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(54) **PULSATION GENERATING MECHANISM, CONNECTING FLOW CHANNEL TUBE, AND FLUID EJECTING APPARATUS**

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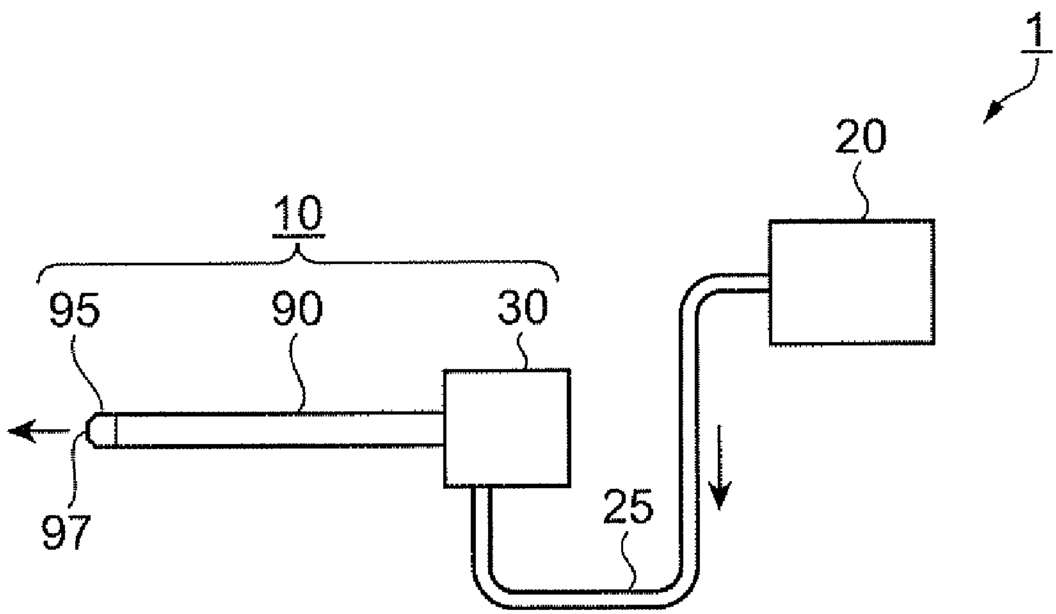
(57) **ABSTRACT**

A fluid ejecting apparatus having a fluid chamber, an inlet flow channel, and a nozzle configured to eject fluid supplied from the inlet flow channel to the fluid chamber from the nozzle in a pulsed manner by changing the volume of the fluid chamber includes: a diaphragm; a wall surface provided so as to oppose the diaphragm; a spacer being provided between the diaphragm and the wall surface and having a cylindrical through hole; a piezoelectric element configured to displace the diaphragm; and a connecting flow channel tube communicated with the fluid chamber, wherein the nozzle is provided at an end of the connecting flow channel tube opposite to the fluid chamber, the fluid chamber is defined by the diaphragm, the wall surface, and an inner surface of the through hole of the spacer, and the inlet flow channel is defined by a groove provided on the wall surface and the spacer and is communicated with the fluid chamber.



