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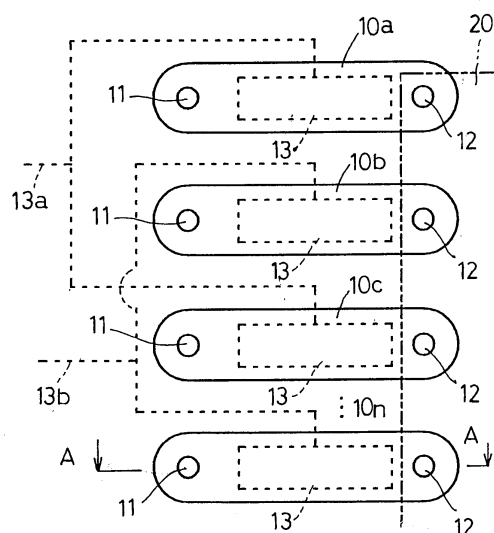
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(54) **Method for driving liquid drop spraying apparatus**

(57) In an apparatus for spraying liquid drops, two pressure chambers (10n and 10n-1) having the adjacent nozzle holes (11a), respectively start pressurization from time T1, end pressurization at time T2, and hold its state until T3. Then, pressure reducing is started from time T3, and pressure reducing is ended at time T4, and the cycle for the next pressurization is repeated. In a duration from a time T3 when one pressure chamber (10n) starts pressure reducing to time T5 when the next pressurization is started, time T1 (-1) for starting pressurization of the other pressure chamber (10n-1) is set. In this manner, the flow from one liquid introducing hole (12) back to the common flow path (20) can be reduced when the other introducing hole is subjected to such back flow. When the back flow caused by the other pressure chamber (10n-1) starting pressurization reaches the introducing hole (12) of one of the adjacent pressure chambers 10n, one pressure chamber 10n enters a state in which pressure reducing is started. Liquid inflow due to pressurization is performed smoothly, charging can be completed within a short period of time, and the time per cycle is reduced, whereby a large amount of spraying can be performed.

FIG. 1



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a method for driving liquid drop spraying or ejecting apparatus, which is used for example in a raw material or fuel discharging device used in a variety of applications, the discharging device treating a liquid or operating by discharging a liquid raw material or fuel.

Description of Prior Art

[0002] In a conventional liquid drop spraying apparatus, a plurality of pressure chambers were connected to an identical flow path via an introducing hole provided in each of the pressure chambers, and liquid drops were discharged from a discharge opening with a volume change of the pressure chamber, thereby performing spraying. The liquid supplied to a plurality of pressure chambers with respect to one flow path was accumulated through the introducing hole formed in each pressure chamber, liquid drops were discharged from a nozzle hole connected to the other of the respective pressure chambers with a volume change of the pressure chamber, and the entirety enters the sprayed state. In particular, a liquid drops spraying apparatus in which piezoelectric / electrostrictive elements are formed at part of the wall of the pressure chamber, and a pressure change is generated at the element with a voltage signal applied to the element was superior in liquid drops sprayed state. In the case where a large amount of liquid was discharged by use of a raw material/fuel discharging device, a plurality of pressure chambers of the liquid drops spraying apparatus were increased or the discharge cycle was decreased.

[0003] In a liquid drops spraying apparatus in which a number of pressure chambers are provided in order to increase a discharge quantity, a large amount of the liquid pressurized by the piezoelectric / electrostrictive elements for the sake of spraying causes back flow from an introducing hole to a flow path. Thus, in the case where the liquid is supplied from the introducing hole immediately after discharge, there has occurred a phenomenon that air bubbles inflow the pressure chamber through the nozzle hole without smooth liquid supplement from the introducing hole. In addition, there has been a problem that the pressure reducing velocity of the pressure chamber is delayed in order to prevent inflow of air bubbles, and a discharge period must be reset so as to be extended, whereby the discharge quantity cannot be increased.

SUMMARY OF THE INVENTION

[0004] According to a first aspect of the present inven-

tion, there is provided the following. That is, in a liquid drops spraying apparatus in which a plurality of pressure chambers are connected to an identical flow path via an introducing hole provided in each of these pressure chambers, and liquid drops are discharged from a discharge opening by means of a volume change of the pressure chambers, thereby performing spraying, a method for driving the apparatus is characterized in that the pressure chambers are divided into at least two or more groups, and drive timings for causing the volume change between these groups are set so as to be different from each other. Here, a drive timing denotes a time when the volume of the pressure chamber starts its change. In this manner, the pressure chambers each produce a volume change by each group, and the quantity of liquid that flows from the introducing hole back to the flow path and fluctuation in the liquid pressure can be reduced. The pressure chambers may be divided into two classes according to a time when pressurization starts, and can be divided into three or more classes by shifting them sequentially and providing a time difference.

