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(11)

EP 0 764 534 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
26.03.1997 Bulletin 1997/13

(51) Int Cl.⁶: **B41J 2/16**

(21) Application number: **96306775.6**

(22) Date of filing: **18.09.1996**

(84) Designated Contracting States:
DE FR GB

(30) Priority: **19.09.1995 US 530867**

(71) Applicant: **SCITEX DIGITAL PRINTING, Inc.**
Dayton, Ohio 45420-4099 (US)

(72) Inventors:
• **Vandagriff, Randy D.**
Beavercreek, Ohio 45430 (US)

• **Glueckert, Henry D.**
Huber Heights, Ohio 45424 (US)
• **Hill, Ronald J.**
Ohio 45385 (US)

(74) Representative: **Hillier, Peter et al**
Reginald W. Barker & Co.,
Chancery House,
53-64, Chancery Lane
London, WC2A 1QU (GB)

(54) Method for manufacturing a fluid cavity in an ink jet print head

(57) A continuous ink jet printing system includes a resonator having an internal fluid cavity. An initial aperture is drilled through the internal fluid cavity. A wire elec-

trical discharge machining process is then applied to the surface of the internal fluid cavity to achieve a desired aperture dimension. The final aperture can be honed to improve surface finish.

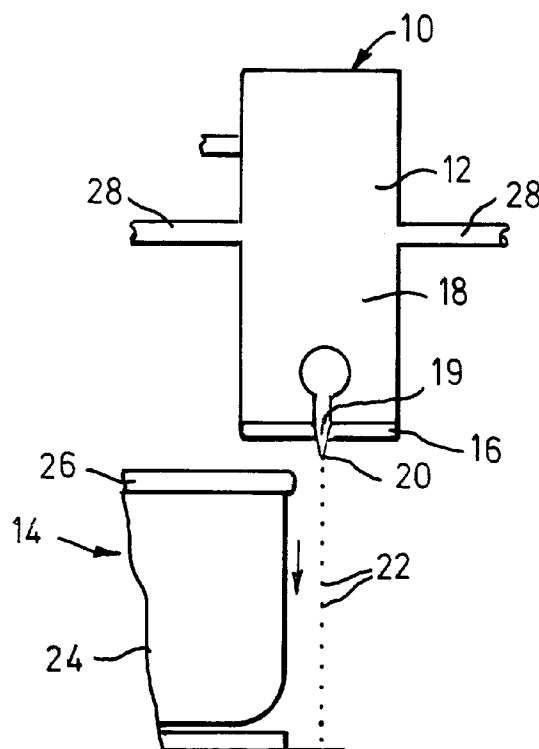


FIG. 1

Description

Technical Field

The present invention relates to continuous ink jet printers and, more particularly, to a method for manufacturing a fluid cavity in an ink jet print head to provide a straight and uniform bore for ink drops exiting the fluid cavity.

Background Art

Continuous ink jet printers comprise a series of electric and fluidic components, including an orifice plate and a charge plate, for generating one or more rows of jets of ink and selectively charging the ink droplets as they form from the jets. Typically, there may be several hundred jets formed in each row, and each jet may be stimulated to produce drops of ink at a given rate. All such drops fall through an electrical deflection field, and those which are charged are deflected into a catcher. Uncharged drops are deposited on a print media positioned below the print head.

In general, continuous ink jet printing apparatus have a print head manifold to which ink is supplied under pressure so as to issue in streams from a print head orifice plate that is in liquid communication with the fluid cavity. Periodic perturbations are imposed on the liquid streams, such as vibrations by an electromechanical transducer, to cause the streams to break-up into uniformly sized and shaped droplets.

A charge plate, comprising an array of addressable electrodes, is located proximate the streams break-off points to induce an electrical charge, selectively, on adjacent droplets, in accord with print information signals. Charged droplets are deflected from their nominal trajectory. For example, in a common, binary, printing mode, charged or non-print droplets are deflected into a catcher device and non-charged droplets proceed to the print medium. The components described above should be precisely sized and positioned to achieve accurate placement of droplets on the print medium or on the catcher face.

One of the critical requirements in ink jet printers is an orifice plate which will produce several hundred jets of ink which are precisely positioned, precisely parallel, and precisely uniform in diameter and shape. The orifice plate is associated with a resonator body which defines a fluid cavity and includes an opening for ejecting fluid from the cavity.