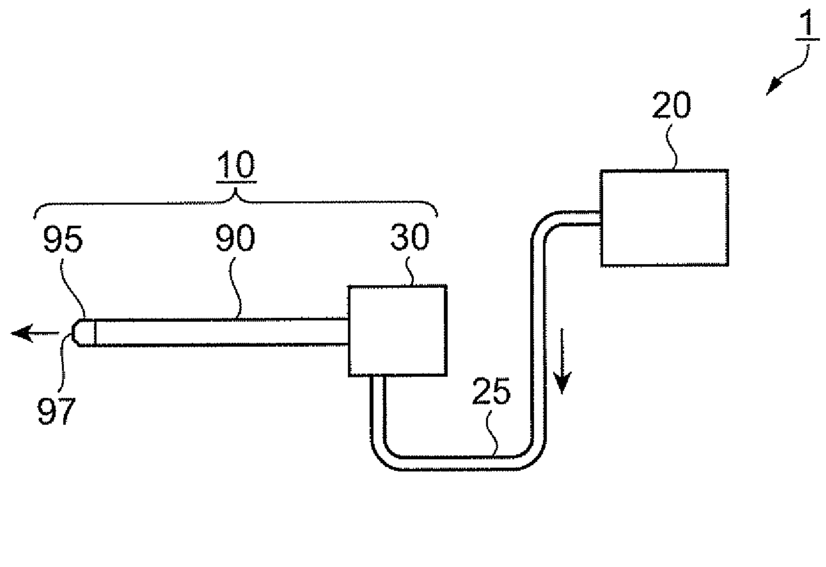

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FIG. 1

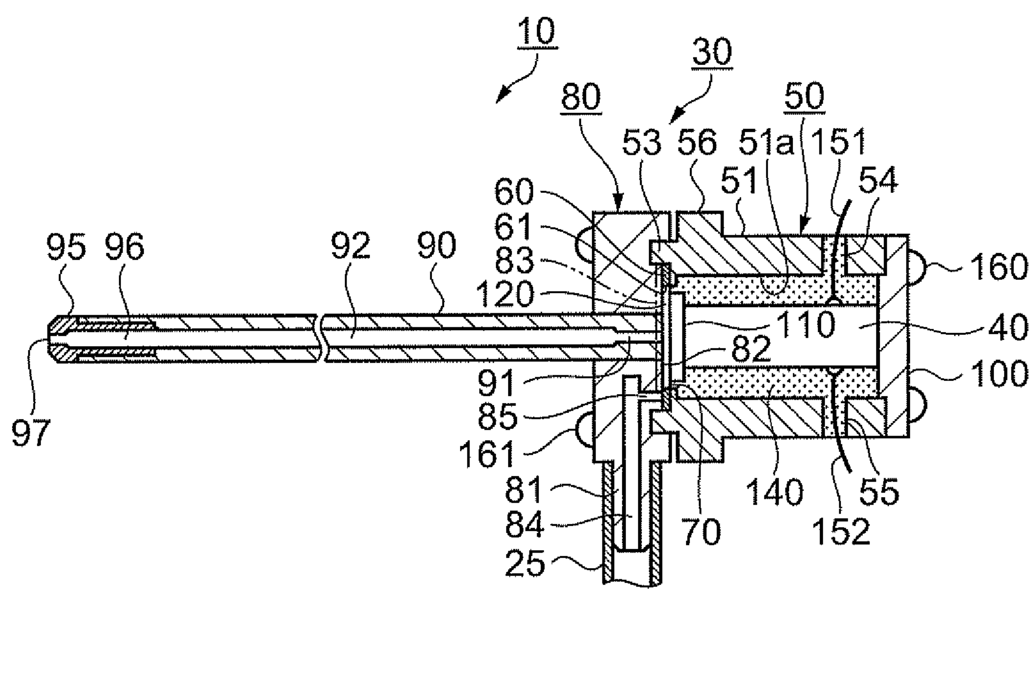
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FIG. 2

