

Description

BACKGROUND OF THE INVENTION

The present invention relates generally to an ink jet recording apparatus, and more particularly to such an ink jet recording apparatus with a multi-nozzle type ink jet printing head which allows gradation control of the recording density when ink is ejected from each of a plurality of ink nozzles of the multi-nozzle type ink jet printing head toward a writing surface placed in opposed relation to the printing head.

Various types of ink jet printers are devised heretofore and one known arrangement is to use a multi-nozzle ink jet printing head of the type wherein printing ink is ejected therefrom toward a writing surface by the aid of an electric field established between two types of electrodes and air-stream supplied from a pressurized air source. Such a multi-nozzle ink jet printing head is illustrated in U.S. Patent No. 4,555,717, for example. An important problem in such multi-nozzle ink jet printing heads relates to the lack of uniformity in recording thickness or density on a writing surface. This is due to the difference in characteristic between the nozzles of the multi-nozzle ink jet printing head.

Document US-4 521 786 discloses a programmable controller for ink jet printheads which improves print quality by controlling pulse width and pulse amplitude of a drive pulse for each ink jet ejector. This programmable controller is used in a system wherein a control processor contains look-up tables necessary to provide the desired amplitude and width data of the drive pulse necessary for a desired drop ejection velocity and droplet size.

However, no adaption of the drive pulse width to a desired print density is provided in the apparatuses of the prior art.

It is therefore an object of the present invention to provide an improved ink jet recording apparatus which is capable of controlling the recording density while preventing the recording thickness irregularity due to the difference in characteristic between the nozzles of the multi-nozzle printing head.

This object is achieved by an ink jet printer comprising ink jet printing head means having a plurality of ink nozzles each ejecting ink toward a writing surface, means for storing a plurality of predetermined density-pulse width characteristics each representing a relation between a desired recording density and a therefore required pulse width of an ink ejecting signal to be applied to each of said plurality of ink nozzles, and control means for selecting one of said plurality of predetermined density-pulse width characteristics in correspon-

dence with each of said plurality of ink nozzles and generating said ink ejecting signal in accordance with said selected density-pulse width characteristic.

Alternatively, this object is achieved by an ink jet recording apparatus comprising a multi-nozzle type ink jet printing head having a plurality of ink nozzles each ejecting ink toward a writing surface, electrode means for establishing an electric field due to an ink ejecting signal applied to said electrode means, so as to eject ink from each of said plurality of ink nozzles by means of said electric field, density determining means for generating a density information signal indicative of a recording density at every ink nozzle of said multi-nozzle type ink jet printing head, and control means responsive to said density determining means and having memory means storing a plurality of density-pulse width characteristics each being predetermined to correspond to one or more of said ink nozzles and each representing a relation between said recording density and a therefore required pulse width of said ink ejecting signal indicative of an ink ejecting amount ejected from each of said plurality of ink nozzles, for selecting one of said density-pulse width characteristics at every ink nozzle, and for generating said ink ejecting signal indicative of said ink ejecting amount determined on the basis of said density information signal from said density determining means in accordance with said selected density-pulse width characteristic, said ink ejecting signal being applied to said electrode means.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described in further detail with reference to the accompanying drawings, in which:

Fig. 1 is a cross-sectional view showing a multi-nozzle type ink jet printing head which may be employed for an ink jet recording apparatus according to an embodiment of the present invention;

Fig. 2 is a block diagram showing a conventional ink ejecting signal generation control circuit;

Fig. 3 is a graphic diagram showing a density-to-pulse width of the ink ejecting signal used in the conventional ink ejecting signal generation control circuit of Fig. 2;

Fig. 4 is a graphic illustration for describing the difference in density-pulse width characteristic between the ink nozzles of a multi-nozzle type ink jet printing head;

Fig. 5 is a block diagram showing a pulse-width control circuit of the ink jet recording apparatus in accordance with the embodiment of the present invention; and

Fig. 6 is a graphic diagram showing density-to-pulse width characteristics used in the pulse-width control circuit of Fig. 5.

DETAILED DESCRIPTION OF THE INVENTION

Prior to describing an embodiment of the present invention, a brief description of a conventional ink jet printing apparatus will be made first with reference to Figs. 1 to 4 for a better understanding of the present invention.