In resonators, such as those described in U.S. Patent No. 4,999,647, it is known to be necessary to apply machining techniques to the surface of the resonator cavity area in order to achieve the appropriate dimension in the area where ink is brought into and expelled from the resonator. For example, drilling in from both ends of the resonator toward the middle of the resonator to create the fluid cavity, has been attempted. Unfortunately,

mis-alignment of holes drilled from the two ends of the cavity can occur. This mis-alignment can be due to a drifting of the hole during a drilling operation. This mis-alignment has the undesirable result of trapping air and debris in the fluid cavity during cross-flush. This also gives non-uniform walls, which adversely affects stimulation. This again yields non-uniform cavity walls, which can adversely affect stimulation. A drift in the cavity location as it passes through the resonator can be partially overcome by machining the exterior of the drop generator to be square to the cavity. Although resquaring the drop generator to the cavity eliminates significant end to end variation in bore location, the bore can still drift in the interior of the drop generator. This can still result in non-uniform stimulation amplitude. Additionally, drilling does not give a uniform surface finish, which can lead to particles being generated inside the cavity.

Another approach is to use gun boring to create the fluid cavity. Gun boring tends to give less drift in the holes than a standard drilling operation. Gun boring allows the cavity to be drilled from one side, avoiding the mismatch in the center. Unfortunately, the bore location and diameter can still vary excessively. Also, the difference in alignment from one end of the cavity to the other can be several mils with the gun boring process, with all the same associated alignment problems which arise with other machining techniques. This again yields non-uniform cavity walls, which can adversely affect stimulation. A drift in the cavity location as it passes through the resonator can be partially overcome by machining the exterior of the drop generator to be square to the cavity. Although resquaring the drop generator to the cavity eliminates significant end to end variation in bore location, the bore can still drift in the interior of the drop generator. This can still result in non-uniform stimulation amplitude.

Since the fluid cavity dimension is so small and precise, most machining methods are impractical, requiring resquaring of the outer dimensions of the drop generator to the bore. Variations in the cavity location and diameter result in changes in resonant frequency and non-uniform vibration amplitude of the resonator. Changing the resonant frequency of the resonator adversely affects drop formation and print quality. Existing machining processes also create a rough surface finish on the resonator, resulting in several print problems. For example, the rough finish can allow the presence of air in the print bar. Debris breaking off from the rough finish can cause crooked or clogged jets.

It is seen then that there exists a need for an improved method of manufacturing the fluid cavity in an ink jet print head which eliminates the problems typically caused by existing machining processes.

Summary of the Invention

This need is met by the method according to the present invention, wherein a fluid cavity in an ink jet print

head is manufactured to provide a straight and uniform bore for ink drops exiting the fluid cavity. Since the bore is uniform and straight, and parallel to the outer dimensions, there is no need to resquare any dimensions.

In accordance with one aspect of the present invention, a continuous ink jet printing system includes a resonator having an internal fluid cavity. Initially, a small first pilot hole or aperture is drilled through the resonator to facilitate feeding a wire through the resonator. Using this wire, an electrical discharge machining (EDM) process is applied to the surface of the internal fluid cavity. The path for the wire defines the desired final aperture dimension, creating a uniform and straight cavity. A finishing or honing step can be applied to improve the texture of the final cavity, as needed.

Accordingly, it is an object of the present invention to provide an improved surface finish for the resonator cavity of an ink jet printing system. The improved surface finish has the advantage of improving drop formation and print quality. The present invention has the further advantage of providing more uniform amplitude along the resonator. Finally, the technique of the present invention allows for various dimensioned holes, rather than being restricted to round holes, thereby offering potential fluid flow advantages.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

Brief Description of the Drawings

Fig. 1 illustrates a portion of a print head structure, including a resonator, for describing the technique of the present invention;

Figs. 2A and 2B illustrate the resonator of Fig. 1; and

Figs. 3A and 3B illustrate the wire EDM process applied to the resonator, in accordance with the present invention.

Detailed Description of the Preferred Embodiments

Referring to the drawings, in Fig. 1 a portion of a print head 10 of an ink jet printer system is illustrated. The print head 10 is comprised of a resonator 12 having associated mounting pins 28. The resonator 12 is typically constructed of a stainless steel material in the form of a predeterminedly dimensioned rectangular solid. The print head 10 further comprises a drop selection means 14. The print head 10 defines one or more rows of orifices on an orifice plate 16 of the resonator 12 which receive an electrically conductive recording fluid, such as a water base ink, from a pressurized fluid supply contained in a fluid cavity 18. The fluid is ejected from the resonator through aperture 19 in rows of parallel streams 20 as ink droplets 22. A drop catcher device 24 and a charge plate 26 define the drop selection means 14 for selectively charging and deflecting the drops 22

in each of the streams and depositing at least some of the drops 22 on a print receiving medium.

It will be understood that the print head 10 and resonator 12 cooperate with other known components used in ink jet printers. The print head 10 and resonator 12 function to produce the desired streams of uniformly sized and spaced drops in a highly synchronous condition. Other continuous ink jet printer components, such as charge and deflection electrodes, drop catcher, media feed system and data input and machine control electronics (not shown) cooperate with the drop streams, produced by the print head 10 to effect continuous ink jet printing.

