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(54) **A CIRCUIT AND METHOD FOR DETECTING AND CONTROLLING VISCO-ELASTICITY CHANGES IN AN INKJET PRINT HEAD**

(57) The present invention relates to a method of operating a droplet ejection device comprising an ejection unit arranged to eject droplets of a liquid and comprising a nozzle formed in a nozzle face, a liquid duct connected to the nozzle, and an electromechanical transducer arranged to create an acoustic pressure wave in the liquid in the duct, wherein a step of detecting visco-elastic liquid in the duct by analyzing in the frequency domain a signal S, of acoustic pressure fluctuations decaying in the duct after the ejection of a droplet obtained from the transducer. The invention further relates to a droplet ejection device, a printing system and a software product suited for or capable of performing said method.

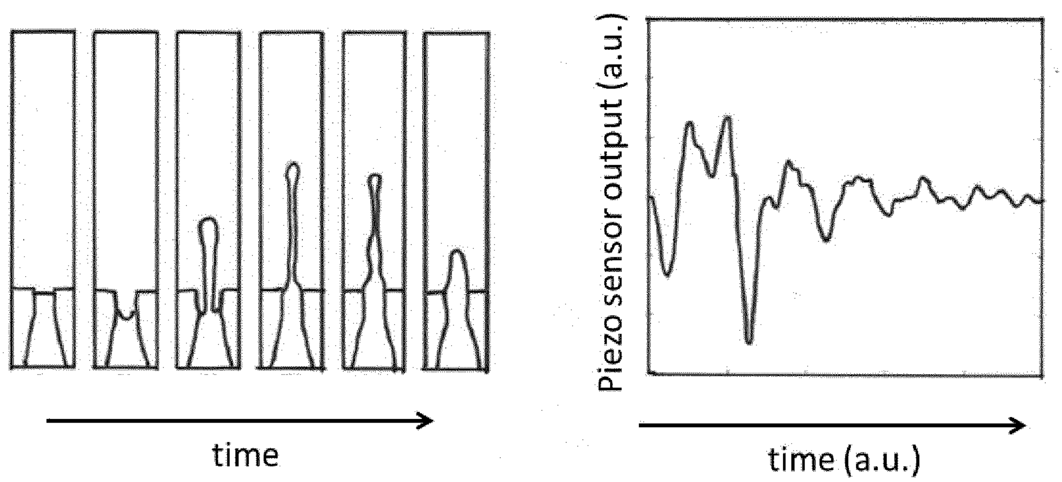

FIG. 2b

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

[0001] The present invention generally pertains to detecting disturbances in a pressure chamber or nozzle of an inkjet print head, in particular a piezo-actuated inkjet print head.

[0002] More particularly, the invention relates to detecting changes in visco-elasticity when printing with water-based ink.

[0003] Visco-elasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Viscous materials, like water, resist shear flow and strain linearly with time when a stress is applied. Elastic materials, on the other hand, strain when stretched, and immediately return to their original state once the stress is removed. Viscoelastic materials have elements of both of these properties and, as such, exhibit time-dependent strain. In viscoelastic materials, the bonds are gradually disrupted and the force required in order to maintain a constant deformation gradually decreases (usually exponentially) over time. Some examples of viscoelastic materials include amorphous polymers, semi-crystalline polymers, biopolymers, metals at very high temperatures, and bitumen materials.

[0004] When the visco-elasticity of ink being jetted changes, the jetting process is disturbed in a particular manner, impacting droplet quality. As a consequence, a droplet could split in multiple droplets, leading to a negative impact on print quality.

[0005] It is known to use a piezo-actuator for generating a pressure wave in a pressure chamber of an inkjet print head such that a droplet of liquid, usually ink, is expelled through a nozzle, which nozzle is in fluid communication with the pressure chamber. Further, it is known that the piezo-actuator (or an additional piezo-element or a dedicated part of the piezo-actuator) may be used to detect a pressure wave in the pressure chamber. For example, after actuation, a residual pressure wave remains in the pressure chamber and the residual pressure wave may be detected using the piezo-actuator.

[0006] It is known analyzing the residual pressure wave detected using the piezo-actuator in order to detect one of a plurality of disturbances in an inkjet print head, such as presence of an air bubble, the presence of residual ink or condensed water outside the nozzles, etc. It is however not possible to detect changes in the visco-elasticity of the ink being jetted by analyzing said residual pressure wave in the time domain.

[0007] Considering the convenience of being able to detect and counteract the effects of visco-elasticity in the ink to be jetted, it is desired to have a method for detecting visco-elasticity changes by analyzing a residual pressure wave, such that its detrimental effect may be counteracted upon.

SUMMARY OF THE INVENTION

[0008] In an aspect of the present invention, a method of operating a droplet ejection device according to claim 1 is provided. In another aspect of the present invention, a droplet ejection device is provided.

[0009] In an alternative embodiment, the present invention comprises a software product comprising program code on a machine-readable non-transitory medium, the program code, when loaded into a processor of the droplet ejection device of the present invention, causes the processor to perform a method of the present invention.

