiates the recording medium P with energy rays to cure the ink. The irradiator **25** includes, for example, a fluorescent tube, such as a low-pressure mercury lamp, and causes the fluorescent tube to emit light to radiate energy rays, such as ultraviolet rays. The irradiator **25** is disposed adjacent to the outer peripheral surface of the image forming drum **21** and downstream of the head units **24** in the conveyance direction of the recording medium P.

[0033] The delivery unit **26** delivers the recording medium P, which has been irradiated with the energy rays by the irradiator **25**, from the image forming drum **21** to the medium ejector **30**. The delivery unit **26** includes a plurality of rollers, for example, a roller **261** and a roller **262**, and a belt **263**. The delivery unit **26** also includes a conveyance mechanism (not illustrated) and a passing drum **264**. The belt **263** is a circular belt stretched by the roller **261** and the roller **262**. The conveyance mechanism drives the belt **263** to convey the recording medium P on the belt **263**. The passing drum **264** is a cylindrical drum that passes the recording medium P from the image forming drum **21** to the conveyance mechanism. The delivery unit **26** conveys the recording medium P passed to the belt **263** by the passing drum **264** through the belt **263**, sending the recording medium P to the medium ejector **30**.

(3) Medium Ejector

[0034] The medium ejector **30** stores the recording medium P sent from the image forming section **20** by the delivery unit **26**. The medium ejector **30** includes a plate-shaped ejection tray **31**, and the like. The recording medium P on which an image has been formed is placed on the ejection tray **31**.

(4) Ink Supplier

[0035] The ink supplier **40** stores ink of each color used for recording an image and supplies the ink to the corresponding head unit **24** of the image forming section **20**. The ink supplier **40** may be disposed in any manner. For example, the ink supplier **40** is disposed in a dedicated rack or the like and is coupled to the image forming section **20** via a pipe material such as a tube. The ink supplied to each head unit **24** of the image forming section **20** is ejected from the nozzles of the heads.

[0036] FIG. **2** is a block diagram illustrating a functional configuration of a control system of the inkjet recording apparatus **1** according to the present embodiment. The inkjet recording apparatus **1** includes a head controller **50** (hardware processor), a controller **60**, and a communicator **70**, as illustrated in FIG. **2**, in addition to the various components described in FIG. **1**. Each component is coupled by a bus B so as to be able to transmit and receive information data to and from each other.

[0037] The head controller **50** drives each of the nozzles in order to suitably eject ink from the nozzles of each of the heads in the head unit **24**. The head controller **50** selects, based on a control signal from the controller **60**, a drive waveform pattern for printing stored in advance. In addition, the head controller **50** generates a drive signal to drive the nozzle in accordance with the selected drive waveform pattern for printing. Further, the head controller **50** switches whether to output the drive signal to each nozzle according to image data to be printed. Hereinafter, the drive signal is also referred to as a "drive waveform".

[0038] In addition, the head controller **50** acquires a waveform of residual vibration generated after each of the plurality of nozzles included in the head is driven. Hereinafter, the waveform of the residual vibration is referred to as a "reverberation waveform". The reverberation waveform is measured and acquired by a residual vibration measurement circuit **100** illustrated in FIG. **4** to be described later. The head controller **50** generates a characteristic distribution of the acquired reverberation waveforms and performs an ejection characteristic control process of controlling the ejection characteristics of the plurality of nozzles to be uniform based on the characteristic distribution. Here, the characteristic distribution is, for example, an amplitude distribution of the reverberation waveforms. The ejection characteristics include at least one of the ejection speed and ejected droplet amount of the nozzle. The ejection characteristic control process will be described in detail later with reference to FIG. **10** and FIG. **11**.

[0039] The controller **60** comprehensively controls the overall operation of the inkjet recording apparatus **1**. The controller **60** includes a central processing unit (CPU **61**), a random-access memory (RAM **62**), a read only memory (ROM **63**), and a memory **64**.

[0040] The CPU **61** performs the image formation process, the ejection characteristic control process, and the like in the inkjet recording apparatus **1** in accordance with programs read from the ROM **63**.

[0041] The RAM **62** includes a storage media such as a volatile memory, for example, and temporarily stores information (data) required for each process performed by the CPU **61**.

[0042] The ROM **63** includes, for example, a storage media such as a nonvolatile memory and stores programs, data, and the like that the CPU **61** executes and refers to. The ROM **63** is used as an example of non-transitory computer-readable storage media storing the programs to be executed by the controller **60**. The memory **64** is an image memory that temporarily stores image data to be recorded, or the like.