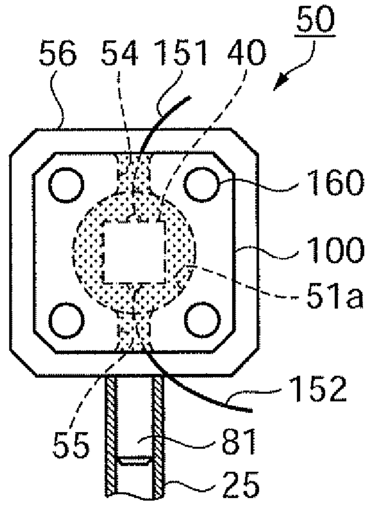


FIG. 3

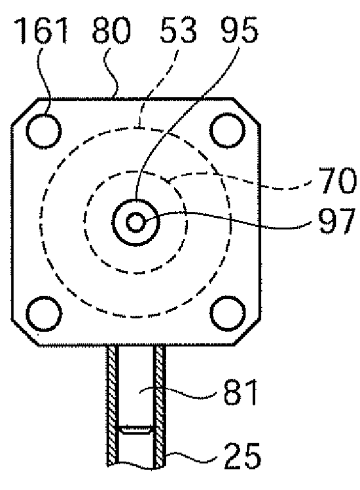
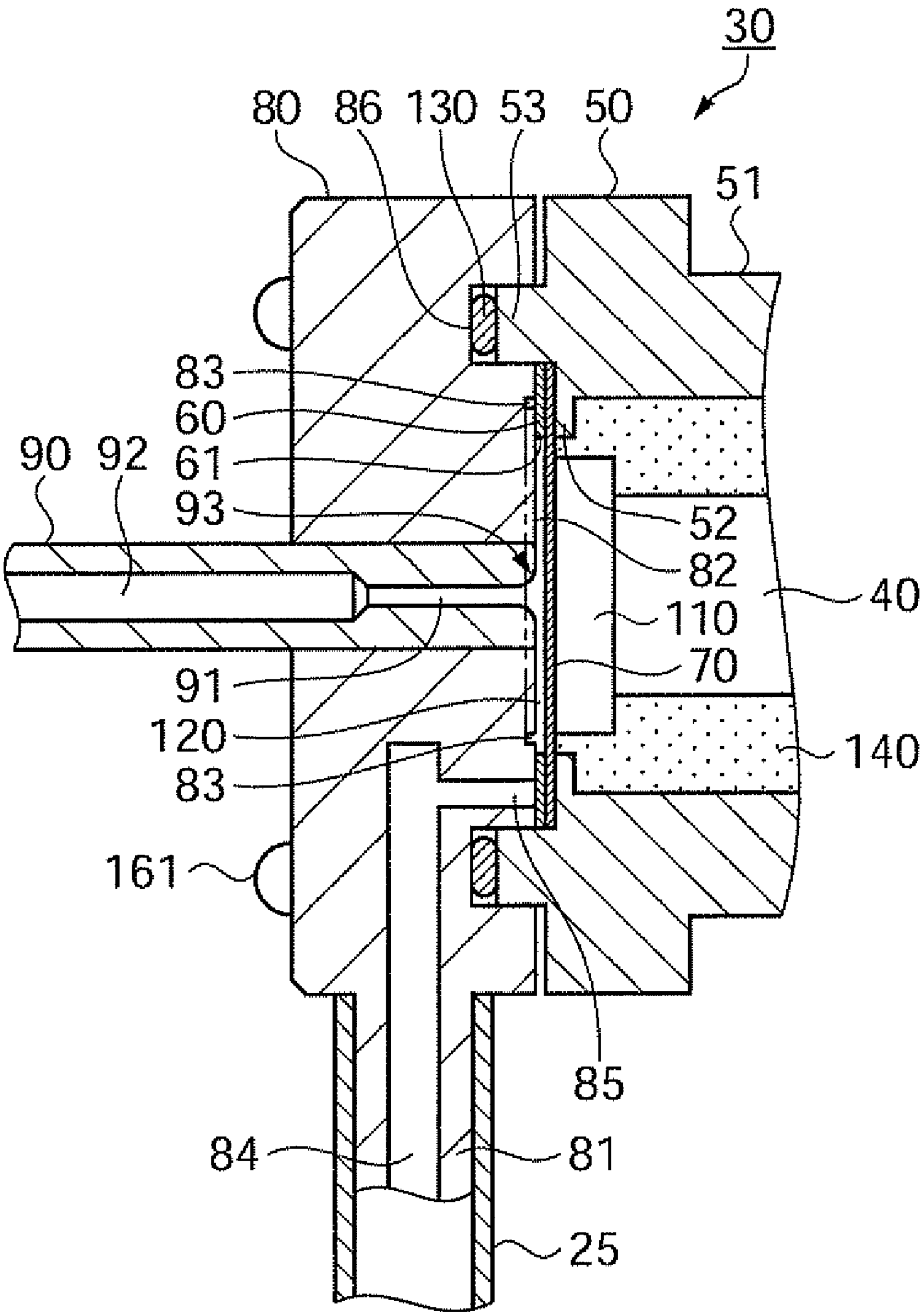


