INK DROPLET SENSING APPARATUS

Ink droplet sensing apparatus for use in an ink jet printer for detecting errors resulting from the omission or misplacement or from the reduced size of a printed dot. In one embodiment the apparatus includes a membrane (14) having a metallic coating thereon which membrane (14) is placed over one side of an electrode member (10) having an uneven surface. Voltage is applied to the electrode member (10) and the metallic coating and ink droplets (20) impinging on the membrane (14) momentarily deflect the membrane and cause a change of capacitance which in turn causes a voltage change at the electrode member (10). The voltage change is coupled through a capacitor (22) and an amplifier (24) to recognition logic for evaluation of the signals.
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INK DROPLET SENSING APPARATUS

Technical Field

The present invention relates to an ink droplet sensing apparatus for use in an ink jet printer.

5 Background Art

In the field of non-impact printing, the most common types of printers have been the thermal printer and the ink jet printer. When the performance of a non-impact printer is compared with that of an impact printer, one of the problems in the non-impact machine has been the control of the printing operation. As is well known, the impact operation depends upon the movement of impact members such as wires or the like and which are typically moved by means of an electromechanical system which is believed to enable a more precise control of the impact members.

The advent of non-impact printing, as in the case of thermal printing, brought out the fact that the heating cycle must be controlled in a manner to obtain maximum repeated operations. Likewise, the control of ink jet printing in at least one form thereof must deal with rapid starting and stopping movement of the ink fluid from a supply of the fluid. In each case, the precise control of the thermal elements and of the ink droplets is necessary to provide for both correct and high-speed printing and to make certain that a clean printed character results from the printed dots.

Endeavors have been made to improve the print quality of dot matrix printers and accordingly arrangements have been proposed for detecting printing errors. Thus, for instance, the U.S. Patent No. 4,067,019 describes a sensing arrangement for accurately detecting the position of ink jet drop impact on the surface of a flat piezoelectric plate between two parallel conductors. A localized charge generated in the
piezoelectric plate generates a signal in each conductor dependent upon the distance of the impact location from the conductor. Using transimpedance amplifiers, the difference of the output signals indicates the impact position.

While the sensing arrangement disclosed in the above U.S. Patent is capable of detecting errors resulting from the misplacement of ink droplets, it has no provisions for overcoming other problems which may arise in jet printing operations. Thus, for instance, the existence of an ink mark or spot and then the non-existence of an ink spot on the paper may indicate that the nozzle plate of the ink jet print head became clogged and requires cleaning or rinsing. Another problem may be that the actual size of the ink spot or mark on the paper does not correspond with the desired ink spot size and wherein the ink droplet drive means may require an adjustment in the operation thereof.

Disclosure of the Invention

It is an object of the present invention to provide a sensing apparatus which is capable of detecting errors resulting from the omission or misplacement or from the reduced size of a printed dot.

Thus according to the invention, there is provided an ink droplet sensing apparatus for use in an ink jet printer, characterized by a flexible membrane arranged during a sensing operation to be aligned with nozzles of an ink jet print head to enable ink droplets to impinge on said membrane, said membrane forming part of electromechanical transducer means responsive to the momentary deflection of said membrane by an impacting ink droplet to produce an output indicative of such impact.

The sensing apparatus is preferably an electrostatic sensing unit positioned in relation to the printing element or print head and capable of detecting the
ink droplet prior to placing an ink mark or spot on the paper. While the sensing apparatus may be positioned in horizontal manner on one side with respect to the printing element, there may be a sensing apparatus on either side of the printing element, or the sensing apparatus may be located in an arrangement beyond the width of the paper but in a position to be reached by the printing element when moving in side-to-side manner.

The sensing apparatus detects small ink droplets and includes an electrode which has an uneven surface across which is tightened or stretched synthetic foil having a layer or coating of metal thereon. A direct voltage is applied between the metal layer and the electrode and whenever ink droplets impinge against the foil, a change in capacitance occurs which in turn causes a voltage change at the electrode. The voltage change is coupled through a capacitor and an amplifier and is then sent to recognition logic means where the signals are evaluated for magnitude of the voltage change at the synthetic foil and for the time of impingement of the ink droplet.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a diagrammatic view of a sensing apparatus for detecting ink droplets;

Fig. 2 is a view of the sensing apparatus with means for preventing drying of the ink;

Fig. 3 is a view showing a sensing apparatus in each of two positions relative to a printing element;