[0043] The communicator **70** is a communication interface that controls a communication operation with an external device. Examples of the communication interface include a plurality of interfaces compatible with various communication protocols, such as a LAN board and a LAN card. The communicator **70** acquires the image data to be recorded and setting data (print job) related to image recording from the external device under the control of the controller **60**.

[0044] Next, a configuration of a control circuit in the inkjet recording apparatus **1** will be described. FIG. **3** is a block diagram illustrating the configuration of the control circuit in the inkjet recording apparatus **1** according to the present embodiment. As illustrated in FIG. **3**, the control circuit in the inkjet recording apparatus **1** includes the heads **80** of the head unit **24** and a drive board **90**. Only one of the heads **80** is shown in FIG. **3**. In practice, all the plurality of heads **80** of the head unit **24** is coupled to the drive board **90** as illustrated in FIG. **3**.

[0045] As illustrated in FIG. **3**, the head **80** includes a plurality of nozzles (nozzles **81_1** to **81**_N) and a drive integrated circuit (IC) **82**. The head **80** also includes a heater **83** and a temperature sensor **84**. Each of the nozzles is coupled to the drive IC **82**. The heater **83**, the temperature sensors **84**, and the drive IC **82** are each coupled to the drive board **90**.

[0046] The drive IC **82** receives a drive waveform for driving the nozzle, image data, and a waveform switching signal from the head controller **50** disposed on the drive board **90**. The drive IC **82** outputs the drive waveform to a target nozzle in accordance with the image data and the waveform switching signal to drive the target nozzle. The heater **83** is supplied with electric power from a heater power supply circuit **92** (described later) on the drive board **90** and increases the temperature of a carriage (not illustrated) in the head **80** to a predetermined temperature. Here, the predetermined temperature can be suitably set within a temperature range in which the ink can be ejected. The temperature sensor **84** detects the temperature of the carriage and outputs the detected temperature to a temperature sensor receiver **93** (described later) on the drive board **90**. The temperature sensor **84** includes, for example, a thermistor.

[0047] As illustrated in FIG. **3**, the drive board **90** includes a heater controller **91**, a heater power supply circuit **92**, and a temperature sensor receiver **93**. The drive board **90** also includes the head controller **50**, a drive circuit **94**, and a reverberation waveform receiver **95**.

[0048] The heater controller **91** includes, for example, a CPU or the like and controls operations of the heater power supply circuit **92** and the temperature sensor receiver **93**. The heater power supply circuit **92** supplies electric power to the heater **83** in the head **80** under the control of the heater controller **91**. The temperature sensor receiver **93** receives the detected temperature from the temperature sensor **84** in the head **80** under the control of the heater controller **91**. The heater controller **91** adjusts the output power of the heater power supply circuit **92** based on the detected temperature received by the temperature sensor receiver **93**.

[0049] In the present embodiment, the head controller **50**, the drive circuit **94**, the reverberation waveform receiver **95**, and the drive IC **82** and the plurality of nozzles of the head **80** illustrated in FIG. **3** constitute a residual vibration measurement circuit **100** (refer to FIG. **4**).

[0050] FIG. **4** is a block diagram illustrating a configuration of the residual vibration measurement circuit **100** in the inkjet recording apparatus **1** according to the present embodiment. The head controller **50** includes a field programmable gate array (FPGA) or the like. The head controller **50** generates and outputs a drive waveform for driving a piezoelectric element (not illustrated) in order to cause each nozzle of the head **80** to suitably eject ink. As illustrated in FIG. **4**, the head controller **50** includes a data output unit **51**, a drive waveform generator **52**, and a reverberation waveform detector **53** common to the plurality of nozzles.

[0051] The data output unit **51** selects image data registered in advance and outputs the image data to a switch controller **821** (described later) of the head **80**. In addition, the data output unit **51** outputs a waveform switching signal indicating an output timing of the drive waveform to the switch controller **821** of the head **80**.

[0052] The drive waveform generator **52** selects a pattern of the drive waveform registered in advance, generates the drive waveform for driving the nozzle, and outputs the drive waveform to the drive circuit **94**.

[0053] The reverberation waveform detector **53** is common to the plurality of nozzles and receives the reverberation waveforms acquired by the reverberation waveform receiver **95**. Furthermore, the reverberation waveform detector **53** generates a characteristic distribution of the received reverberation waveforms and determines whether there is a defective nozzle based on the characteristic distribution. In the present embodiment, the head controller **50** excludes a nozzle determined to be a defective nozzle by the reverberation waveform detector **53** from the target of the ejection characteristic control process. Note that the determination of a defective nozzle based on the characteristic distribution (amplitude distribution) will be described later with reference to FIG. **6**.