FIG. 4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140
161
85
84
81
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FIG. 5

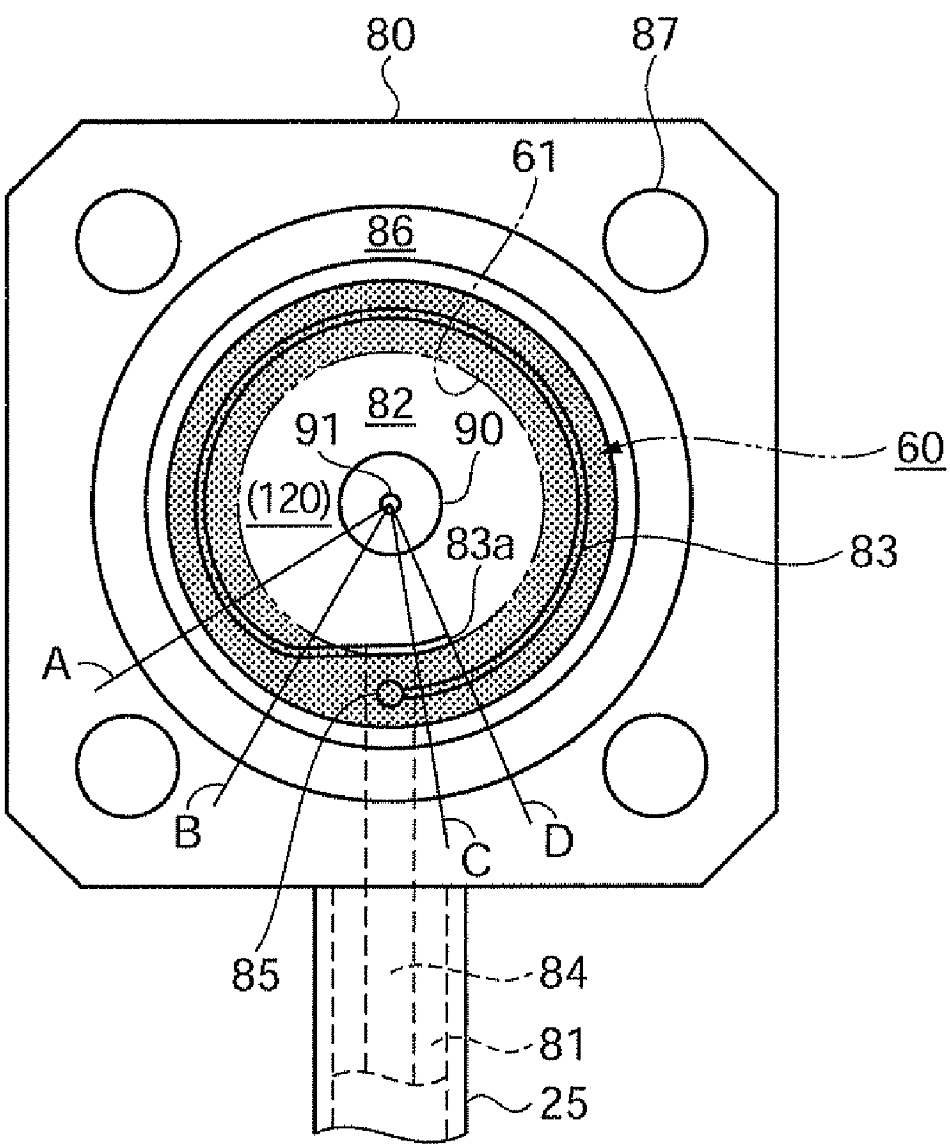

FIG. 6

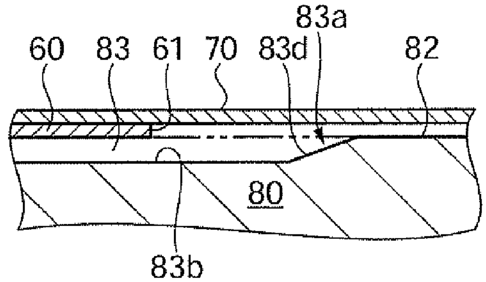

FIG. 7

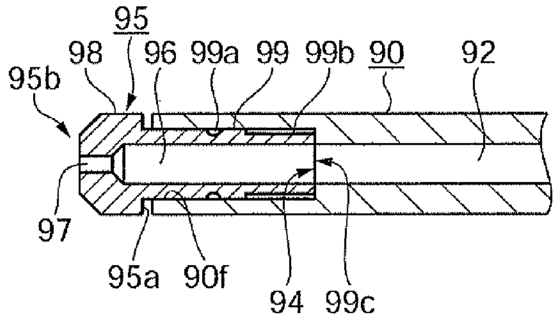

FIG. 8

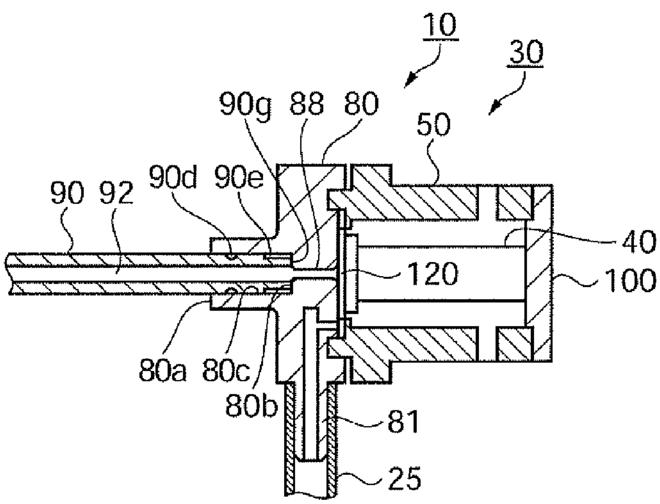

FIG. 9

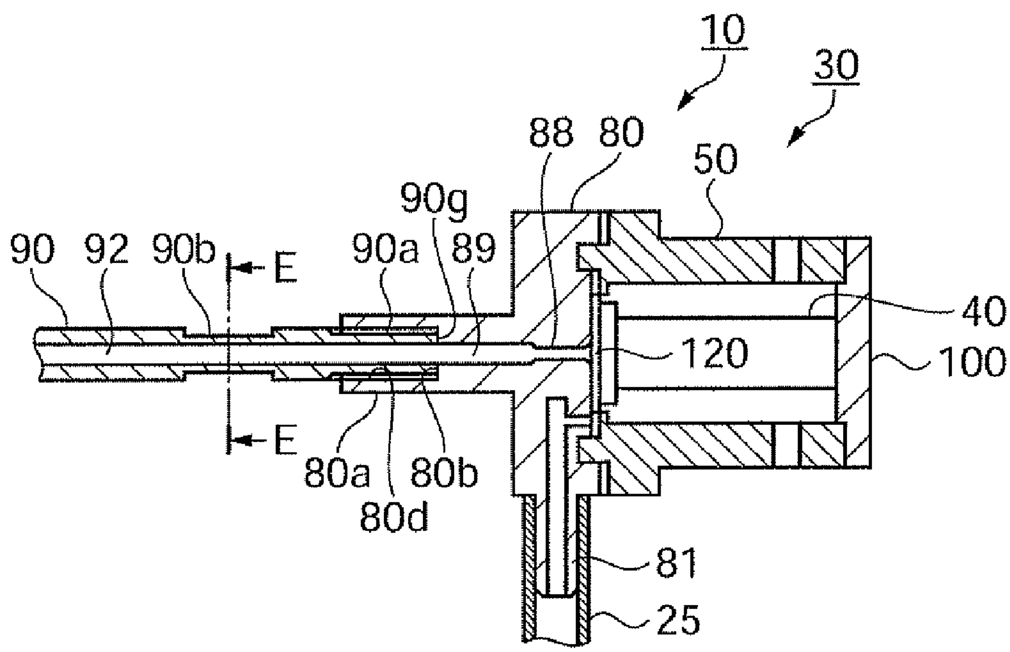

FIG.10A

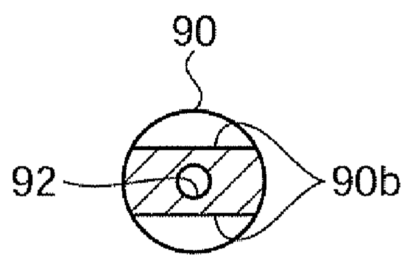

FIG.10B

PULSATION GENERATING MECHANISM, CONNECTING FLOW CHANNEL TUBE, AND FLUID EJECTING APPARATUS

[0001] This application claims priority to Japanese Application No. 2008-217671 filed in Japan on Aug. 27, 2008, the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Technical Field

[0003] The present invention relates to a pulsation generating mechanism configured to discharge fluid with pulsation, a connecting flow channel tube to be inserted into the pulsation generating mechanism, and a fluid ejecting apparatus having the same and being configured to eject the fluid in a pulsed manner.

