1 567 676

PATENT SPECIFICATION

(11) 1 567 676

(21) Application No. 44408/77 (22) Filed 25 Oct. 1977
(31) Convention Application No. 741825
(32) Filed 15 Nov. 1976 in
(33) United States of America (US)
(44) Complete Specification published 21 May 1980
(51) INT CL³ B41J 3/04
(52) Index at acceptance
B6F LR

(19)

(72) Inventors JOHN MAKO and
WALTER THORNTON PIMBLEY

(54) INK JET PRINTING APPARATUS

(71) We, INTERNATIONAL BUSINESS MACHINES CORPORATION, a Corporation organized and existing under the laws of the State of New York in the United States of America, of Armonk, New York 10504, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to ink jet printing apparatus.

In ink jet printers a nozzle unit is connected to a reservoir or other supply of liquid ink which is maintained under constant pressure. This causes ink to be discharged from an orifice in the nozzle unit in a continuous stream. The nozzle unit is vibrated in a manner which causes perturbations to be formed in the stream such as to cause it to break up into individual drops a relatively short distance from the nozzle. The vibrating mechanism may be either a piezoelectric or a magnetostrictive device.

The invention provides ink jet printing apparatus comprising a nozzle chamber to which liquid ink under pressure is supplied and from an outlet of which a continuous filament jet of ink issues, means for establishing periodic pressure variations in the ink in the chamber so that the ink jet is caused to break-up at a predetermined distance from the outlet into a stream of equal sized uniformly ink droplets, and damping means acting selectively to damp pressure waves in the ink in the chamber occurring within the audio range of frequencies, said damping means comprising a body of elastomeric or other resiliently deformable material having an extended surface contiguous with the ink in the chamber so as to absorb audio frequency energy therefrom.

Ink jet printing apparatus embodying the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic drawing of a type of ink jet printer in which the invention is useful;

Figure 2 is a simplified drawing of a magnetorestrictive type nozzle;

Figure 3 is a cross-section along line 3—3 of the nozzle of Figure 2; and

Figure 4 is a performance graph illustrating the operation of the nozzle of Figure 2.

As seen in Figure 1, a magnetic ink jet printer system comprises nozzle 10 through which a stream of field controllable ink, such as a ferrofluid, is ejected under pressure from a pump 12 connected to an ink reservoir 13. Drops 11 are formed in the ink stream by a transducer 14, which vibrates nozzle 10 at a predetermined frequency established by pulses from clock 15 to produce perturbations in the ink stream whereby drops 11 are caused to be formed at a fixed point in the trajectory of the stream as the drops move toward a print medium 16. Drops not used for printing are deflected from the initial stream trajectory by a magnetic selector 17 into a gutter 18 located in advance of print medium 16. Data pulses are applied to the magnetic selector 17 in timed relation with the flight of ink drops 11. A raster scan signal is applied by raster generator 19 to a magnetic deflector 20, which causes ink drops to be dispersed in an orthogonal direction to become deposited onto paper 16 in a predetermined data pattern. The printer system thus far described is known in the art. Further details of construction and operation of such a system may be more fully understood by reference to U.S. Patent 3,959,797, issued May 25, 1976, to D. F. Jensen.

In a preferred embodiment of the present invention, as shown in Figure 2, the nozzle 10 is a tube 21 of magnetostrictive material such as nickel. One end of the tube 21 is attached to a reaction mass 22, which is maintained stationary. At the other end, tube 21 has an orifice 23 through which the ink stream is discharged when fluid ink is supplied under pressure through inlet port 24 in the one end of the tube 21. The transducer for magnetostrictively exciting tube 21 comprises an exciter coil 25 electrically connected to be energized by an alternating signal generated at a desired frequency under control of clock 13, as seen in Figure 1. The magnetostrictive excitation of tube 21 by the longitudinal field of coil 25 sets up standing waves in the fluid mass 26 within the fluid chamber of tube 21 and causes perturbations on the ink mass passing through the tube and out orifice 23 that controls the drop breakup process.

In the preferred embodiment, tube 21 at its primary resonance has a length which is approximately 1/4 wavelength. Tests on a nickel tube, such as tube 21, without ink within the fluid chamber have shown that the resonance curve of the structure is without any secondary resonance maxima or minima in the vicinity of the primary resonance. With ink in the tube, however, standing waves are or maybe set up in the liquid column which complicate the resonance curve greatly. The liquid column resonances are not stable, since they depend on the ink properties and the entrance condition of the ink into the tube, as well as the tube dimensions. As seen in Figure 4, curve 30 shows the characteristic curve for a ferrofluid ink showing maxima and minima peaks 31 and 32.

The maxima and minima peaks shown in Figure 4, depend upon the use of a damper means which filters out the liquid column resonances. As seen in Figure 2, the damping means in this example comprises an elongate tube or rod 27 located inside the fluid chamber of tube 21. The rod 27 is totally immersed in the fluid mass 26. The rod in its preferred form occupies about half the cross-sectional area of the inside of tube 21. The size of the damper rod is not critical. Various lengths could be used which would be effective depending upon the quality of the ink and amount of energy imparted to the ink during vibration. Various materials may be used for the damping material for absorbing the soundwave energy propagated by the magnetostrictive vibration of the tube to the fluid mass 26. A preferred material comprises a resilient elastomeric material such as butyl rubber. One such material used has the following parameters:

Diameter of damper	.063 inches
Length of damper	1.0 inch
Durometer	50
Length of nickel tube	1.0 inch
Inside dia. of nickel tube	.095 inches
External dia. of nickel tube	.125 inches
Orifice diameter	.0025 inches

A ferrofluid ink was used having the following properties:

Density	1.3 gms/cc
Viscosity	8.5 c poise
Magnetic moment	24 abamps/cm^2/gm

A process for making such ink is described in U.S. Patent 3,990,981.