Fig. 4 is a circuit showing a form of noise suppression for the sensing apparatus;

Fig. 5 is a pulse diagram showing the time relationship in the noise suppression of the sensing apparatus;
Fig. 6 is a view showing a plurality of ink droplets being ejected from the nozzle of the printing element;

Fig. 7 is a pulse diagram of the arrangement for identifying the nozzles for a plurality of ink droplets;

Fig. 8 is a view of an arrangement of the electronic components connected with the sensing apparatus;

Fig. 9 is a view showing a modification of the ink droplet sensing apparatus;

Fig. 10 is a view showing a further modification of the ink droplet sensing apparatus; and

Fig. 11 is a view showing a still-further modification of the ink droplet sensing apparatus.

Best Mode for Carrying Out the Invention

Fig. 1 shows in diagrammatic form the design of an electrostatic foil converter for detecting ink droplets which are ejected from the nozzles of a print head of an ink jet printer. A counter electrode 10 in the form of a metallic block has a rough or uneven surface 12 consisting of grooves or like indentations along a face portion of the electrode and corresponding to the column of nozzles in the print head. A thin sheet of synthetic foil 14 is covered or coated with a layer of gold, aluminum, copper or like conductive material, and is stretched across the surface 12 and secured to the electrode by means of a ring 16. The synthetic foil 14 serves as a dielectric and also as an insulator between the electrode 10 and the metallic layer or coating. A direct voltage of 100 volts is supplied through a resistor 18, having a value of 5 megohms, and is connected to apply voltage between the metal layer of the foil 14 and a connecting portion of the electrode 10.
Droplets 20 of ink from the print head are caused to be impinged against the foil 14 and cause a momentary deflection of the foil by reason of the rough surface 12. The deflection of the foil 14 causes a change in capacitance which in turn causes a voltage change at the counter electrode 10 in view of the momentary charge. This voltage change is coupled through a capacitor 22 and a preamplifier 24 to be transmitted to recognition type logic where the voltage change is evaluated in dependence on signals which are to be expected and which signals are utilized in well-known manner in regard to monitoring the printer operation. The recognition logic utilizing the voltage changes coming from the sensing means monitors proper ink jet operation and can initiate certain corrective or warning actions, such actions indicating and/or providing for wiping and cleaning the face plate of the print head, or sounding an alarm or adjusting the voltages applied to ink droplet drive elements. In well-known manner, the monitoring function may be performed upon operator request or automatically at regular intervals, for example, at the end of each line, at the end of each printed page, or after a predetermined plurality of printed lines or pages. It is here noted that the recognition logic and corrective action may correspond to an arrangement disclosed in a copending International Application No. US81/01367 entitled Dot Matrix Printer.

The magnitude of the voltage pulse on the synthetic foil 14 depends on the electrical values of resistance and applied voltage and on the mechanical parameters of the impinging ink droplet such as the velocity and mass of the ink droplet 20. The impinging of the ink droplet 20 onto the foil 14 initiates or generates the leading edge of the voltage change which is detected by the circuitry. Thus the time of impingement of the ink droplet 20 and the pulse caused thereby can be detected.
Fig. 2 shows the counter electrode 10 with the rough surface 12 and with the foil 14 stretched thereacross and secured by the ring 16. The ink droplets 20 are directed toward the metallic covered foil in the manner and with the result as described in Fig. 1. An ink solvent atmosphere 30 is established or created adjacent the foil 14 and in the path of the ink droplets 20 by means of an absorbent felt member 32. The member 32 is trained around the rough surface 12 to provide the atmosphere 30 for the purpose of preventing drying of the ink on the metal plated foil 14. The member 32 is placed with one end thereof in a container 34 of solvent 36 and in a manner wherein the ink droplets remain moist and flow downwardly along the foil 14 and onto the felt. Such an absorbent member may not be required where the ink is of a consistency that the ink can remain on the foil layer without drying or in the case where the ink solvent is not absorbed by the felt.

Fig. 3 shows in diagrammatic form the operation of the electrostatic sensor in connection with an ink jet print head 40 and the paper 42 on which printing is to be performed. Detection of the ink droplets can be accomplished by placing an electrostatic sensor 44 outside the margin of the paper 42 or to the left thereof and the print head 40 is caused to travel beyond the paper to enable sensing the ink droplets. In this arrangement and after completion of each line of printing the ink jet print head 40 runs over the sensor 44 and a monitor signal is generated which is characteristic of the impinged ink droplet.