[0004] 2. Related Art

[0005] Operation with ejected fluid enables incision of organ substances while maintaining vasculature such as blood vessels and, in addition, an incidental damage applied to anatomy other than the portion to be incised is small and hence a burden applied to a patient is small. Furthermore, since the amount of bleeding is small, visibility of an operation field is not hindered by blood, and hence quick operation is enabled, so that this technology is applied to many clinical surgeries specifically such as hepatic resection which causes medical personnel hardship due to the bleeding from small blood vessels.

[0006] As a fluid ejecting apparatus configured to incise or remove anatomy, a fluid ejecting apparatus including a pulsation generating mechanism configured to reduce the volume of a fluid chamber to discharge fluid and a connecting flow channel tube having a nozzle connected at one end thereof to an outlet flow channel of the pulsation generating mechanism and being reduced in diameter at the other end thereof to a diameter smaller than that of the outlet flow channel is known (for example, see JP-A-2005-152127).

[0007] According to a fluid ejecting apparatus disclosed in JP-A-2005-152127 described above, since a pumping action is performed by the fluid ejecting apparatus by itself, a priming action and an elimination of air bubbles in a pump chamber are needed at the time of activation from its driving characteristics.

[0008] The fluid (liquid) includes gas (air) although the quantity is not much. When the gas exists in the liquid, the gas gradually gets together to form air bubbles and stays therein. When the air bubbles stay in the fluid chamber, the internal pressure cannot rise sufficiently when the volume is reduced, so that a pulsation discharge might not be achieved.

SUMMARY

[0009] An advantage of some aspects of the invention is to solve at least a part of the problem mentioned above and the invention can be embodied in the following aspects or application examples.