[0054] The drive circuit **94** receives the drive waveform generated by the drive waveform generator **52** and applies the drive waveform to the nozzle via the drive IC **82** (described later) of the head **80** to drive the nozzle.

[0055] The reverberation waveform receiver **95** includes an analog-to-digital (AD) converter or the like. The reverberation waveform receiver **95** acquires a reverberation waveform generated in a nozzle and converts the waveform into a digital signal. Furthermore, the reverberation waveform receiver **95** outputs the reverberation waveform converted into the digital signal to the reverberation waveform detector **53** of the head controller **50**.

[0056] The head **80** includes, for example, the plurality of nozzles of the nozzles **81_1** to **81**_N. The drive IC **82** includes the same number of two-channel switches (switches **82_1** to **82**_N) as the number of the nozzles. The output side of each of the two-channel switches is coupled to the corresponding nozzle. The ON-side input terminal of the switch is coupled to the output side of the drive circuit **94** on the drive board **90**. The OFF-side input terminal of the switch is coupled to the input side of the reverberation waveform receiver **95** on the drive board **90**. When the switch is set to the ON-side, the corresponding nozzle coupled to the switch is driven by the drive waveform. When the switch is set to the OFF-side, the reverberation waveform generated in the corresponding nozzle coupled to the switch is acquired by the reverberation waveform receiver **95**.

[0057] The switch controller **821** receives the image data and the waveform switching signal from the data output unit **51** of the head controller **50**. Furthermore, the switch controller **821** is coupled to each of the two-channel switches and controls the ON/OFF operation of the switch according to the image data and the waveform switching signal. When a nozzle is to be driven, the corresponding switch coupled to the nozzle to be driven is set to ON. When a reverberation waveform is to be acquired, the corresponding switch coupled to the nozzle whose reverberation waveform is to be acquired is switched from ON to OFF. In this case, the switches coupled to the nozzles other than the acquisition target remain OFF. The reverberation waveform receiver **95** acquires a reverberation waveform generated after the drive waveform of the nozzle to be measured is turned off, and outputs the reverberation waveform to the reverberation waveform detector **53**.

[0058] FIG. **5** is a diagram illustrating a reverberation waveform acquired from a nozzle; The horizontal axis of FIG. **5** represents time, for example, in microseconds (μs). The vertical axis of FIG. **5** represents the amplitude of the reverberation waveform, for example, in millivolts (mV). As illustrated in the drawing, the reverberation waveform is composed of a sine wave. The peak-to-peak value of the first wave of a reverberation waveform is the amplitude of the reverberation waveform. The amplitude of the reverberation waveform changes according to the temperature of the nozzle from which the reverberation waveform is acquired. When the temperature of the nozzle is high, the amplitude of the reverberation waveform is large. When the temperature of the nozzle is low, the amplitude of the reverberation waveform is small. That is, an amplitude distribution of reverberation waveforms of the respective nozzles has the same distribution as a temperature distribution adjacent to the nozzles. Uniformly controlling the amplitude of a reverberation waveform of each nozzle means uniformly controlling the temperature adjacent to the nozzle. Therefore, by uniformly controlling the amplitude of a reverberation waveform of each nozzle, it is possible to uniformly control the ejection characteristics of each nozzle.

[0059] Note that in the head **80**, there is a temperature distribution adjacent to the nozzles depending on, for example, the disposed position of the heater **83** and operating conditions of the components around the nozzles. Due to this temperature distribution, the temperature of each of the nozzles is different. Here, the temperature distribution adjacent to the nozzles is such that the temperature adjacent to the nozzle at the center position is the highest, while the temperature adjacent to the nozzles at both end positions is the lowest. Amplitude distributions of reverberation waveforms of the respective nozzles in this case are illustrated in FIG. **6**. FIG. **6** is a diagram illustrating the amplitude distributions of the reverberation waveforms.

[0060] The horizontal axis of FIG. **6** represents a nozzle number indicating the position of each nozzle of the head **80**. The vertical axis of FIG. **6** represents the amplitude of the reverberation waveform, for example, in millivolts (mV). FIG. **6** illustrates the amplitude distributions (characteristic distributions) of the reverberation waveforms when the heating temperature of the heater **83** is set to 60° C., 70° C., and 80° C. As illustrated in the drawing, the higher the heating temperature of the heater **83**, the higher the overall value of each amplitude distribution of the reverberation waveforms. Furthermore, the amplitude distribution of the reverberation waveforms has the same characteristics as the temperature distribution adjacent to the nozzles, and the amplitude at the central position is the highest and the amplitude at the end positions is the lowest.