[0010] In an embodiment, a method of operating a droplet ejection device comprises an ejection unit arranged to eject droplets of a liquid and comprising a nozzle formed in a nozzle face, a liquid duct connected to the nozzle, and an electro-mechanical transducer arranged to create an acoustic pressure wave in the liquid in the duct, characterized by a step of detecting visco-elastic liquid in the duct by analyzing in the frequency domain a signal S, of acoustic pressure fluctuations decaying in the duct after the ejection of a droplet obtained from the transducer.

[0011] Signal S of acoustic pressure fluctuations is detected with the piezo actuator which acts as a sensor and provides an electric signal that corresponds to the residual pressure wave in the ink duct as a function of time. For the method of the present invention, this time domain signal is transformed to the frequency domain and then further analyzed. Standard ways may be used for transforming the signal to the frequency domain, for example Fourier transforms may be used.

[0012] In an embodiment, the step of detecting comprises analyzing in the frequency domain a decay time constant, τ_s, of signal S of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet, which pressure fluctuations cause a response of the transducer (28); and determining a decay time constant difference, $\Delta\tau$, between the decay time constant of signal S of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet, τ_s, and the decay time constant of reference signal S_{ref}, τ_{ref}, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet in a properly functioning reference ejection unit, and determining whether the decay time constant difference, $\Delta\tau$, exceeds a threshold.

[0013] The decay time constant of a main peak of signal S in the frequency domain can be determined by squaring the signal S, thereby reaching a power signal, and determining the frequencies f_L and f_H at which the power is half of the power at the central frequency f_c. Subsequently, a factor Q is calculated, wherein $Q = f_c/(f_H - f_L)$. Finally, the decay time constant, or damping ratio, is determined by D = 1/(2Q). D correlates to τ_s as follows:

$$D = 1/(2^*\pi^*\tau_s^*f_c) \qquad \text{equation 1}$$

wherein:

- D is the damping ratio [-];
- τ_s is the decay time constant of signal S [s];
- f_c is the central frequency of a resonance peak of signal S (in the frequency domain) [Hz]

[0014] In an embodiment, the step of detecting comprises a step of analyzing in the frequency domain an energy, E_s, of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet, which pressure fluctuations cause a response of the transducer (28); and determining an energy difference, ΔE, between the decay time constant of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet and the energy of reference signal S_{ref}, E_{ref}, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet in a properly functioning reference ejection unit, and determining whether the energy difference, ΔE, exceeds a threshold.

[0015] Alternatively, it has been determined that it is equivalent when detecting visco-elasticity analyzing the amplitude of acoustic pressure fluctuations decaying in the duct after the ejection of a droplet to analyzing the energy.

[0016] In an embodiment, the step of detecting comprises a step of analyzing in the frequency domain a frequency, f_s, of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet, which pressure fluctuations cause a response of the transducer (28); and determining a frequency difference, Δf, between the decay time constant of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet and the decay time constant of reference signal S_{ref}, f_{ref}, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet in a properly functioning reference ejection unit, and determining whether the frequency difference, Δf, exceeds a threshold.

[0017] In an embodiment, the method of the present invention comprises that a visco-elastic liquid is detected in the duct when it is determined that the decay time constant difference $\Delta\tau$, the energy difference ΔE, and the frequency difference Δf each exceed their respective thresholds simultaneously.

[0018] In an embodiment, the method of the present invention comprises determining a composite parameter and composite threshold both of which include a factor for each of the decay time constant difference $\Delta\tau$, the energy difference ΔE, and the frequency difference Δf, and determining that visco-elastic liquid is detected in the duct when the composite parameter exceeds the composite threshold.

[0019] For example, a composite parameter may be defined as shown in equation 2

$$y = a^* \Delta\tau + b^* \Delta E + c^* \Delta f \qquad \text{equation 2}$$

wherein:

- y is the composite parameter
- a, b and c are constants
- $\Delta\tau$ is the decay time constant difference as defined above
- ΔE is the energy difference as defined above
- Δf and the frequency difference

[0020] In an embodiment, the method of the present invention comprises performing a maintenance action in the ejection unit when it is determined that visco-elastic liquid is detected in the duct.

[0021] In an embodiment, the present invention comprises a step of adapting one or more parameters of the liquid to be jetted when the analysis in the frequency domain of signal, S, determines the presence of visco-elastic liquid on the nozzle face (24), wherein the one or more parameters of the liquid to be jetted are the amount of viscosity correction component added to the liquid, and the temperature of the liquid to be jetted.

[0022] In an embodiment, the method of the present invention comprises a step of adapting parameters of the acoustic pressure wave created in the liquid in the duct when the analysis in the frequency domain of signal, S, determines the presence of visco-elastic liquid on the nozzle face.

[0023] In an embodiment, the step of adapting parameters of the acoustic pressure wave created in the liquid in the duct comprises adapting a jetting pulse applied to the electro-mechanical transducer arranged to create an acoustic pressure wave in the liquid in the duct.

[0024] In an embodiment, the step of adapting parameters of the acoustic pressure wave created in the liquid in the duct comprises adapting an under pressure created in the liquid in the duct such that the amount of liquid jetted is changed.