APPLICATION EXAMPLE 1

[0010] Application example 1 is directed to a fluid ejecting apparatus having a fluid chamber, an inlet flow channel, and a nozzle configured to eject fluid supplied from the inlet flow channel to the fluid chamber from the nozzle in a pulsed manner by changing the volume of the fluid chamber including: a diaphragm; a wall surface provided so as to oppose the diaphragm; a spacer being provided between the diaphragm and the wall surface and having a cylindrical through hole; a piezoelectric element configured to displace the diaphragm; and a connecting flow channel tube communicated with the fluid chamber, in which the nozzle is provided at an end of the connecting flow channel tube opposite to the fluid chamber, the fluid chamber is defined by the diaphragm, the wall surface, and an inner surface of the through hole of the spacer, and the inlet flow channel is defined by a groove provided on the wall surface and the spacer and is communicated with the fluid chamber.

[0011] In this configuration, the inlet flow channel is formed with an arcuate shaped inlet flow channel on the wall surface which constitutes part of the fluid chamber. Therefore, an inertance on the inlet flow channel side of the fluid chamber may be set to a value sufficiently larger than an inertance on an outlet flow channel side of the fluid chamber from both facts that a long flow channel length of the inlet flow channel is secured, and that the cross-sectional area in the vertical direction with respect to the direction of flow of the fluid can be set to be small. In this configuration, a simple structure in which a check valve is not provided is realized.

[0012] Consequently, an operation to supply the fluid from the inlet flow channel into the fluid chamber at a constant pressure, and convert the same to a strong pulsation by changing the volume of the fluid chamber by the diaphragm is enabled. Therefore, a priming action is no longer necessary and, since an inflow of the fluid is continued even though air bubbles are generated, they are discharged in a certain time period and hence the normal operation may be restored.

APPLICATION EXAMPLE 2

[0013] Preferably, the groove on the wall surface includes a first end portion provided with a hole through which the fluid is supplied into the groove of the wall surface, is formed to extend from the first end portion in an arcuate shape along the wall surface, is formed to extend from the opposite side of the portion formed into the arcuate shape to the first end portion to the inner surface of the spacer along a direction of a tangent line of the inner surface of the spacer, and is formed from the opposite side of the portion formed along a direction of a tangent line of the inner surface of the spacer opposite to the arcuate portion along an edge of the inner surface of the spacer.

[0014] In this configuration, the fluid is caused to flow along the inner surface of the through hole of the spacer (that is, the inner peripheral surface of the fluid chamber), so that a whirling flow is generated in the fluid chamber.

[0015] By causing the fluid to whirl, the fluid is directed outward from the fluid chamber by a centrifugal force, and the air bubbles get together at the center portion and is discharged to the outside in association with discharge of the fluid through the connecting flow channel tube. Therefore, the air bubbles are prevented from staying in the fluid chamber, and the pressure in the interior of the fluid chamber may be increased sufficiently, so that a reliable pulsation discharge is achieved.

APPLICATION EXAMPLE 3

[0016] Preferably, a terminal end portion of the groove on the wall surface formed along the edge of the inner surface of the spacer is formed into an inclined surface continuing from a bottom surface of the groove on the wall surface which defines the inlet flow channel to the wall surface.

[0017] In this configuration, since the inlet flow channel is communicated with the fluid chamber continuously from the bottom surface of the groove which constitutes the inlet flow channel to the wall surface by the inclined surface, a fluid resistance at a connecting portion between the inlet flow channel and the wall surface is reduced, and also turbulence of the whirling flow and generation of the air bubbles due to a vortex flow generated by sudden change of the flow channel is restrained.

APPLICATION EXAMPLE 4

[0018] Preferably, the fluid chamber is formed with a coating layer on an inner wall surface thereof

[0019] Here, as the coating layer, for example, a membrane layer formed by plating may be employed.

[0020] Gas contained in liquid generates from the fluid when the pressure in the fluid chamber is reduced. The air bubbles get together to the center of the fluid chamber by the whirling flow. However, when small gaps or corners of components exist, the air bubbles might be adhered to these points and hence might not be discharged.

[0021] Therefore, by coating the small gaps or joint corners to form a continuous surface by forming the continuous coating layer in the interior of the fluid chamber, generation of the air bubbles is restrained.