A prior multi-nozzle ink jet printing head, as shown in Fig. 1, comprises an insulating air-ink nozzle plate 81 having a plurality of air-ink nozzles 82 to 85 successively arranged in a row at a predetermined interval. A common electrode 86 is attached at the circumferential portions of the plurality of air-ink nozzles 82 to 85 to a surface of the insulating air-ink nozzle plate 81. In parallel to the air-ink nozzle plate 81 is provided an ink nozzle plate 87 having a plurality of ink nozzles 88 to 91 successively arranged in a row and aligned with the air-ink nozzles 82 to 85 with one-to-one correspondance therebetween. The respective ink nozzles 88 to 91 are coupled to an ink chamber 93 with ink which is in turn coupled through an ink supply passage 92 to an ink source, not shown. On the other hand, the respective air-ink nozzles 82 to 85 are coupled through an air chamber 95 and an air supply passage 94 to an air source, not shown so that air supplied from the air supply passage 94 makes an air stream 96 because of the ink nozzle plate 87 and is then discharged curvedly from the air-ink nozzles 82 to 85. Control electrodes 100 whose number corresponding to the number of the ink nozzles 88 to 91 are independently provided at the circumferential portions of the ink nozzles 88 to 91 and on the rear surface of the ink nozzle plate 87 facing the ink chamber 93. An electric field is established between the common electrode 86 and the control electrodes 100 to form menisci in the ink nozzles 88 to 91 and, in response to selective application of ink-ejection control signals 96 to 99 to the control electrodes 100, the menisci in the selected ink nozzles are extended toward the air-ink nozzles 82 to 85 and carried by the air-stream 96 so as to be ejected as inkdroplets from the corresponding air-ink nozzles.

This type ink jet printing head is arranged to cause ink to discharge due to an electrostatic force produced in response to the application of the ink-ejection control signals 96 to 99 which are pulse signals, respectively. The ink-discharging amount, i.e., recording density, is substantially proportional to the pulse width, or length, of each of the ink-ejection control signals applied to the control electrodes 88 to 91 and thus controllable under control of the pulse width thereof. One known ink-ejection

control arrangement will be described hereinbelow with reference to Fig. 2 which is a block diagram showing a device for generating the ink-ejection control pulse signals which are in turn applied to n ink nozzles of a multi-nozzle type ink jet printing head such as illustrated in Fig. 1. In Fig. 2, the control pulse generating device 110 comprises a pulse width control circuit 152 which produces pulse signals 111 to 114 with pulse widths corresponding to N -bit input signals 101 to 104 respectively having information relating to the recording densities in correspondance with the respective ink nozzles 141 to 144 of the multi-nozzle type ink jet printing head 140. The produced pulse signals 111 to 114 are respectively supplied through amplifiers 121 to 124 to the control electrodes of the ink nozzles 141 to 144. Also included in the control pulse generating device 110 is a memory 153 which stores density-pulse width characteristic curves as illustrated in Fig. 3.

In operation, in response to inputs of the N -bit density information signals 101 to 104, the memory is controlled to convert them into 1-bit pulse width information signals respectively corresponding to the inputted density information signals 101 to 104 which are in turn supplied to the pulse width control circuit 152 which produces the corresponding one-bit pulse width signals 111 to 114 and supplies them through the amplifiers 121 to 124 to the control electrodes of the ink nozzles 141 to 144, resulting in ink discharges with amounts corresponding to the density information. However, this arrangement causes recording density irregularity irrespective of application of control signals with the same pulse width, because of the difference in the density-pulse width characteristic between the ink nozzles as shown in Fig. 4.