[0025] In an embodiment, the method according to the present invention comprises the composite parameter y as defined above and a first composite threshold T_1, a second composite threshold T_2, wherein:

- a first maintenance action is performed when $T_1 < y \leq T_2$
- a second maintenance action is performed when $T_2 < y$

[0026] In a further embodiment, the method comprises a third composite threshold T_3, wherein:

- the second maintenance action is performed when $T_2 < y \leq T_3$
- a third maintenance action is performed when $T_3 < y$.

[0027] In an embodiment the first maintenance action comprises adapting the under pressure created in the liquid in the duct, the second maintenance action comprises adapting the temperature of the liquid in the duct, the third maintenance action comprises adapting the jetting pulse waveform.

[0028] It is to be understood that the actual thresholds as defined above depend on the configuration of the printing system, e.g. the acoustics of the ink duct and the ink present in said ducts. Therefore, for each printing system threshold values need to be determined. Numerical values of ranges for thresholds are therefore system dependent.

[0029] In another aspect, the present invention also comprises a droplet ejection device comprising a number of ejection units arranged to eject droplets of a liquid and each comprising a nozzle formed in a nozzle face, a liquid duct connected to the nozzle, and an electro-mechanical transducer arranged to create an acoustic pressure wave in the liquid in the duct, characterized in that at least one of the number of ejection units is associated with a processor configured to perform any of the methods of the present invention.

[0030] In yet another aspect, the present invention also comprises a software product comprising program code on a machine-readable non-transitory medium, the program code, when loaded into a processor of the droplet ejection device of the present invention, causes the processor to perform any of the methods of the present invention.

[0031] Lastly, in another aspect the present invention comprises a printing system comprising the droplet ejection device of the present invention, and a software product comprising program code on a machine-readable non-transitory medium, the program code, when loaded into a control unit of the printing system according the present invention, causes the control unit to perform the method according to any of the embodiments of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The present invention will become more fully understood from the detailed description given below, and the accompanying drawings which are given by way of illustration only, and are thus not limitative of the present invention, and wherein:

Fig. 1 is a cross-sectional view of mechanical parts of a droplet ejection device according to the invention, together with an electronic circuit for controlling and monitoring the device.

Fig. 2a shows the jetting behavior (left) and a waveform of acoustic pressure fluctuations in the duct after ejection of a droplet (right) of a properly functioning ejection unit of a droplet ejecting device.

Fig. 2b shows the jetting behavior (left) and a waveform of acoustic pressure fluctuations in the duct after ejection of a droplet (right) of an ejection unit of a droplet ejecting device affected by visco-elastic behavior of the liquid to be jetted.

Fig. 3a shows the waveform of acoustic pressure fluctuation in the duct after ejection of a droplet of both a properly functioning ejection unit and an ejection unit affected by visco-elastic behavior.

Fig. 3b shows the waveform in the frequency domain of acoustic pressure fluctuation in the duct after ejection of a droplet of both a properly functioning ejection unit and an ejection unit affected by visco-elastic behavior.

DETAILED DESCRIPTION OF EMBODIMENTS

[0033] The present invention will now be described with reference to the accompanying drawings, wherein the same or similar elements are identified with the same reference numeral.

[0034] A single ejection unit of an ink jet print head is shown in Fig. 1. The print head constitutes an example of a droplet ejection device according to the invention. The device comprises a wafer 10 and a support member 12 that are bonded to opposite sides of a thin flexible membrane 14.

[0035] A recess that forms an ink duct 16 is formed in the face of the wafer 10 that engages the membrane 14, e.g. the bottom face in Fig. 1. The ink duct 16 has an essentially rectangular shape. An end portion on the left side in Fig. 1 is connected to an ink supply line 18 that passes through the wafer 10 in thickness direction of the wafer and serves for supplying liquid ink to the ink duct 16.

[0036] An opposite end of the ink duct 16, on the right side in Fig. 1, is connected, through an opening in the membrane 14, to a chamber 20 that is formed in the support member 12 and opens out into a nozzle 22 that is formed in a nozzle face 24 constituting the bottom face of the support member.

[0037] Adjacent to the membrane 14 and separated from the chamber 20, the support member 12 forms another cavity 26 accommodating a piezoelectric actuator 28 that is bonded to the membrane 14.

[0038] An ink supply system which has not been shown here keeps the pressure of the liquid ink in the ink duct 16 slightly below the atmospheric pressure, so as to prevent the ink from leaking out through the nozzle 22.

[0039] The nozzle face 24 is made of or coated with a material which is wetted by the ink, so that adhesion forces cause a pool 30 of ink to be formed on the nozzle face 24 around the nozzle 22. The pool 30 is delimited on the outward (bottom) side by a meniscus 32a.

[0040] The piezoelectric transducer 28 has electrodes 34 that are connected to an electronic circuit that has been shown in the lower part of Fig. 1. In the example shown, one electrode of the transducer is grounded via a line 36 and a resistor 38. Another electrode of the transducer is connected to an output of an amplifier 40 that is feedback-controlled via a feedback network 42, so that a voltage V applied to the transducer will be proportional to a signal on an input line 44 of the amplifier. The signal on the input line 44 is generated by a D/A-converter 46 that receives a digital input from a local digital controller 48. The controller 48 is connected to a processor 50.