Referring now to Figs. 2A and 2B, in accordance with the present invention, the resonator 12 is machined and ground to predetermined outer dimensions. As illustrated in Fig. 2B, a pilot hole or aperture 30 is drilled through the resonator 12. The pilot hole 30 is smaller than the final desired cavity size. To hold location and concentricity, the resonator 12 is counterbored at both ends, using any suitable process, such as a CNC mill.

Figs. 3A and 3B illustrate the wire EDM process according to the present invention, which is applied to the resonator 12 following the drilling step illustrated in Fig. 2B. As seen in Fig. 3A, a wire 32 is inserted through pilot hole 30, and held taut as it moves continuously through pilot hole 30, along an axial burn rate path in the direction of arrow 34. As the wire 32 burns along its axial path, it also rotates around the perimeter of the pilot hole 30 in the direction of arrow 36, gradually and uniformly widening the pilot hole or aperture, as illustrated in Fig. 3B, to form the desired cavity 30'. The uniformity and straightness of the cavity 30', as the cavity 30' size approaches the desired cavity size, is maintained using the wire EDM process. The shape of cavity 30' remains true, even if the shape is not circular. Hence, the resonator is not restricted to circular cavities, allowing for various dimensioned cavities to be achieved.

As the wire EDM process increases the dimensions of the initial pilot hole or aperture 30, and approaches the desired cavity 30' dimension, the speed of burn can be changed to improve the finish. Additionally, to further improve the texture finish and remove the recast layer of the final cavity, a honing step can be applied. This step requires the use of a honing machine that will remove a small amount of material from the cavity. This is done by circulating a very high precision and hardened stone in and out of the cavity from both ends. A layer of recast material left over after the EDM process is removed, and a smooth mirror-like finish remains on the cavity wall. The honing step does not introduce a new dimension to the final aperture, compromise the integrity of the final aperture, or adversely affect the trueness or accuracy of the aperture.

Industrial Applicability and Advantages

The present invention is useful in the field of ink jet

printing, and has the advantage of eliminating the undesirable print problems caused by existing fluid cavity machining processes. The present invention also provides more uniform amplitude along the resonator, since the location and size of the fluid cavity are now uniform.

Having described the invention in detail and by reference to the preferred embodiment thereof, it will be apparent that other modifications and variations are possible without departing from the scope of the invention defined in the appended claims.

Claims

1. A method for manufacturing a fluid cavity in a component of an jet printing system, the method comprising the steps of:
 - a. providing a resonator;
 - b. drilling an initial aperture through the resonator;
 - c. feeding a wire through the initial aperture;
 - d. defining a path for the wire to create a desired final cavity dimension in the resonator, the cavity having a cavity surface.
2. A method for manufacturing a fluid cavity as claimed in claim 1 wherein the step of defining a path for the wire comprises the step of using the wire to apply wire electrical discharge machining to the surface of the cavity to achieve the desired final cavity dimension.
3. A method for manufacturing a fluid cavity as claimed in claim 1 further comprising the step of honing the desired final cavity dimension to improve surface finish of the desired final cavity dimension.
4. A method for manufacturing a fluid cavity in a component of an jet printing system, the method comprising the steps of:
 - a. providing a resonator;
 - b. applying a machining technique to the resonator to create a fluid cavity with a desired final cavity dimension;
 - c. honing the fluid cavity to improve surface finish of the desired final cavity dimension.
5. A method for manufacturing a fluid cavity as claimed in claim 4 wherein the step of applying a machining technique to the resonator to create a fluid cavity with a desired final cavity dimension further comprises the steps of:
 - a. drilling an initial aperture through the resonator;
 - b. feeding a wire through the initial aperture;
 - c. defining a path for the wire.
6. A method for manufacturing a fluid cavity as claimed in claim 5 wherein the step of applying a machining technique to the resonator to create a fluid cavity with a desired final cavity dimension further comprises the step of using the wire to apply wire electrical discharge machining to the surface of the cavity to achieve the desired final cavity dimension.
7. A method for manufacturing a fluid cavity in a component of an jet printing system, the method comprising the steps of:
 - a. drilling an initial aperture through the component;
 - b. feeding a wire through the initial aperture;
 - c. defining a path for the wire to create a desired final cavity dimension in the component, the cavity having a cavity surface.
8. A method for manufacturing a fluid cavity as claimed in claim 7 wherein the step of defining a path for the wire comprises the step of using the wire to apply wire electrical discharge machining to the surface of the cavity to achieve the desired final cavity dimension.