[0061] In the present embodiment, the reverberation waveform detector **53** determines a defective nozzle based on an amplitude distribution of reverberation waveforms. The reverberation waveform detector **53** determines a defective nozzle, for example, based on the amplitude distribution of the reverberation waveforms illustrated in FIG. **6**. In this case, as illustrated in FIG. **6**, a nozzle corresponding to a position (nozzle number) where there is no amplitude in the amplitude distribution of the reverberation waveforms is determined to be a defective nozzle.

[0062] Note that the ejection characteristics, such as the ejection speed and ejected droplet amount of a nozzle, change with temperature. That is, when the temperature of each nozzle is different, the ejection characteristics of each nozzle are different, and the ejection characteristics of each nozzle cannot be uniformly maintained. Since the degree of uniformity of the ejection characteristics of the nozzles is linked to the image quality of a printed image, it is important to uniformly maintain the ejection characteristics of the nozzles in order to achieve high image quality. In the present embodiment, the ejection characteristic control process is performed based on the amplitude distribution of the reverberation waveforms so that the ejection characteristics of the nozzles become uniform. Hereinafter, the control process of the inkjet recording apparatus **1** will be described with reference to FIGS. **7** to FIG. **11**.

[Procedure of Initialization Process of Inkjet Recording Apparatus]

[0063] First, an initialization process of the inkjet recording apparatus **1** will be described. FIG. **7** is a diagram illustrating a procedure of the initialization process of the inkjet recording apparatus **1** according to the present embodiment. The process described below is started when the inkjet recording apparatus **1** is activated.

[0064] First, the controller **60** of the inkjet recording apparatus **1** starts temperature adjustment of the carriage (S**100**). The head **80** and the drive board **90** are mounted on the carriage. In this step, the controller **60** outputs an instruction to start the temperature adjustment to the heater controller **91** of the drive board **90**. The heater controller **91** controls the output power of the heater power supply circuit **92** to adjust the temperature inside the head **80** according to the instruction of the controller **60**.

[0065] Next, the controller **60** causes each component of the carriage to wait until the temperature of the component reaches a temperature setting value for performing the printing operation (S**101**). In addition, in this step, when the temperature of each component of the carriage reaches the temperature setting value, the controller **60** outputs an instruction to start the process to the head controller **50**.

[0066] Next, the head controller **50** performs the ejection characteristic control process (S**300**). That is, the head controller **50** performs the ejection characteristic control process in the initialization process performed when the inkjet recording apparatus **1** is activated. After the process of S**300**, the controller **60** ends the initialization process. Note that the ejection characteristic control process will be described in detail later with reference to FIG. **9**.

[Procedure of In-Printing Control Process of Inkjet Recording Apparatus]

[0067] First, an in-printing control process of the inkjet recording apparatus **1** will be described. FIG. **8** is a diagram illustrating a procedure of the in-printing control process of the inkjet recording apparatus **1** according to the present embodiment. The process described below is started when a print job is executed.

[0068] First, the head controller **50** selects and sets, based on a control signal from the controller **60**, a drive waveform pattern for printing stored in advance (S**200**).

[0069] Next, the controller **60** controls the medium supplier **10** to start sheet conveyance (S**201**).

[0070] Next, the controller **60** controls each component to perform the image formation process (S**202**).

[0071] Next, the controller **60** determines whether printing of the last line of a sheet being printed is complete (S**203**). That is, the controller **60** determines whether the current time falls in the interval between the printing times of pages being printed.

[0072] If it is determined that printing of the last line of a sheet being printed is not complete (NO in S**203**), the controller **60** returns the process to S**202** and repeatedly executes S**202** to S**203**.

[0073] On the other hand, when the controller **60** determines that printing of the last line of a sheet being printed is complete (YES in S**203**), the controller **60** outputs an instruction to start the ejection characteristic control process to the head controller **50** (S**204**).

[0074] Next, the head controller **50** performs the ejection characteristic control process (S**300**). That is, while a print job is being executed, the head controller **50** performs the ejection characteristic control process for each page in the interval between the printing times of the pages included in the print job. Note that the ejection characteristic control process will be described in detail later with reference to FIG. **9**.

[0075] Next, the controller **60** determines whether all the pages included in the print job have been printed (S**205**).

[0076] If it is determined that all the pages have not been printed (NO in S**205**), the controller **60** returns the process to S**202** and repeatedly executes S**202** to S**205**.