[0005] In particular, according to a second aspect of the present invention, there is provided a method for dividing a liquid drops spraying apparatus in which piezoelectric / electrostrictive elements are provided at a part of the wall of the pressure chamber so that a time of command for applying a voltage signal to the piezoelectric / electrostrictive elements by each of the groups is different from another. In this manner, the voltage signal applied to the piezoelectric / electrostrictive elements is controlled at a short period, whereby the spraying quantity can be increased.

[0006] In addition, according to a third aspect of the present invention, there is provided a method for driving a liquid drops spraying apparatus in which two pressure chambers having the adjacent discharge openings are divided into another group. The adjacent pressure chambers are most likely to be affected by the flow from each introducing hole back to the flow path. Thus, an advantageous effect of differentiating the drive timing is significantly attained. On the other hand, there is provided an advantage that the back flow from one of the adjacent pressure chambers is utilized, whereby the liquid can be supplied smoothly to the other pressure chamber. The wires for applying voltage signals to the piezoelectric / electrostrictive elements of the pressure chamber may be provided alternately. In addition, individual wiring is provided to a control unit, whereby a timing of applying a voltage signal from the control unit can be controlled. In particular, in the latter case, the timing of applying the signal can be set via wiring or flexibly.

[0007] Further, according to a fourth aspect of the present invention, there is provided the following. That is, in a liquid drops spraying apparatus in which a plurality of pressure chambers are connected to an identical flow path via the introducing hole provided in each of these pressure chambers, and liquid drops are dis-

charged from the discharge opening by means of a volume change of these pressure chambers by pressure reduced after the pressure chamber has been pressurized, a method for driving liquid drops spraying apparatus is characterized in that, in a duration from a time when pressure reducing of one pressure chamber starts to a time when the next pressurization starts, the pressurization of the other pressure chamber is started. In this manner, the flow from the introducing hole back to the flow path can be prevented, and the back flow generated in one of the adjacent pressure chambers is utilized, whereby the liquid can be supplied smoothly to the other chamber.

[0008] In particular, according to a fifth aspect of the present invention, there is provided a method for driving a liquid drops spraying apparatus in which, when pressure reducing of one pressure chamber starts in a duration from a time when pressure reducing of said one pressure chamber to a time when the next pressurization of that pressure chamber starts, the pressurization of the other pressure chamber is started.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] For a better understanding of the present invention, reference is made to the following detailed description of the invention, taken in conjunction with the following drawings in which:

FIG. 1 is an illustrative view illustrating a face on which the discharge openings of the liquid drops spraying apparatus are arranged;
 FIG. 2 is a sectional view taken along line A-A of Fig. 1;
 FIG. 3 is an illustrative view illustrating a timing of applying voltage signals to the piezoelectric / electrostrictive elements; and
 FIG. 4 is an illustrative view illustrating another timing of applying voltage signals to the piezoelectric / electrostrictive strain elements.

PREFERRED EMBODIMENTS OF THE INVENTION

[0010] Hereinafter, one mode for carrying out a method for driving a liquid drops spraying apparatus according to the present invention will be described in detail.

[0011] Fig. 1 is an illustrative view illustrating a face on which a discharge opening 11 of a liquid drops spraying apparatus 1 is arranged. At one end, pressure chambers 10a, 10b,... 10n-1, 10n having an outwardly opening discharge opening 11 provided therein are arranged in order. An introducing hole 12 is provided to be inserted into the other end of a face opposite to the face on which the discharge opening 11 of each pressure chamber 10n is provided, and a number of pieces of pressure chambers are connected to the identical flow path 20 via the introducing hole 12. The flow path 20 can be provided to a liquid supply source in one or more multiple

arrays. In addition, in the pressure chamber 20, the piezoelectric / electrostrictive elements 13 are provided at part of its wall, and each of the piezoelectric / electrostrictive elements 13 laminates upper electrode (not shown) and each piezoelectric / electrostrictive layer and a lower electrode (not shown). At least one of the upper and lower electrodes laminated on each of the piezoelectric / electrostrictive elements 13 is coupled via wires 13a and 13b adjacently connected to the control unit alternately.