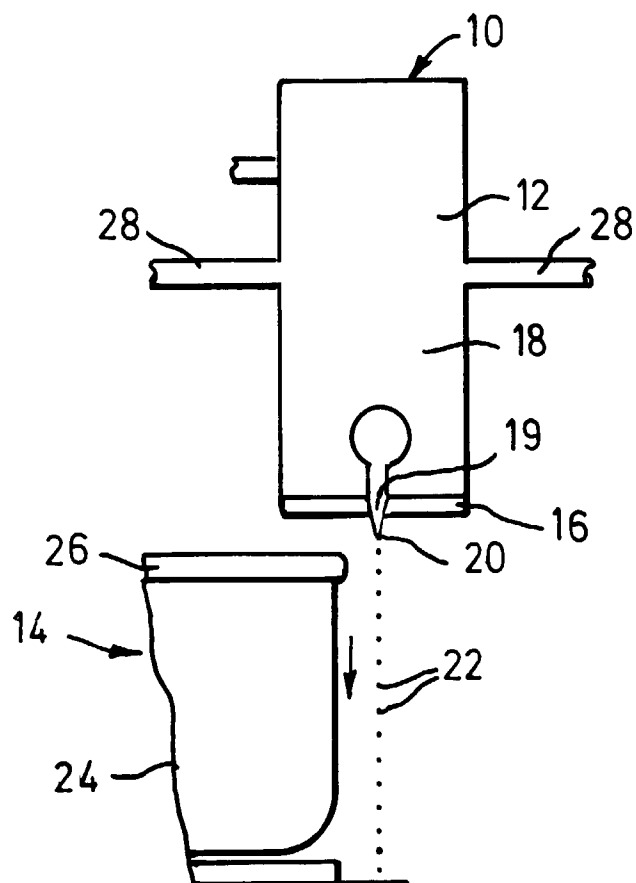


FIG. 1

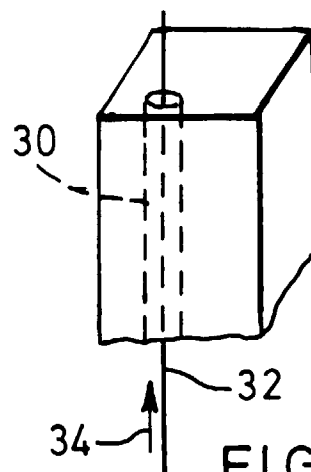


FIG. 3A

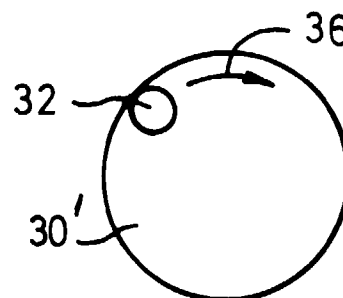


FIG. 3B

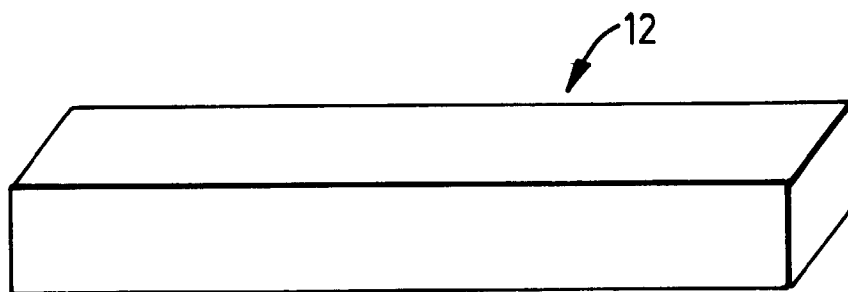


FIG. 2A

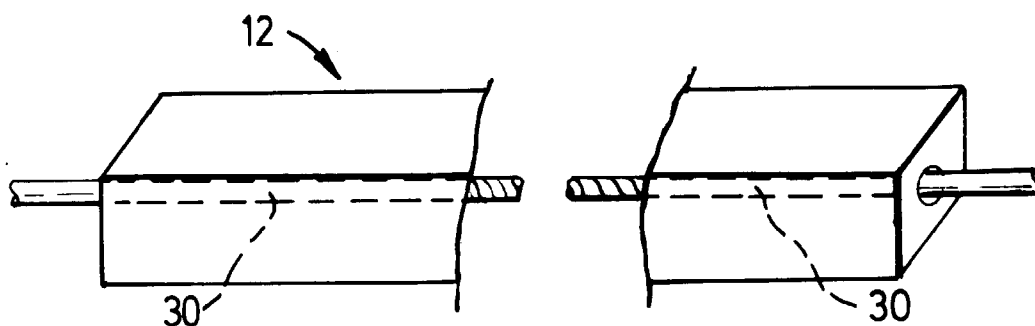


FIG. 2B