Another arrangement of the detection or sensing means is shown in Fig. 3 wherein an electrostatic sensor 46 is placed within the margin of the paper 42 and the sensor is moved directly with the print head 40. In this manner no extra movement of the print head 40 is necessary for monitoring or testing the impingement of the ink droplets. An additional movement of the sensor
46 is necessary to uncover the print head 40 for printing or to cover the print head for a test step. When the printer is at rest the sensor 46 may serve as a cover member for protecting the print head against dust or drying of the ink at the nozzles.

Fig. 4 shows a circuit employing a time mask and Fig. 5 shows a corresponding pulse diagram for accomplishing a logical decision for filtering out noises from the electrostatic sensor 44 or 46 (Fig. 3).

An initiating pulse 50 or voltage $V_I$ is generated through a time window 52 in the form of a monostable multivibrator and then through an adjustable window 54 also in the form of a multivibrator to serve as one input ($V_M$) of an AND gate 56. A pulse or ink droplet signal 58 or voltage $V_S$ is sent from the electrostatic sensor 44 or 46 through limiting amplifiers 60 and 62 and serves as the other input ($V_S'$) of the AND gate 56 which has an output signal 64 or voltage pulse $V_N$. The time window 52 is generated by determining the time of propagation of the signals within the ink channel of the print head and a narrow detection time reduces the noise sensitivity of the electrostatic sensor. The use of a time mask for noise suppression of the sensor relates to the timing and coding of the successive emission of ink droplets by a plurality of sensors, as disclosed below. An initiating signal 50 or voltage pulse $V_I$ from the character generator triggers a time signal of length $t_1$ in the multivibrator 52 which signal length is equal to the electrical delay seen during ink droplet emission plus time of flight of the droplet from the nozzle to the foil 14. After time $t_1$, the multivibrator 54 is triggered to emit a pulse $V_T$ of a length $t_2$ corresponding to the impact duration of the droplet on the sensor 44 or 46.

The signal 58 or voltage pulse $V_S$ transmitted from the sensor consists of the signal to be recognized or detected plus any noise disturbance, so that the
signal 58 includes a time delay \( t_1 \) and a length \( t_2 \). It is only when this condition is true that an output signal 64 or voltage pulse \( V_N \) is generated by the AND gate 56, and noise suppression is achieved.

Fig. 6 shows a print head 66 with a plurality of nozzles 68 in an arrangement wherein it is sufficient to use only one electrostatic sensor for testing all the nozzles. A coding of the individual nozzles 68 enables a detecting of the proper operation of all the nozzles or for the detection of errors in the ejection of ink droplets from one or more of the nozzles. In this case the top nozzle ejects one droplet, the next nozzle two droplets, and so forth with the coded pulse pattern for identifying the individual nozzles shown in the timing pattern of Fig. 7. Any suitable method such as a single timing operation for correlating the individual output signals of the sensor with a respective nozzle may likewise be used in the sensing operation.

Fig. 8 shows an arrangement permitting a compact design of the sensing apparatus and a high electromagnetic noise suppression in an instance wherein the high resistance line, designated as 58 in Fig. 4, is of short length. The arrangement in Fig. 8 uses a preamplifier which may be an integrated circuit performing as a counter electrode to enable the advantages of a stable design and short supply lines. A support plate 70 including normal electrical components and printed leads carries an integrated circuit 72 as a supporting member for the counter electrode 74 which electrode takes the form of sheet metal having a rough surface at a face portion thereof. A metallic foil 76 is secured to the support plate 70 and is stretched across the rough surface of the electrode 74 and is secured on the back side of the counter electrode.

Fig. 9 shows a schematic arrangement of an electromagnetic microphone for detecting ink droplets 80 and including a membrane 82 suitably supported and
connected with a rotatable reed armature 84 which is positioned through a coil 85 and operably associated with a permanent magnet 86 and a soft iron core 88. Since the operation of a microphone apparatus is well-known, it is seen that whenever ink droplets 80 impact on the membrane 82, the generated voltage changes are input to the recognition logic and are used in corrective or warning actions as described above.

Fig. 10 shows a modified arrangement of an electromagnetic microphone for detecting ink droplets 90 and including a membrane 92 suitably supported in an air gap between an armature 94 and a soft iron core 96 operably associated with and surrounding a permanent magnet 98 and a coil 100. The impact of droplets 90 against the membrane 92 generates voltage changes for input to the recognition logic as mentioned just above.