[0012] Fig. 2 is a cross section taken in line A-A of Fig. 1. The introducing hole 12 connected to each pressure chamber 10n is provided at the flow path 20 common to a plurality of pressure chambers 10n. The piezoelectric / electrostrictive elements 13 are provided at part of the upper wall of the pressure chamber 10n. A discharge opening 11 for outwardly discharging a liquid is punched at the tip end of the lower face, and a nozzle hole 11a is formed at its tip end. Fig. 1 is a view showing a direction indicated by the arrow B.

[0013] A predetermined voltage signal is applied to the upper and lower electrodes laminated on the piezoelectric / electrostrictive elements 13, whereby a piezoelectric / electric strain layer is deformed with a change in electric field generated between the upper and lower electrodes. By means of the pressurization force generated in the pressure chamber 10n by deforming the wall of the fixed pressure chamber 10n, the liquid supplied to the pressure chamber 10n is discharged as liquid drops from the discharge opening 11, and the liquid drops are sprayed in a sprayed state by means of a plurality of discharge openings and a plurality of flow paths 20.

[0014] Fig. 3 is an illustrative view illustrating a timing of applying voltage signals to the piezoelectric / electrostrictive elements 13. In the figure, there is shown how a signal is applied in the case where a wall face having the piezoelectric / electrostrictive elements fixed thereto is deformed in a direction in which the volume reduction (pressurization) of the pressure chamber takes place when a voltage is applied, i.e., when an electric field is applied. According to the fixing method or the shape of the wall face, the volume reduction (pressurization) of the pressure chamber may be generated, when a voltage is released. In this case, the direction of voltage application or release is reversed. In the case of Fig. 3, two pressure chambers 10n and 10n-1 each having the adjacent nozzle holes 11a hold a state when pressurization is started from time T1, and is ended at time T2, and holds on its state until time T3 has come. Pressure reducing is started from time T3, pressure reducing is ended until time T4 has come, and a time ready for the next pressurization has come. This cycle is repeated. At this time, in a duration from time T3 when one pressure chamber 10n starts pressure reducing to time T5 when the next pressurization is started, time T1 (-1) for starting pressurization of the other pressure chamber 10n-1 is set. In this manner, the flow from one

introducing hole back to the flow path can be reduced when such flow is subjected to the other introducing hole. When one pressure chamber 10n performs pressure reducing, the other adjacent pressure chamber 10n-1 starts pressurization by using the same flow path 20. The back flow caused by pressurization reaches the introducing hole 12 of one pressure chamber 10n through the flow path 20, the liquid inflows smoothly, charging can be completed within a short period of time, and a large amount of spraying can be performed while the time per cycle is reduced. In particular, at the same time as time T3 when one pressure chamber 10n starts pressure reducing, time T1 for starting pressurization of the other pressure chamber 10n-1 is set, whereby the back flow pressure coming up to the fluid momentarily can be efficiently used for liquid movement at an earlier stage of pressure reducing.

[0015] In addition, in Fig. 3, although a signal application timing is differentiated from another between the adjacent pressure chambers, the timing may be differentiated between pressure chambers which are not adjacent to each other. Further, in the case where a large number of pressure chambers are connected to the flow path, groups for differentiating the timing may be divided into three or more sections. In that case, at the pressurization start time of each group, as shown in Fig. 4, times T1 (1) and T1 (2) for starting the next pressurization may be provided in a driving cycle with equal intervals.

[0016] As has been described above, according to the first aspect of the present invention, there is provided a method for driving a liquid drops spraying apparatus in which the pressure chambers of the liquid drops spraying apparatus are divided into at least two or more groups, and drive timings for generating the volume change between these groups are set so as to be different from each other. Thus, unlike the conventional method, all of the pressure chambers do not cause a volume change simultaneously, and a change in liquid quantity and liquid pressure during liquid flowing from the introducing hole back to the flow path can be reduced.

[0017] In addition, according to the second aspect of the present invention, piezoelectric / electrostrictive elements are provided at part of the wall of the pressure chamber so that a time of command for applying a voltage signal to the piezoelectric / electrostrictive element by each of the groups is differentiated from another. Thus, the voltage signals to be applied to the piezoelectric / electrostrictive elements are controlled within a short cycle, whereby the discharge count per unit time can be increased, and the spraying quantity can be increased.

[0018] According to the third aspect of the present invention, the groups of the pressure chambers having the adjacent discharge openings are divided into two groups. Thus, the back flow from one of the adjacent pressure chambers is utilized, whereby the liquid can be supplied smoothly to the other pressure chamber.