[0077] On the other hand, if the controller **60** determines that all the pages have been printed (YES

in S**205**), the controller **60** ends the in-printing control process.
[0078] Note that in the above description, an operation in which the ejection characteristic control process is performed for each page in the interval between the printing times of the pages has been exemplified, but the present invention is not limited thereto. For example, the ejection characteristic control process may be performed for every several pages in the interval between the printing times of the pages.
[Procedure of Ejection Characteristic Control Process]
[0079] Next, the ejection characteristic control process of the inkjet recording apparatus **1** will be described. In the ejection characteristic control process, the head controller **50** controls the amplitude distribution of the reverberation waveforms of the respective nozzles to fall within a predetermined range. By such control, the ejection characteristics of the plurality of nozzles included in the head **80** are controlled to be uniform. In the present embodiment, the head controller **50** sets a nozzle in which the amplitude of the reverberation waveform falls outside the predetermined range as the target nozzle of the ejection characteristic control process. The head controller **50** controls the ejection characteristics of the plurality of nozzles to be uniform by performing at least one of a process of applying a shaking waveform and a predetermined image correction process on the target nozzle. Here, the predetermined range is a range for determining whether the amplitude distribution of the reverberation waveforms is uniform. The predetermined range varies depending on the accuracy required for the uniformity of the ejection characteristics of the nozzles, the model of the head **80** to be used, the control temperature inside the head **80**, and the like.
[0080] FIG. **9** is a diagram illustrating a procedure of the ejection characteristic control process of the inkjet recording apparatus **1** according to the present embodiment. The process described below is called and executed as a subroutine in S**300** shown in FIGS. **7** and S**300** shown in FIG. **8**.
[0081] First, the drive waveform generator **52** of the head controller **50** generates and sets a drive waveform for reverberation waveform measurement (S**301**). Furthermore, the drive waveform generator **52** outputs the set drive waveform to the drive circuit **94**.
[0082] Next, the data output unit **51** outputs image data for the reverberation waveform measurement to the switch controller **821** of the drive IC **82** of the head **80** (S**302**).
[0083] Next, the switch controller **821** of the drive IC **82** couples a nozzle to be measured to the drive circuit **94** to drive the nozzle (S**303**).
[0084] Next, the switch controller **821** of the drive IC **82** switches the nozzle to be measured from the drive circuit **94** to the reverberation waveform receiver **95** and couples the nozzle to the reverberation waveform receiver **95** (S**304**).
[0085] Next, the reverberation waveform receiver **95** of the head controller **50** acquires a reverberation waveform of the nozzle to be measured (S**305**). In addition, the reverberation waveform receiver **95** outputs the acquired reverberation waveform of the nozzle to be measured to the reverberation waveform detector **53**.
[0086] Next, the reverberation waveform detector **53** of the head controller **50** measures the amplitude from the reverberation waveform of the nozzle to be measured (S**306**).
[0087] Next, the reverberation waveform detector **53** determines whether the measurement of the amplitudes from the reverberation waveforms of all the nozzles to be measured is complete (S**307**).
[0088] If it is determined that the measurement of the amplitudes from the reverberation waveforms of all the nozzles to be measured is not complete (NO in S**307**), the reverberation waveform detector **53** returns the process to S**303**. The reverberation waveform detector **53** repeatedly executes S**303** to S**307**.
[0089] On the other hand, if it is determined that the measurement of the amplitudes from the reverberation waveforms of all the nozzles to be measured is complete (YES in S**307**), the reverberation waveform detector **53** advances the process to S**308**. In the process of S**308**, the head controller **50** generates an amplitude distribution of the reverberation waveforms of the measured