Fig. 11 shows another arrangement of a ceramic microphone for detecting ink droplets 102 and including a membrane 104 suitably supported and connected with a piezo ceramic bending oscillator 106. The oscillator 106 is operably connected in an impedance matching stage arrangement which includes a field effect transistor 108. Likewise, the droplets 102 impact against the membrane 104 and generate the voltage changes.

Another possibility as an alternative to the use of the metallic foil 14, as shown in Figs. 1 and 2, is the use of an electret converter which has an electric polarity sufficient for detection of the ink droplets. The electret converter can use either synthetic foils or thin layers of piezo ceramic materials. While the electret converters or transducers are commercially available, they eliminate the need for the high applied voltage and the large resistance in the detection circuit and thus are considered to be unique in detecting or sensing ink droplets.
The application of an electrical sensor offers an early opportunity to detect failure of the ink jet printing which may take the form wherein (1) the ink droplet does not impinge on the foil, (2) the impact of the ink droplet on the foil is too small to cause the required electrical pulse, or (3) the ink droplet does not impinge on the foil at the proper time, that is, the propagation time of the electrical signals and the time of the pressure waves in the ink jet printing device are too large. The first and the third failure indications or forms may normally be removed or solved by activating a rinsing device for keeping the ink jet nozzles free and clear. The third indication may also be removed by means of controllable electrical delay elements or by using variable propagation times in the electrical signaling scheme. The second failure indication can usually be removed within certain limits by readjusting the energizing voltage for the piezo drive element.

A further application of the electrostatic sensor is in the detection of a defined geometric shape. A small sensor could detect changes in the configuration of the ink jet flow and a large electrostatic converter could be used with a hole pattern wherein the ink droplets are detected only if the impingement is in the exact geometrical configuration.
CLAIMS:

1. Ink droplet sensing apparatus for use in an ink jet printer, characterized by a flexible membrane (e.g. 14) arranged during a sensing operation to be aligned with nozzles of an ink jet print head to enable ink droplets to impinge on said membrane, said membrane forming part of electromechanical transducer means (e.g. 10, 12, 14, 16, 18, 22) responsive to the momentary deflection of said membrane by an impacting ink droplet to produce an output indicative of such impact.

2. Sensing apparatus according to claim 1, characterized in that said transducer includes an electrode member (10, 74) having an uneven surface, said membrane (14, 76) covering said uneven surface and having an electrically conducting coating on one side thereof which coating is insulated from said electrode member (10, 74), whereby said coating and said electrode member (10, 74) form capacitive means, the arrangement being such that a momentary deflection of said membrane (14, 76) brought about by an impacting ink droplet brings about a momentary change in the capacitance of said capacitive means, thereby causing the production of said output.

3. Sensing apparatus according to claim 2, characterized in that said membrane (14, 76) is stretched across said uneven surface.

4. Sensing apparatus according to claim 2, characterized in that said membrane (14, 76) is of an electrically insulating material and has a metallic coating on the side thereof distal from said electrode member (10, 74).
5. Sensing apparatus according to claim 2, characterized in that said electrode member (10, 74) is a metallic block having a plurality of grooves (12) on one surface thereof, said one surface being that surface of said electrode member (10, 74) covered by said membrane (14, 76).

6. Sensing apparatus according to claim 5, characterized in that said grooves (12) are positioned to receive ink droplets from a respective number of nozzles (68) of an ink jet print head (66).

7. Sensing apparatus according to any one of claims 2 to 6, characterized by means (32) adjacent said membrane (14) for maintaining an atmosphere of moist air (30) therearound for preventing drying of ink on the membrane (14).

8. Sensing apparatus according to claim 2, characterized by circuit means (52, 54) for filtering noise from the sensing apparatus.

9. Sensing apparatus according to claim 1, characterized in that said electromechanical transducer is an electromagnetic microphone (82, 84, 85, 86, 88; 92, 94, 96, 98, 100).

10. Sensing apparatus according to claim 1, characterized in that said electromechanical transducer is a ceramic microphone (104, 106, 108).
INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) 3

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. Cl 3 G01D 1/00
U.S. Cl. 346/75

II. FIELDS SEARCHED

Minimum Documentation Searched 4

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III. DOCUMENTS CONSIDERED TO BE RELEVANT 14

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IV. CERTIFICATION

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26 January 1982                                            | 10 FEB 1982                                             

International Searching Authority 4 | Signature of Authorized Officer 50
ISA/US                                                        | W.J. Brady

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