[0019] Further, according to the fourth aspect of the present invention, there is provided a liquid drops spraying apparatus for discharging liquid drops from the discharge opening by means of a volume change of these pressure chambers by pressure reduced after the pressure chamber has been pressurized, thereby performed spraying, in which in a duration from a time when pressure reducing of one pressure chamber starts to a time when the next pressurization of the pressure chamber is started. Thus, the back flow caused by the pressurization of one of the adjacent pressure chambers is utilized, whereby the liquid can be supplied smoothly to the other chamber.

[0020] In particular, according to the fifth aspect of the present invention, when pressure reducing of one pressure chamber starts in a duration from a time when pressure reducing of said one pressure chamber to a time when the next pressurization of that pressure chamber starts, the pressurization of the other pressure chamber is started. Thus, a back flow pressure can be efficiently utilized.

[0021] The invention also provides liquid drop spraying or ejecting apparatus having control means arranged to carry out the methods herein described.

Claims

1. A method of driving a liquid drop spraying apparatus in which a plurality of pressure chambers are connected to one flow path via an introducing hole provided in each of the pressure chambers, and liquid drops are discharged from a discharge opening by means of a volume change of the pressure chamber, thereby performing spraying, comprising the steps of: dividing the pressure chambers into at least two or more groups, and setting drive timings for causing the volume change between these groups so as to be different from each other.
2. A method as claimed in claim 1, wherein a piezoelectric / electrostrictive element is provided at part of the wall of said pressure chamber so that the timings of commands for applying a voltage signal to the piezoelectric / electrostrictive elements of said each group are different from each other.
3. A method as claimed in claim 1, wherein the groups of said pressure chambers are divided into two sections in which the discharge openings in one section are contiguous to the discharge openings in another section.
4. A method of driving a liquid drop spraying apparatus in which a plurality of pressure chambers are connected to one flow path via an introducing hole provided in each of the pressure chambers, and liquid

drops are discharged from a discharge opening by means of a volume change of the pressure chamber by pressure reduction after the pressure chambers have been pressurized, thereby performing spraying, comprising the step of, in a duration from a time when pressure reduction of one pressure chamber starts to a time when the next pressurization of that pressure chamber starts, starting the pressurization of another pressure chamber.

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5. A method as claimed in claim 4, wherein, when pressure reducing of one pressure chamber starts in a duration from a time when pressure reducing of said one pressure chamber to a time when the next pressurization of that pressure chamber starts, the pressurization of the other pressure chamber is started.

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FIG. 1

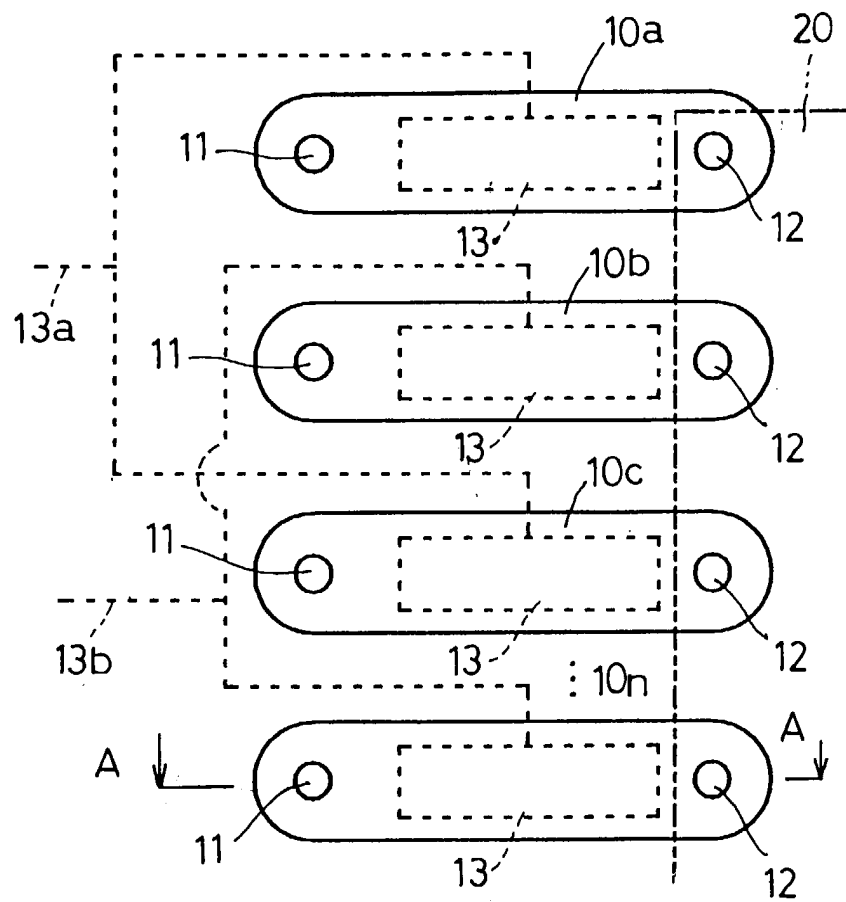
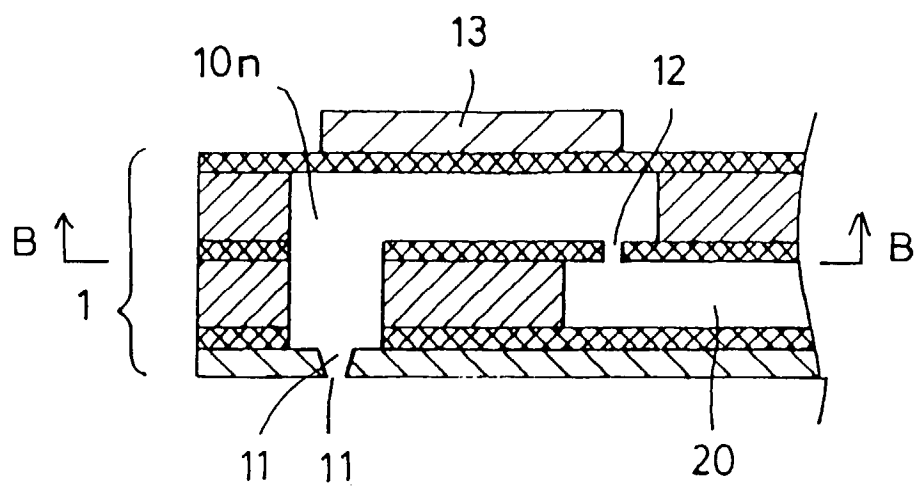