Referring now to Fig. 5, there is illustrated a control pulse generating unit according to an embodiment of the present invention designated at numeral 1, which may be coupled to a multi-nozzle type ink jet printing head such as shown in Fig. 1 and which comprises a pulse width control circuit 2 for, at every ink nozzles, producing a pulse signal with the width corresponding to a N -bit density information signal inputted from the external circuit. Also included in the control pulse generating unit 1 are a first memory 11 to a m^{th} memory 13 (m = integer not less than 2) which store density-pulse width characteristic curves as shown in Fig. 6, respectively. Although it is better in general that a density-pulse width characteristic curve is determined at every ink nozzle so that the number n of the ink nozzles equals to the number m of the density-pulse width characteristic curves, it is sufficient in practice that m density-pulse width characteristic curves are prepared and one of the m density-pulse width characteristic curves is select-

ed to be closer to the density-pulse characteristic curve of each of the n ink nozzles ($n > m$).

Illustrated at numeral 3 is a memory designating circuit for specifying memories in correspondence with the ink nozzles, respectively, which is presetable from the external. In the memory designating circuit 3 are preset and stored addresses of the memories 11 to 13 which respectively prestore the density-pulse width characteristic curves corresponding to the respective ink nozzles of a multi-nozzle type ink jet printing head used in this ink jet recording apparatus. In response to inputting of each of N -bit density information signals for the respective ink nozzles to the control pulse generating unit 1, the memory designating circuit generates a k -bit memory address signal on the basis of each of the density information signals at every nozzle and the pulse width control circuit 2 obtains a l -bit pulse width information signal on the basis of each of the density information signals and the density-pulse width characteristic curve stored in the corresponding memory (k and l are positive integers). The pulse width control circuit 2 further produces a one-bit pulse signal with width corresponding to each of the pulse width information signals which is in turn supplied to the control electrode of each of the ink nozzles after amplified by amplifying means.

It should be understood that the foregoing relates to only a preferred embodiment of the present invention, and that it is intended to cover all changes and modifications of the embodiment of the invention herein used for the purposes of the disclosure, which do not constitute departures from the scope of the invention as defined in the appended claims.

Claims

1. An ink jet printer comprising:

- ink jet printing head means having a plurality of ink nozzles (141-144) each ejecting ink toward a writing surface, characterized by
- means (11-13) for storing a plurality of predetermined density-pulse width characteristics each representing a relation between a desired recording density and a therefore required pulse width of an ink ejecting signal to be applied to each of said plurality of ink nozzles (141-144); and
- control means (1) for selecting one of said plurality of predetermined density-pulse width characteristics in correspondence with each of said plurality of ink nozzles (141-144) and generating said ink ejecting signal in accordance with

said selected density-pulse width characteristic.

2. An ink jet printer according to claim 1, characterized in that said ink jet printing head means is a signal head and said plurality of ink nozzles (141-144) are integrally arranged in a row.
3. An ink jet printer according to claim 1, characterized in that said ink jet printing head means comprises a plurality of ink jet printing heads (140) each having one of said plurality of ink nozzles (141-144).
4. An ink jet recording apparatus comprising:
 - a multi-nozzle type ink jet printing head having a plurality of ink nozzles (141-144) each ejecting ink toward a writing surface, characterized by
 - electrode means (86,100) for establishing an electric field due to an ink ejecting signal applied to said electrode means (86,100), so as to eject ink from each of said plurality of ink nozzles (141-144) by means of said electric field;
 - density determining means (2) for generating a density information signal indicative of a recording density at every ink nozzle (141-144) of said multi-nozzle type ink jet printing head; and
 - control means (1) responsive to said density determining means (2) and having memory means (11-13) storing a plurality of density-pulse width characteristics each being predetermined to correspond to one or more of said ink nozzles (141-144) and each representing a relation between said recording density and a therefore required pulse width of said ink ejecting signal indicative of an ink ejecting amount ejected from each of said plurality of ink nozzles (141-144), for selecting one of said density-pulse width characteristics at every ink nozzle (141-144), and for generating said ink ejecting signal indicative of said ink ejecting amount determined on the basis of said density information signal from said density determining means (2) in accordance with said selected density-pulse width characteristic, said ink ejecting signal being applied to said electrode means (86,100).
5. An ink jet recording apparatus according to claim 4, characterized in that said electrode

means (86,100) of said multi-nozzle type ink jet printing head comprise a common electrode (86) and a plurality of control electrodes (100) each being provided in correspondence with each of said plurality of ink nozzles (88-91) and positioned in opposed relation to said common electrode, said pulse signal with a width corresponding to said density information signal being applied to said corresponding control electrode (100).