[0041] When an ink droplet is to be expelled from the nozzle 22, the processor 50 sends a command to the controller 48 which outputs a digital signal that causes the D/A-converter 46 and the amplifier 40 to apply an actuation pulse to the transducer 28. This voltage pulse causes the transducer to deform in a bending mode. More specifically, the transducer 28 is caused to flex downward, so that the membrane 14 which is bonded to the transducer 28 will also flex downward, thereby to increase the volume of the ink duct 16. As a consequence, additional ink will be sucked-in via the supply line 18. Then, when the voltage pulse falls off again, the membrane 14 will flex back into the original state, so that a positive acoustic pressure wave is generated in the liquid ink in the duct 16. This pressure wave propagates to the nozzle 22 and causes an ink droplet to be expelled. The pressure wave will then be reflected at the meniscus 32a and will oscillate in the cavity formed between the meniscus and the left end of the duct 16 in Fig. 1. The oscillation will be damped due to the viscosity of the ink. Further, the transducer 28 is energized with a quench pulse which has a polarity opposite to that of the actuation pulse and is timed such that the decaying oscillation will be suppressed further by destructive interference.

[0042] The electrodes 34 of the transducer 28 are also connected to an A/D converter 52 which measures a voltage drop across the transducer and also a voltage drop across the resistor 38 and thereby implicitly the current flowing through the transducer. Corresponding digital signals S are forwarded to the controller 48 which can derive the impedance of the transducer 28 from these signals. The measured electric response (current, voltage, impedance, etc.) is signaled to the processor 50 where the electric response is processed further.

[0043] The ejection in time of a droplet of liquid from a droplet ejection device in the case in which the liquid to be jetted is not visco-elastic is shown in the left part of Fig. 2a. As it can be observed, a droplet of liquid is correctly formed. This phenomenon is particularly clear when comparing the ejection in time of a droplet of liquid in the left part of Fig. 2a with the ejection in time of a droplet of liquid in the left part of Fig. 2b, the latter corresponding to the case in which the liquid to be jetted is visco-elastic.

[0044] In the left part of Fig. 2a the typical stages in the formation of a droplet of liquid can be observed. The first stage, which is depicted in the two first images from left to right in Fig. 2a, is usually referred to as start-up phase. In this start-up phase, a negative pressure wave hits the connection-nozzle interface, causing the surface of the liquid to be sucked into the nozzle. This stage is required in order to build up enough energy for the second stage, usually referred to as drop initiation stage. In this drop initiation stage, the pressure at the connection-nozzle interface becomes positive, causing the free surface to be pushed out of the nozzle. Subsequently, a third different stage begins when the pressure decreases again. The free surface (usually referred to as ligament in this stage) has enough velocity and inertia at this third stage to overcome the surface tension, and to not reverse its direction. As a consequence, the ligament becomes thinner, as can be readily observed in the fourth image from left to right. Finally, a final stage in the droplet formation process is reached, reflected in the last two images from left to right, which is usually referred to as viscous loss in tail resorption. In this last stage, the ligament breaks off and a drop is created travelling with a certain velocity and volume. The liquid in the duct still oscillates slightly, but these residual vibrations are usually damped out by viscous dissipation, and are usually too small to result in an additional drop.

[0045] It can be observed in the left part of Fig. 2b that when the liquid to be jetted has visco-elastic properties a droplet of liquid is not correctly formed, A person skilled in the art would readily understand, when observing simultaneously the ejections in time of a droplet of liquid shown in the left part of Fig. 2a and the left part of Fig. 2b, that the ejection in time of a droplet when the liquid to be jetted has visco-elastic properties shows influences in the shape, and size of the droplets formed, even leading to inability of the droplet ejection unit to eject liquid through its nozzles. It can be observed in the left part of Fig. 2a that the visco-elasticity of liquid affects the ejection of a droplet such that the standard stages described in relation to the left part of Fig. 2a cannot be correctly followed.

[0046] The acoustic pressure fluctuations decaying in the duct of the droplet ejection device after the ejection of a droplet obtained from the transducer of the droplet ejection device in the case in which the liquid to be jetted is not visco-elastic are shown in the right part of Fig. 2a. Accordingly, the acoustic pressure fluctuations decaying in the duct of the droplet ejection device after the ejection of a droplet obtained from the transducer of the droplet ejection device in the case in which the liquid to be jetted has visco-elastic properties are shown in the right part of Fig. 2b. When comparing the acoustic pressure fluctuations shown in in the right part of Fig. 2a with those in the right part of Fig. 2b, it can be readily observed that there are significant similarities between both, and that it is cumbersome to distinguish one waveform from the other. These similarities become even clearer in relation with Fig. 3a below.