FIG. 2



F I G. 3

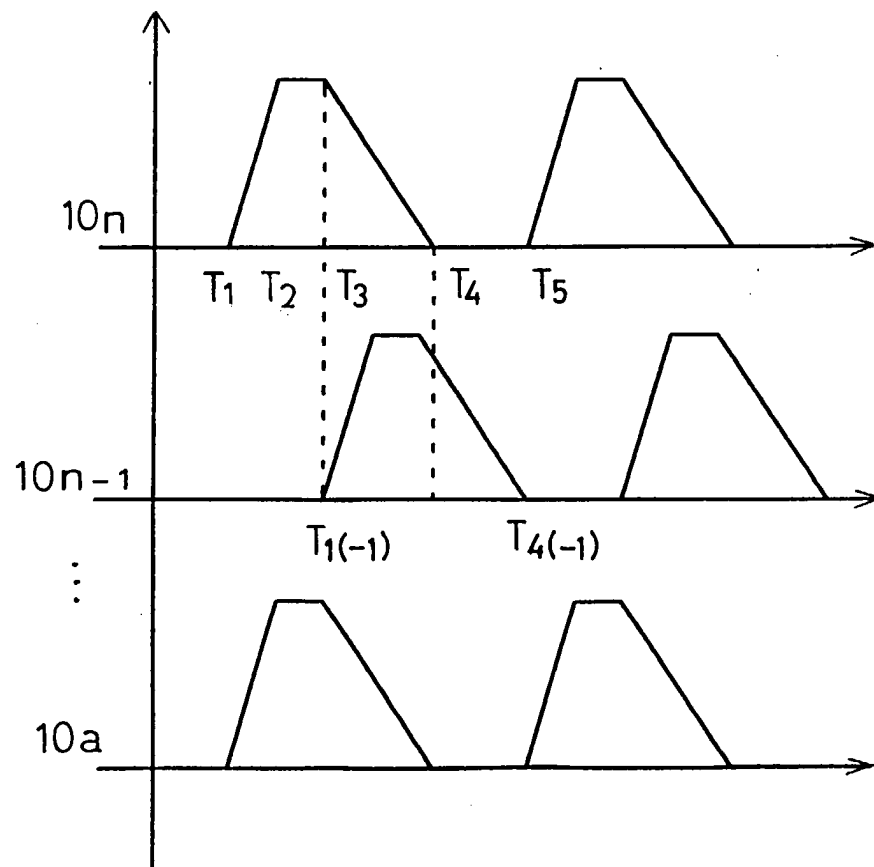


FIG. 4