While the physics of how the damper eliminates the liquid column resonances is not fully understood, it is believed that an elastomeric material responds to pressure fluctuations within the fluid mass 26 in a manner analogous to a capacitor so that the length of the damper 27 acts analogously to a continuous filter network.

The damper 27 can be merely placed within the liquid mass 26 without attachment to the tube 21. Curve 33 in Figure 4 shows the results, in that secondary resonance peaks have been eliminated. An alternative arrangement, however, would be to bond the damper elastomeric material to the inside of the tube 21. This configuration would have the additional advantage that a measure of controlled damping is added to the vibration of tube 21 by electromagnet 25.

While the use of a fluid damper is illustrated in connection with a magnetostrictive transducer, a similar damper could be used in an ink jet nozzle where soundwaves are propagated in a liquid ink mass within a nozzle chamber by other vibrating means such as piezoelectric crystal, voice coil, etc.

It should be noted that the nozzle structure described herein has application where dielectric or other type inks might be used, e.g. in electrostatic ink jet printers or the like, as well as with the ferrofluids illustrated.

We were able to show that the vibration of the nozzle by the transducer at the frequency necessary to produce a stream of usable droplets causes soundwaves i.e. vibrations at frequencies within the audio range of frequencies, to be propagated in the liquid ink within the tube 21. It is found that the damper 27 damps these soundwaves.

WHAT WE CLAIM IS:—

1. Ink jet printing apparatus comprising a nozzle chamber to which liquid ink under pressure is supplied and from an outlet of which a continuous filament jet of ink issues, means for establishing periodic pressure variations in the ink in the chamber so that the ink jet is caused to break-up at a predetermined distance from the outlet into a stream of equal sized uniformly ink droplets, and damping means acting selectively to damp pressure waves in the ink in the chamber occurring within the audio range of frequencies, said damping means comprising a body of elastomeric or other resiliently deformable material having an extended surface contiguous with the ink in the chamber so as to absorb audio frequency energy therefrom.

2. Apparatus as claimed in Claim 1, in which the body is submerged or otherwise immersed in the ink in the chamber.

3. Apparatus as claimed in Claim 1 or 2, in which the nozzle chamber is elongate and in which the body extends within the chamber for substantially the full length of the chamber.

4. Apparatus as claimed in Claim 3, in which the elongated body has a cross-sectional area approximately equal to one-half the cross-sectional area of the chamber.

5. Apparatus as claimed in any one of Claims 1 to 4, in which the body is attached to the wall of the nozzle chamber.

6. Apparatus as claimed in any one of Claims 1 to 5, in which the body is formed of butyl rubber.

7. Apparatus as claimed in any one of Claims 1 to 6, in which the pressure-variation-means comprise an electro-mechanical transducer.

8. Apparatus as claimed in Claim 7, in which the transducer comprises a cantilevered tube, which tube provides the peripheral wall of the nozzle chamber and is formed of magnetostrictive material, and a driving coil surrounding the tube.

9. Ink jet printing apparatus comprising a nozzle unit substantially as hereinbefore described with reference to and illustrated in Figures 2 and 3 of the accompanying drawings.

ALAN J. LEWIS,
Chartered Patent Agent,
Agent for the Applicants.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1980
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

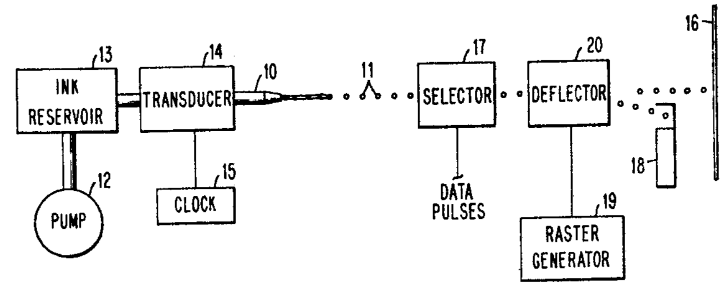

FIG. 1

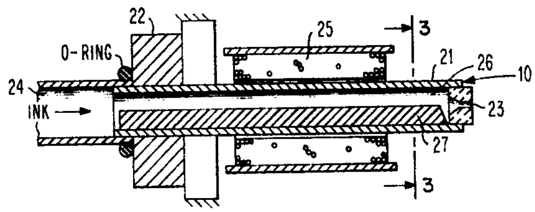

FIG. 2

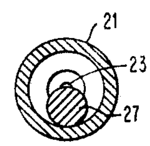

FIG. 3

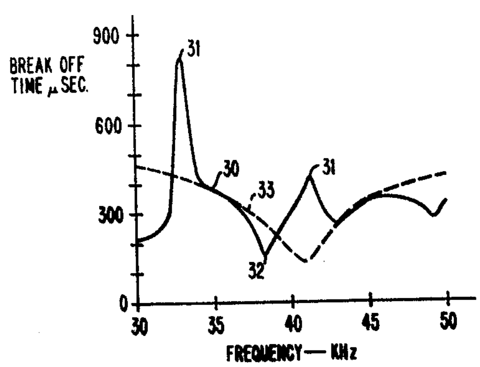

FIG. 4