[0047] The acoustic pressure fluctuations waveform 31 is shown in Fig. 3a along with the acoustic pressure fluctuations waveform 32. The acoustic pressure fluctuations waveform 31 relates to the acoustic pressure fluctuations decaying in the duct of the droplet ejection device after the ejection of a droplet obtained from the transducer of the droplet ejection device in the case in which the liquid to be jetted is not visco-elastic. On the other hand, acoustic pressure fluctuations waveform 32 relates to the acoustic pressure fluctuations decaying in the duct of the droplet ejection device after the ejection of a droplet obtained from the transducer of the droplet ejection device in the case in which the liquid to be jetted has visco-elastic properties. Fig. 3a allows readily observing that waveform 31 and waveform 32 are perceptibly similar. A person skilled in the art would readily understand that it would be very complicated designing a reliable algorithm capable of accurately distinguishing between waveform 31 and waveform 32 based on their parameters, without incurring in false positives (declaring visco-elastic behavior of the liquid to be jetted when that is not accurate) and false negatives (declaring non visco-elastic behavior of the liquid to be jetted when that is not accurate).

[0048] The acoustic pressure fluctuations waveform 31 and the acoustic pressure fluctuations waveform 32 shown in Fig. 3a are transformed to the frequency domain by using a Fast Fourier Transform. A person skilled in the art would readily contemplate any other operator to transform a signal in the time domain to the frequency domain.

[0049] Fig. 3b shows the acoustic pressure fluctuations waveform 31 and the acoustic pressure fluctuations waveform 32 once they have been transformed to the frequency domain, which has as a result acoustic pressure fluctuations waveform 41 and acoustic pressure fluctuations waveform 42. Accordingly, acoustic pressure fluctuations waveform 41 relates to the acoustic pressure fluctuations decaying in the duct of the droplet ejection device after the ejection of a droplet obtained from the transducer of the droplet ejection device in the case in which the liquid to be jetted is not visco-elastic. On the other hand, acoustic pressure fluctuations waveform 42 relates to the acoustic pressure fluctuations decaying in the duct of the droplet ejection device after the ejection of a droplet obtained from the transducer of the droplet ejection device in the case in which the liquid to be jetted has visco-elastic properties. It can be readily observed that the differences shown in the time domain between acoustic pressure fluctuations waveform 31 and acoustic pressure fluctuations waveform 32 have been exacerbated by the transformation to the frequency domain. In this way, it becomes feasible designing an algorithm capable of distinguishing acoustic pressure fluctuations waveform 41 from acoustic pressure fluctuations waveform 42 based on their parameters. An analysis of the parameters of acoustic pressure fluctuations waveform 41 and acoustic pressure fluctuations waveform 42 is better understood in relation with Table 1.

Table 1. Main parameters measured in an ejection unit with non-viscoelastic (nominal) and visco-elastic liquid.

	Nominal	Viscoelastic	% Change
Frequency	129.31	121.98	-5.6%
Amplitude	35.3	28.8	-18.4%
Energy	525.6	447.9	-14.7%
Damping	0.0116	0.0210	+81%

[0050] Table 1 shows the parameters measured from acoustic pressure fluctuations waveform 41 and acoustic pressure fluctuations waveform 42. The parameters relating to acoustic pressure fluctuations waveform 41 are shown in the left part of Table 1 in the column Nominal. At the same time, the parameters relating to acoustic pressure fluctuations waveform 42 are shown in the left part of Table 1 in the column Viscoelastic. Further, Table 1 relates to an analysis of the parameters of the main peak of the acoustic pressure fluctuations waveforms 41 and 42. An analysis of the parameters shown in the upper part of Table 1 allows inferring approximate thresholds related to frequency, energy, and damping, which allow detecting the presence of visco-elastic liquid.

[0051] It can be observed in Table 1 that the frequency of the main peak has diminished a 5.6% from the correctly functioning reference to the visco-elastic case. A reasonable threshold may be set in a 5% reduction. Alternatively, a lower threshold may be set, as for example 3%, that even though does not allow completely confirming the presence of visco-elastic liquid may be used to trigger a maintenance action, as it is to be considered an indication that visco-elastic behavior is beginning to appear in the liquid to be jetted.

[0052] It can also be observed in Table 1 that the damping of the main peak has abruptly grown 81% from the correctly functioning reference to the visco-elastic case. A reasonable threshold may be set in a 50% or 70% growth. Alternatively, a lower threshold may be set, as for example 30% or 40%, that even though does not allow completely confirming the presence of visco-elastic liquid may be used to trigger a maintenance action, as it is to be considered an indication that visco-elastic behavior is beginning to appear in the liquid to be jetted.

[0053] It is to be understood the above example represents a specific configuration of the printing system with acoustics of the ink duct and the ink present in said ducts that are specific for said printing system. Therefore, for the indicated threshold values are specifically determined for the exemplified printing system. In another printing system, the thresholds for the same parameters may be quite different and even outside the presently determined range.

[0054] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A method of operating a droplet ejection device comprising an ejection unit arranged to eject droplets of a liquid and comprising a nozzle (22) formed in a nozzle face (24), a liquid duct (16) connected to the nozzle (22), and an electro-mechanical transducer (28) arranged to create an acoustic pressure wave in the liquid in the duct (16), **characterized by** a step of detecting visco-elastic liquid in the duct (16) by analyzing in the frequency domain a signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet obtained from the transducer (28).