Patentansprüche

1. Tintenstrahldrucker mit:

- a) einer Tintenstrahldruckkopfeinrichtung, die eine Vielzahl von Tintendüsen (141-144) aufweist, von denen jede Tinte in Richtung einer Schreiboberfläche ausstößt, **gekennzeichnet durch**
- b) eine Einrichtung (11-13) zur Speicherung einer Vielzahl von vorbestimmten Dichte-Pulsdauer-Charakteristiken, von denen jede ein Verhältnis zwischen einer gewünschten Aufzeichnungsdichte und einer dafür erforderlichen Pulsdauer eines an jede der Vielzahl von Tintendüsen (141-144) anzulegenden Tintenausstoßsignals darstellt, und
- c) eine Steuereinrichtung (1) zur Auswahl einer der Vielzahl von vorbestimmten Dichte-Pulsdauer-Charakteristiken entsprechend jeder der Vielzahl von Tintendüsen (141-144) und zur Erzeugung des Tintenausstoßsignals in Abhängigkeit der ausgewählten Dichte-Pulsdauer-Charakteristik.

2. Tintenstrahldrucker nach Anspruch 1, **dadurch gekennzeichnet**, daß die Tintenstrahldruckkopfeinrichtung ein Signalkopf ist und daß die Vielzahl von Tintendüsen (141-144) integral in einer Reihe angeordnet sind.

3. Tintenstrahldrucker nach Anspruch 1, **dadurch gekennzeichnet**, daß die Tintenstrahldruckkopfeinrichtung eine Vielzahl von Tintenstrahldruckköpfen (140) umfaßt, von denen jeder eine der Vielzahl von Tintendüsen (141-144) aufweist.

4. Tintenstrahlaufzeichnungsvorrichtung mit:

- a) einem mehrdüsigem Tintenstrahldruckkopf, der eine Vielzahl von Tintendüsen (141-144) aufweist, von denen jede Tinte in Richtung einer Schreiboberfläche ausstößt, **gekennzeichnet durch**
- b) eine Elektrodevorrichtung (86, 100) zur Erzeugung eines elektrischen Feldes aufgrund eines an die Elektrodevorrichtung (86, 100) angelegten Tintenausstoßsignals,

um mit Hilfe des elektrischen Feldes Tinte aus jeder der Vielzahl von Tintendüsen (141-144) auszustoßen,

c) einer Dichteerfassungseinrichtung zur Erzeugung eines Dichteinformationssignals, das die Aufzeichnungsdichte an jeder Tintendüse (141-144) des mehrdüsigem Tintenstrahldruckkopfes anzeigt, und

d) eine auf die Dichteerfassungseinrichtung ansprechende Steuereinrichtung (1) mit einer Speichereinrichtung (11-13) zur Speicherung einer Vielzahl von Dichte-Pulsdauer-Charakteristiken, von denen jede für eine oder mehrere der Tintendüsen (141-144) vorbestimmt ist und von denen jede ein Verhältnis zwischen der Aufzeichnungsdichte und einer dafür erforderlichen Pulsdauer des die von jeder der Vielzahl von Tintendüsen (141-44) ausgestoßene Tintenausstoßmenge angegebenden Tintenausstoßsignals darstellt, wobei die Steuereinrichtung (1) eine der Dichte-Pulsdauer-Charakteristiken für jede Tintendüse auswählt und das die Tintenausstoßmenge angegebene Tintenausstoßsignal erzeugt, welches auf Grundlage des Dichteinformationssignals der Dichteerfassungseinrichtung entsprechend der gewählten Dichte-Pulsdauer-Charakteristik bestimmt wurde, wobei das Tintenausstoßsignal an die Elektrodevorrichtung (86, 100) angelegt wird.

5. Tintenstrahlaufzeichnungsvorrichtung nach Anspruch 4, **dadurch gekennzeichnet**, daß die Elektrodevorrichtung (86, 100) des mehrdüsigem Tintenstrahldruckkopfes eine gemeinsame Elektrode (86) aufweist und eine Vielzahl von Steuerelektroden (100), von denen jede einer der Vielzahl von Tintendüsen (88-91) zugeordnet und gegenüber der gemeinsamen Elektrode (86) angeordnet ist, wobei das Impulssignal mit einer dem Dichteinformationssignal entsprechenden Pulsdauer an die entsprechende Steuerelektrode (100) angelegt wird.