nozzles.
[0090] Next, the head controller **50** determines whether the amplitude distribution of the reverberation waveforms falls within a predetermined range (S**309**). For example, the predetermined range is set to ±5 mV, which is an amplitude variation range of the reverberation waveform corresponding to a temperature change of the nozzle of about ±1° C. Here, −5 mV is the lower limit value of the predetermined range, and +5 mV is the upper limit value of the predetermined range. When the amplitude distribution of the reverberation waveforms (the amplitudes of the reverberation waveforms of all the nozzles) is within the range of ±5 mV, it is determined that the amplitude distribution of the reverberation waveforms is uniform. That is, it is determined that the ejection characteristics of the nozzles are uniform.
[0091] If it is determined that the amplitude distribution of the reverberation waveforms falls outside the predetermined range (NO in S**309**), the head controller **50** advances the process to S**310**. In the process of S**310**, the head controller **50** applies a shaking waveform to the target nozzle when the amplitude of the reverberation waveform of the target nozzle is smaller than the lower limit value of the predetermined range. Applying a shaking waveform makes it possible to control the amplitude of the reverberation waveform of the target nozzle to be within the predetermined range. Here, the shaking waveform is, for example, a waveform having the same waveform as the reverberation waveform and a predetermined amplitude. The nozzle whose reverberation waveform amplitude is smaller than the lower limit of the predetermined range is a nozzle whose temperature is lower than the desired temperature. When the shaking waveform is applied, the temperature of the nozzle having a low temperature increase. The head controller **50** repeatedly applies the shaking waveform until the amplitude of the reverberation waveform of the target nozzle falls within the predetermined range.
[0092] Furthermore, in the process of S**310**, when the amplitude of the reverberation waveform of the target nozzle is larger than the upper limit value of the predetermined range, the head controller **50** performs a predetermined image correction process on the target nozzle. Here, the predetermined image correction process includes at least one of a process of thinning the number of ejections of the target nozzle and a process of reducing the size of the ejected droplets of the target nozzle. The nozzle whose reverberation waveform amplitude is larger than the upper limit value of the predetermined range is a nozzle whose temperature is higher than the desired temperature. When the temperature of the nozzle becomes higher than the desired temperature, the density of the printed image at the position corresponding to the nozzle becomes higher. By performing the predetermined image correction process, the density of the printed image can be corrected to be low. In addition, since the number of ejections or the ejected droplet amount of the target nozzle is reduced by performing the predetermined image correction process, the temperature of the target nozzle is also decreased. Through the process of applying a shaking waveform, the temperature of a nozzle having a low temperature increase. Through the image correction process, the temperature of a nozzle having a high temperature decrease. As a result, the ejection characteristics of the nozzles of the head become uniform. After the process of S**310**, the head controller **50** returns the process to S**302** and repeatedly executes S**302** to S**309**.
[0093] On the other hand, if it is determined that the amplitude distribution of the reverberation waveforms falls within the predetermined range (YES in S**309**), the head controller **50** performs the process in S**311**. In S**311**, the head controller **50** selects and sets, based on a control signal from the controller **60**, a drive waveform pattern for printing stored in advance. After the process of S**311**, the head controller **50** ends the ejection characteristic control process.
[Effects]
[0094] As described above, in the inkjet recording apparatus **1** according to the present embodiment, the head controller **50** acquires reverberation waveforms of respective nozzles after the nozzles are driven. The head controller **50** generates an amplitude distribution of the reverberation waveforms of the nozzles from the acquired reverberation waveforms of the

respective nozzles. The head controller **50** performs the ejection characteristic control process so that the amplitude distribution of the reverberation waveforms of the nozzles falls within a predetermined range. By performing the ejection characteristic control process, the amplitudes of the reverberation waveforms of the respective nozzles become uniform, and the ejection characteristics of the nozzles also become uniform. Therefore, the inkjet recording apparatus **1** according to the present embodiment can uniformly control the ejection characteristics of the nozzles of the head.

Second Embodiment

[0095] Although the ejection characteristic control process that includes the process of applying a shaking waveform and the predetermined image correction process has been described in the first embodiment, the present invention is not limited thereto. The ejection characteristic control process may be a process of adjusting the drive voltage of the target nozzle such that the amplitude of the reverberation waveform of the target nozzle falls within a predetermined range. In the second embodiment, a control process of the inkjet recording apparatus **1** when the ejection characteristic control process is a process of adjusting the drive voltage will be described. Note that the configuration of the inkjet recording apparatus **1** according to the second embodiment is the same as the configuration of the inkjet recording apparatus **1** according to the first embodiment (see FIGS. **1** to FIG. **4**), and therefore, redundant description is omitted. The procedures of the initialization control process and the in-printing control process (see FIG. **7** and FIG. **8**) in the second embodiment are also the same as the procedures of the respective processes in the first embodiment, and therefore, redundant descriptions are omitted.

[0096] FIG. **10** is a diagram illustrating a drive voltage correction table T**10** in the inkjet recording apparatus **1** according to the present embodiment. The drive voltage correction table T**10** is a table used for adjusting the drive voltage of a nozzle in the ejection characteristic control process according to the present embodiment. The drive voltage correction table T**10** defines correction values for the drive voltage to be applied to a nozzle, corresponding to amplitude correction values for the reverberation waveform of the nozzle. As illustrated in FIG. **10**, the drive voltage correction table T**10** includes an amplitude correction value column T**11** and a drive voltage correction value column T**12**. The amplitude correction value column T**11** stores a correction value, for example, in mV for correcting the amplitude of the reverberation waveform of a nozzle to be within a predetermined range. The drive voltage correction value column T**12** stores a correction value of the drive voltage, for example, in units of mV, when the amplitude of the reverberation waveform is corrected with the corresponding amplitude correction value. For example, when the amplitude correction value is “0”, that is, when no correction is made, the drive voltage correction value is also “0”. Furthermore, for example, when the amplitude correction value is “1”, that is, when the amplitude of the current reverberation waveform is corrected to be 1 mV higher, the drive voltage correction value is “50 (mV)”. Note that the example of the drive voltage correction table T**10** illustrated in FIG. **10** was arbitrarily created for descriptive purposes. However, the drive voltage correction table T**10** to be actually used needs to be acquired by preliminary measurement and registered in the inkjet recording apparatus **1**.