2. The method according to claim 1, wherein the step of detecting comprises analyzing in the frequency domain a decay time constant, τ_s, of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet, which pressure fluctuations cause a response of the transducer (28); and determining a decay time constant difference $\Delta\tau$, between the decay time constant of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet and the decay time constant of a reference signal S_{ref}, τ_{ref}, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet in a properly functioning reference ejection unit, and determining whether the decay time constant difference, $\Delta\tau$, exceeds a threshold.

3. The method according to claim 1 or 2, wherein the step of detecting comprises analyzing in the frequency domain an energy, E_s, of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet, which pressure fluctuations cause a response of the transducer (28); and determining an energy difference, ΔE, between the decay time constant of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet and the energy of the reference signal S_{ref}, E_{ref}, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet in a properly functioning reference ejection unit, and determining whether the energy difference, ΔE, exceeds a threshold..

4. The method according to any one of the preceding claims, wherein the step of detecting comprises analyzing in the frequency domain a frequency, f_s, of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet, which pressure fluctuations cause a response of the transducer (28); and determining a frequency difference, Δf, between the decay time constant of signal S, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet and the decay time constant of the reference signal S_{ref}, f_{ref}, of acoustic pressure fluctuations decaying in the duct (16) after the ejection of a droplet in a properly functioning reference ejection unit, and determining whether the frequency difference, Δf, exceeds a threshold..

5. The method according to any one of the preceding claims, wherein visco-elastic liquid is detected in the duct when it is determined that the decay time constant difference $\Delta\tau$, the energy difference ΔE, and the frequency difference Δf each exceed their respective thresholds simultaneously.

6. The method according to any one of claims 1 to 4, further comprising determining a composite parameter and a composite threshold both of which include for each of the decay time constant difference $\Delta\tau$, the energy difference ΔE, and the frequency difference ΔE, and determining that visco-elastic liquid is detected in the duct when the composite parameter exceeds the composite threshold.

7. The method according to any one of the preceding claims, further comprising performing a maintenance action in the ejection unit when it is determined that visco-elastic liquid is detected in the duct.

8. The method according to any of the preceding claims, further comprising a step of adapting one or more parameters of the liquid to be jetted when the analysis in the frequency domain of signal, S, determines the presence of visco-elastic liquid on the nozzle face (24), wherein the one or more parameters of the liquid to be jetted are the amount of viscosity correction component added to the liquid, and the temperature of the liquid to be jetted.

9. The method according to any of the preceding claims, further comprising a step of adapting parameters of the acoustic pressure wave created in the liquid in the duct when the analysis in the frequency domain of signal S, determines the presence of visco-elastic liquid on the nozzle face (24).

10. The method according to claim 9, wherein the step of adapting parameters of the acoustic pressure wave created in the liquid in the duct comprises adapting a jetting pulse applied to the electro-mechanical transducer (28) arranged to create an acoustic pressure wave in the liquid in the duct (16).

11. The method according to claim 9, wherein the step of adapting parameters of the acoustic pressure wave created in the liquid in the duct comprises adapting an under pressure created in the liquid in the duct (16) such that the amount of liquid jetted is changed.

12. A droplet ejection device comprising a number of ejection units arranged to eject droplets of a liquid and each comprising a nozzle (22) formed in a nozzle face (24), a liquid duct (16) connected to the nozzle (22), and an electro-mechanical transducer (28) arranged to create an acoustic pressure wave in the liquid in the duct (16), **characterized in that** at least one of the number of ejection units is associated with a processor configured to perform any of the methods according to claims 1 to 11.

13. A printing system comprising the droplet ejection device according to claim 12 as an ink jet print head, and a control unit.

14. A software product comprising program code on a machine-readable non-transitory medium, the program code, when loaded into a control unit of device printing system according to claim 13, causes the control unit to perform the method according to any of the claims 1 to 11.