Revendications

1. Imprimante à jet d'encre, comprenant :

- un moyen formant tête d'impression par jet d'encre qui comprend une pluralité de buses à encre (141-144) dont chacune envoie de l'encre vers une surface d'écriture, caractérisée par :
- des moyens (11-13) pour mémoriser une pluralité de caractéristiques prédéterminées de largeur des impulsions de densité, représentant chacune une relation entre la densité d'écriture souhaitée et la

largeur d'impulsion par conséquent requise d'un signal d'éjection d'encre qu'il faut appliquer à chaque buse à encre de ladite pluralité (141-144), et

- un moyen de commande (1) pour choisir l'une parmi ladite pluralité de caractéristiques prédéterminées de largeur des impulsions de densité en correspondance avec chacune de ladite pluralité de buses à encre (141-144) et pour produire ledit signal d'éjection d'encre en accord avec ladite caractéristique de largeur de l'impulsion de densité qui a été choisie.

2. Imprimante à jet d'encre selon la revendication 1, caractérisée en ce que ledit moyen formant tête d'impression par jet d'encre est une tête à signal et ladite pluralité de buses à encre (141-144) est disposée intégralement dans une rangée.

3. Imprimante à jet d'encre selon la revendication 1, caractérisée en ce que ledit moyen formant tête d'impression par jet d'encre comprend une pluralité de têtes d'impression (140) par jet d'encre contenant chacune l'une de ladite pluralité de buses à encre (141-144).

4. Appareil d'enregistrement par jet d'encre comprenant :

- une tête d'impression par jet d'encre, du type multibuses, avec une pluralité de buses à encre (141-144) dont chacune envoie de l'encre vers une surface d'écriture, caractérisé par :
- des moyens formant électrodes (86, 100) pour établir un champ électrique d0 à un signal d'éjection d'encre appliqué auxdits moyens formant électrodes (86, 100), de façon à éjecter de l'encre depuis chacune de ladite pluralité de buses à encre (141-144) au moyen dudit champ électrique,
- un moyen (2) de détermination de la densité pour produire un signal d'information de densité indiquant la densité d'écriture pour chaque buse à encre (141-144) de ladite tête d'impression par jet d'encre du type multibuses, et
- un moyen de commande (1) répondant audit moyen (2) de détermination de la densité et comportant des moyens formant mémoire (11-13) qui stockent une pluralité de caractéristiques de largeur des impulsions de densité, dont chacune est prédéterminée pour correspondre à une ou plusieurs desdites buses à encre (141-144) et dont chacune représente

une relation entre ladite densité d'écriture et la largeur d'impulsion par conséquent requise dudit signal d'éjection d'encre qui indique la quantité d'éjection d'encre éjectée par chacune de ladite pluralité de buses à encre (141-144), servant à choisir l'une desdites caractéristiques de largeur d'impulsion de densité pour chaque buse à encre (141-144) et à produire ledit signal d'éjection d'encre indiquant ladite quantité d'éjection d'encre, déterminé sur la base dudit signal d'information d'intensité provenant dudit moyen (2) de détermination de densité en accord avec ladite caractéristique de largeur d'impulsion de densité qui a été choisie, ledit signal d'éjection d'encre étant appliqué auxdits moyens (86, 100) formant électrodes.

5. Appareil d'enregistrement par jet d'encre selon la revendication 4, caractérisé en ce que lesdits moyens formant électrodes (86, 100) de ladite tête d'impression par jet d'encre du type multibuses comprennent une électrode commune (86) et une pluralité d'électrodes de commande (100) dont chacune est placée en correspondance avec chacune des buses à encre de ladite pluralité (88-91) et est positionnée en vis-à-vis de ladite électrode commune, ledit signal d'impulsion qui a une largeur correspondant audit signal d'information de densité, étant appliqué à ladite électrode de commande correspondante (100).