[0097] FIG. **11** is a diagram illustrating a procedure of the ejection characteristic control process of the inkjet recording apparatus **1** according to the present embodiment. The head controller **50** controls the amplitude distribution to be within a predetermined range by correcting the drive voltage applied to the target nozzle based on the drive voltage correction table T**10**. The process described below is called and executed as a subroutine in S**300** shown in FIGS. **7** and S**300** shown in FIG. **8**. Furthermore, for the same processes (S**301** to S**308**) illustrated in FIG. **10** as those in FIG. **7**, redundant descriptions are omitted.

[0098] In the process of S**401**, the head controller **50** obtains the difference between the amplitude of the reverberation waveform of each nozzle and a predetermined reference value based on the distribution of the amplitudes of the reverberation waveforms. Here, the predetermined reference value varies depending on the accuracy required for the uniformity of the ejection characteristics of the nozzles, the model of the head **80** to be used, the control temperature inside the head **80**, and the like. The predetermined reference value is registered in the inkjet recording apparatus **1** in advance.

[0099] Next, the head controller **50** obtains an amplitude correction value corresponding to each nozzle for the difference between the amplitude of the reverberation waveform of the nozzle and the predetermined reference value (S**402**). The head controller **50** takes, for example, the result of rounding off the difference between the amplitude of the reverberation waveform of each nozzle and the predetermined reference value as the amplitude correction value.

[0100] Next, the head controller **50** obtains a drive voltage correction value for each nozzle based on the amplitude correction value corresponding to the nozzle and the drive voltage correction table T**10** (S**403**).

[0101] Next, the head controller **50** adjusts the drive voltage to each nozzle based on the drive voltage correction value for the nozzle (S**404**). Further, in this step, the head controller **50** instructs the drive circuit **94** of the value of the corrected drive voltage. Thereafter, the head controller **50** performs the process of S**311**.

[Effects]

[0102] As described above, in the inkjet recording apparatus **1** according to the present embodiment, the head controller **50** adjusts the drive voltage applied to each nozzle so that the amplitude of the reverberation waveform of the nozzle becomes a predetermined reference value. Therefore, the inkjet recording apparatus **1** according to the present embodiment can also uniformly control the ejection characteristics of the nozzles of the head.

[0103] Note that the present invention is not limited to the above-described embodiments. Various other applications and modification examples can be made without departing from the scope of the present invention described in the appended claims.

[0104] Each of the embodiments described above is a detailed and specific explanation of the configuration of the inkjet recording apparatus to clearly explain the present invention. However, the present invention is not necessarily limited to those including all the described configurations. Furthermore, a part of the configurations of the embodiments described here can be replaced with a configuration of another embodiment. Furthermore, a configuration of one embodiment may be added to a configuration of another embodiment. Furthermore, it is also possible to add, delete, or replace another configuration for a part of the configuration of each embodiment.

[0105] In addition, control lines and information lines considered to be necessary for description are illustrated, and all of the control lines and information lines on a product are not necessarily illustrated. In reality, it may be considered that almost all of the components are coupled to each other.

[0106] In the above embodiments, an example has been described in which the amplitude of the reverberation waveform is obtained for each nozzle to generate the amplitude distribution of the reverberation waveforms, but the present invention is not limited thereto. For example, for every predetermined number of adjacent nozzles, the amplitude of the reverberation waveforms may be acquired from one of the adjacent nozzles to generate the amplitude distribution of the reverberation waveforms.

[0107] In addition, in each of the above-described embodiments, an example has been described in which the ejection characteristic control process is performed in the interval between the printing times of the pages, but the present invention is not limited thereto. For example, while a print job is being executed, the head controller **50** may perform the ejection characteristic control process on a nozzle corresponding to a non-printing region of each page included in the print job. Here, for example, when image data does not exist over two or more continuous lines at a position corresponding to a nozzle (the image data is a white dot), the position is treated as a non-printing region.