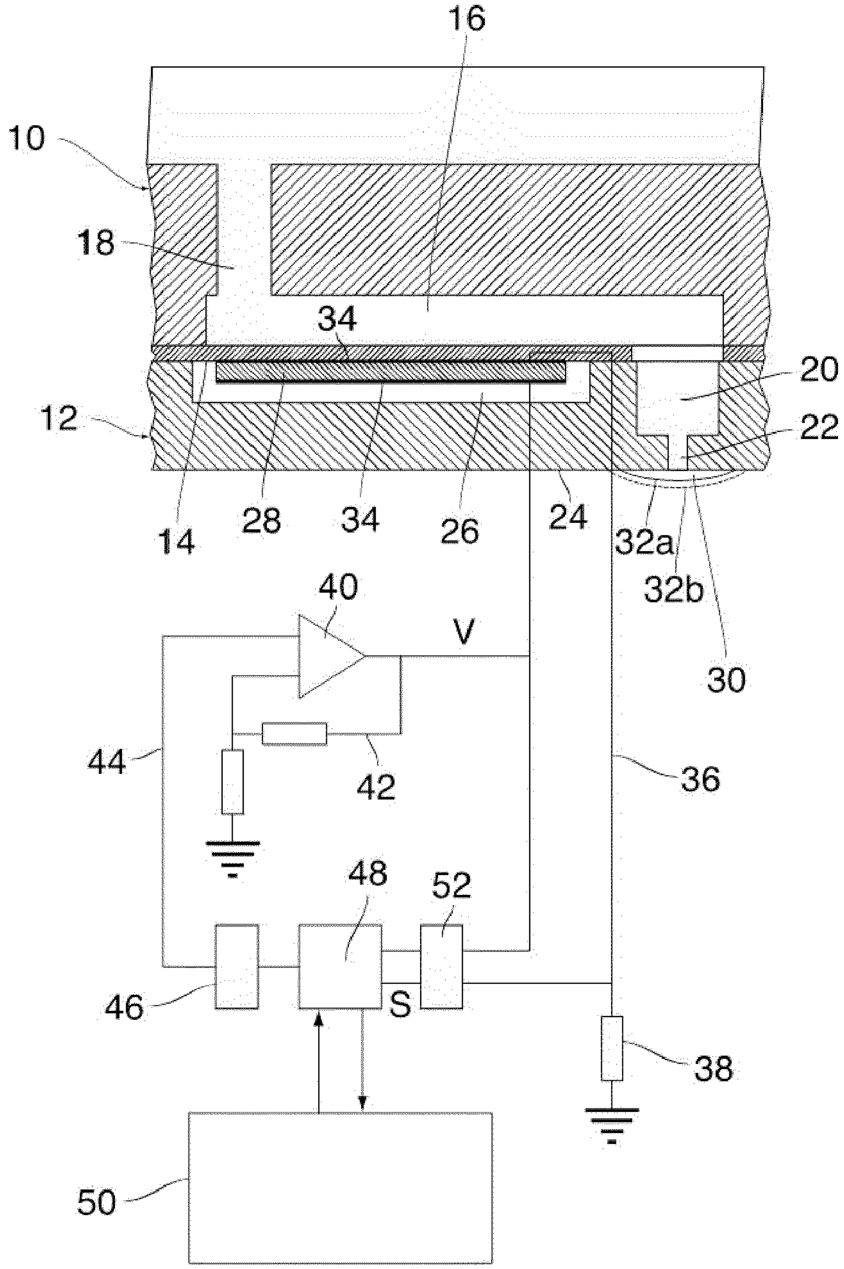
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FIG. 1

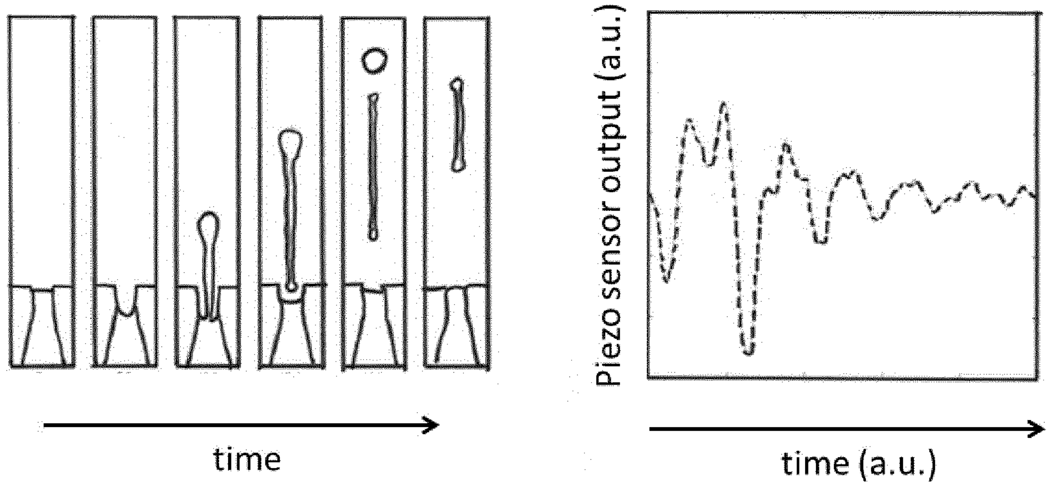
time
Piezo sensor output (a.u.)
time (a.u.)

FIG. 2a

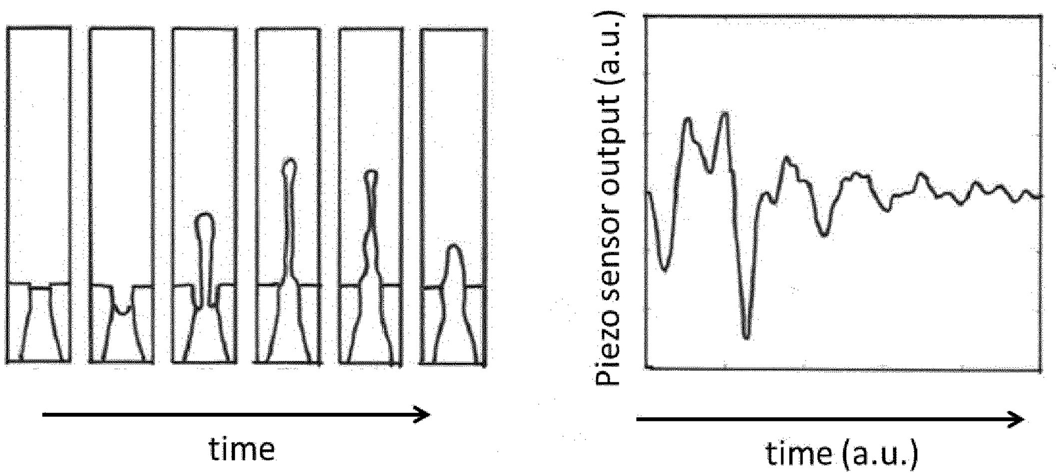
time
Piezo sensor output (a.u.)
time (a.u.)

FIG. 2b

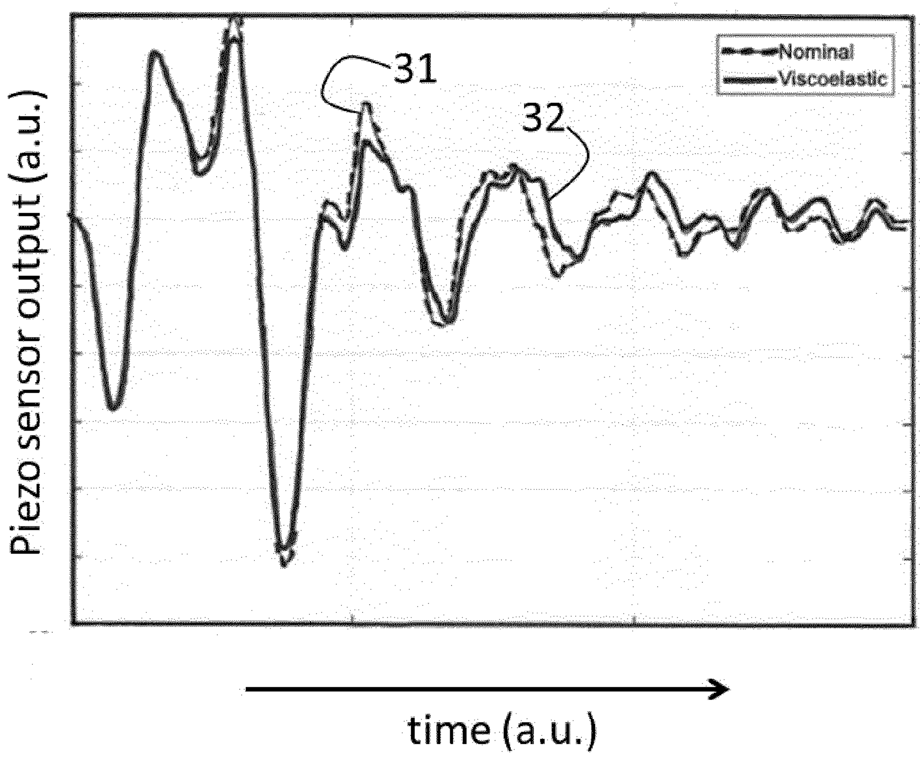
Nominal
Viscoelastic
31
32
Piezo sensor output (a.u.)
time (a.u.)

FIG. 3a

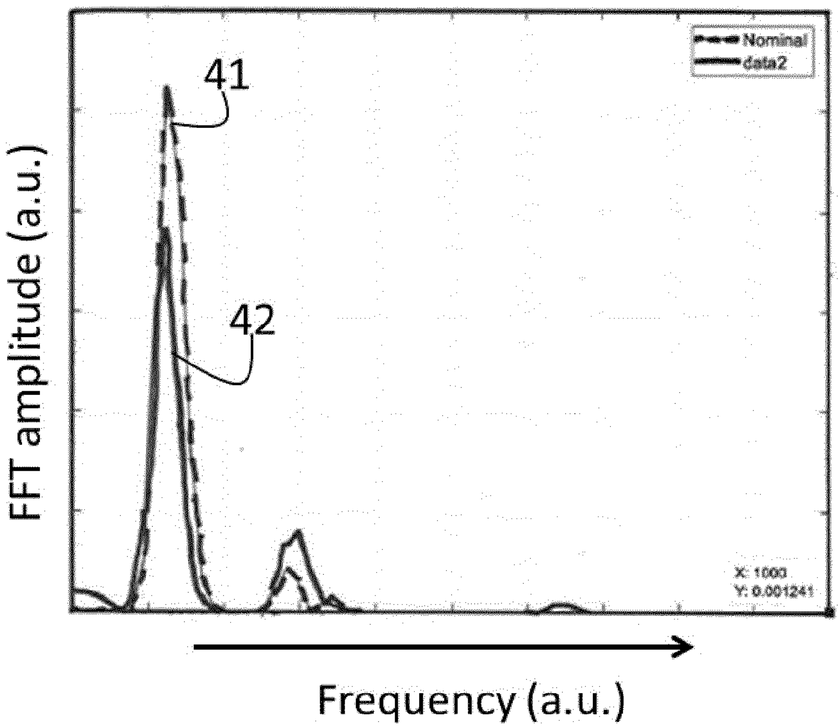
Nominal
data2
41
42
X: 1000
Y: 0.001241
FFT amplitude (a.u.)
Frequency (a.u.)

FIG. 3b

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EUROPEAN SEARCH REPORT

Application Number
EP 18 21 3111

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