[0108] Furthermore, in each of the above-described embodiments, an example has been described

in which the process of applying a shaking waveform, the predetermined image correction process and the drive voltage adjustment process are performed to control the amplitude of the reverberation waveform of each nozzle to be uniform. However, the present invention is not limited to this. For example, a plurality of heaters may be disposed at different positions in the head **80**. In this case, the head controller **50** may control the heating temperatures of the plurality of heaters so that the amplitude distribution of the reverberation waveforms falls within a predetermined range.
[0109] Although embodiments of the present invention have been described and shown in detail, the disclosed embodiments are made for purposes of illustration and example only and not limitation. The scope of the present invention should be interpreted by terms of the appended claims.

Claims

1. An inkjet recording apparatus comprising: a head that includes a plurality of nozzles configured to eject ink onto a recording medium; a drive waveform generator that generates drive waveforms to drive the respective plurality of nozzles; a reverberation waveform receiver that acquires reverberation waveforms generated in the respective plurality of nozzles to be measured in accordance with the drive waveforms; and a hardware processor that generates a characteristic distribution of the acquired reverberation waveforms and performs, based on the characteristic distribution, an ejection characteristic control process of controlling an ejection characteristic of the plurality of nozzles to be uniform.
2. The inkjet recording apparatus according to claim 1, wherein the characteristic distribution is an amplitude distribution of the reverberation waveforms.
3. The inkjet recording apparatus according to claim 2, wherein the ejection characteristic includes at least one of an ejection speed of the plurality of nozzles and an ejected droplet amount of the plurality of nozzles.
4. The inkjet recording apparatus according to claim 3, wherein in the ejection characteristic control process, the hardware processor controls the amplitude distribution to fall within a predetermined range, thereby controlling the ejection characteristic of the plurality of nozzles to be uniform.
5. The inkjet recording apparatus according to claim 4, wherein, among the plurality of nozzles, the hardware processor sets a nozzle in which an amplitude of the reverberation waveform falls outside the predetermined range as a target nozzle, and performs at least one of a process of applying a shaking waveform, a predetermined image correction process, and a process of correcting a drive voltage on the target nozzle, thereby controlling the ejection characteristic of the plurality of nozzles to be uniform.
6. The inkjet recording apparatus according to claim 5, wherein the shaking waveform has a same waveform as the reverberation waveform and a predetermined amplitude, and when the amplitude of the reverberation waveform of the target nozzle is smaller than a lower limit value of the predetermined range, the hardware processor performs the process of applying the shaking waveform on the target nozzle, thereby controlling the amplitude of the reverberation waveform of the target nozzle to fall within the predetermined range.
7. The inkjet recording apparatus according to claim 6, wherein when the amplitude of the reverberation waveform of the target nozzle is larger than an upper limit value of the predetermined range, the hardware processor performs the predetermined image correction process on the target nozzle.
8. The inkjet recording apparatus according to claim 7, wherein the predetermined image correction process includes at least one of a process of thinning a number of ejections of the target nozzle and a process of reducing a size of an ejected droplet of the target nozzle.
9. The inkjet recording apparatus according to claim 5, wherein a drive voltage correction table that

defines a correction value of the drive voltage applied to the target nozzle corresponding to an amplitude correction value of the reverberation waveform of the target nozzle is preset, and the hardware processor performs the process of correcting the drive voltage applied to the target nozzle based on the drive voltage correction table, thereby controlling the amplitude distribution to fall within the predetermined range.

10. The inkjet recording apparatus according to claim 4, wherein a plurality of heaters is disposed at different positions in the head, and the hardware processor controls heating temperatures of the plurality of heaters such that the amplitude distribution falls within the predetermined range.

11. The inkjet recording apparatus according to claim 4, wherein, among the plurality of nozzles, the hardware processor excludes a nozzle determined to be a defective nozzle from the ejection characteristic control process.

12. The inkjet recording apparatus according to claim 4, wherein the hardware processor performs the ejection characteristic control process in an initialization process performed when the inkjet recording apparatus is activated.

13. The inkjet recording apparatus according to claim 4, wherein while a print job is being executed, the hardware processor performs the ejection characteristic control process for each page in an interval between printing times of pages included in the print job.

14. The inkjet recording apparatus according to claim 4, wherein while a print job is being executed, the hardware processor performs the ejection characteristic control process on a nozzle, among the plurality of nozzles, corresponding to a non-printing region of each page included in the print job.

15. A method for controlling an inkjet recording apparatus that includes a head including a plurality of nozzles configured to eject ink onto a recording medium, the method comprising: generating drive waveforms to drive the respective plurality of nozzles; acquiring reverberation waveforms generated in the respective plurality of nozzles to be measured in accordance with the drive waveforms; and generating a characteristic distribution of the acquired reverberation waveforms to perform, based on the characteristic distribution, an ejection characteristic control process of controlling an ejection characteristic of the plurality of nozzles to be uniform.