APPLICATION EXAMPLE 5

[0022] Preferably, the fluid ejecting apparatus includes a holding portion configured to hold a peripheral edge portion of the diaphragm, and the piezoelectric element is disposed in the interior of the holding portion and resin is filled in a space between the piezoelectric element and the holding portion.

[0023] In this configuration, by coating the periphery of the piezoelectric element with the resin, inter-electrode short circuit due to attachment of water content to the piezoelectric element is prevented. Therefore, the resin to be filled preferably has low water absorbability.

APPLICATION EXAMPLE 6

[0024] Preferably, the resin has thermal conductivity.

[0025] When the fluid ejecting apparatus in this application example is driven continuously for a long time, heat is generated from the piezoelectric element. Therefore, by filling a material having a high coefficient of thermal conductivity by itself or resin mixed with a material having a high coefficient of thermal conductivity in a space between the piezoelectric element and the holding portion, the generated heat is dispersed to the outside via the holding portion, so that the piezoelectric element is effectively prevented from being deteriorated in performance due to the temperature rise.

APPLICATION EXAMPLE 7

[0026] Preferably, a connecting portion between the inner wall of the connecting flow channel tube and the inner wall of the fluid chamber is connected into a substantially arcuate shape.

[0027] In this configuration, the fluid resistance of a communicating portion between the fluid chamber and the connecting flow channel tube is reduced, and generation of the vortex flow at the joint portion is restrained, so that pressure waves generated when reducing the volume of the fluid chamber is transmitted to the nozzle without being attenuated.

APPLICATION EXAMPLE 8

[0028] Preferably, the nozzle is inserted into the connecting flow channel tube and the groove is provided along a joint surface of the nozzle with respect to the connecting flow channel tube.

[0029] The nozzle and the connecting flow channel tube are coupled by press-fitting and the joint portion between these members is reinforced by the adhesive agent, and the joint portion is hermetically sealed. In this case, it is difficult to apply the adhesive agent uniformly over the entire portion of the joint portion. Therefore, by forming the groove on the joint surface of the nozzle to provide an adhesive agent trap, reinforcement and hermeticity are ensured.

APPLICATION EXAMPLE 9

[0030] Preferably, the connecting flow channel tube is detachably attached.

[0031] Here, as a detachably attached structure, for example, a screwing structure may be employed.

[0032] In this configuration, easy replacement of the connecting flow channel tube as well as removal for cleaning in the unlikely event that the nozzle is clogged are achieved.

[0033] Also, there is also an effect that the shape of the connecting flow channel tube may be selected and attached as needed according to the object of usage by preparing a plurality of shapes of the connecting flow channel tube.

APPLICATION EXAMPLE 10

[0034] Application example 10 is directed to a pulsation generating mechanism having a fluid chamber and an inlet flow channel, and being configured to discharge fluid supplied from the inlet flow channel to the fluid chamber in a pulsed manner from a flow channel being in communication with the fluid chamber by changing the volume of the fluid chamber including: a diaphragm; a wall surface provided so as to oppose the diaphragm; a spacer being provided between the diaphragm and the wall surface and having a cylindrical through hole; and a piezoelectric element configured to displace the diaphragm, in which the fluid chamber is defined by the diaphragm, the wall surface, and an inner surface of the through hole of the spacer, and the inlet flow channel is defined by a groove provided on the wall surface and the spacer and is communicated with the fluid chamber.

[0035] According to the application example, an inertance of the inlet flow channel side of the fluid chamber may be set to a value sufficiently larger than that on the outlet flow channel side of the fluid chamber from both facts that a long flow channel length of the inlet flow channel is secured, and that the cross sectional area in the vertical direction with respect to the direction of flow of the fluid can be set to be small. Accordingly, the pulsation flow is achieved. Accordingly, a pulsation generating mechanism having a simple structure in which a check valve is not provided is realized.

APPLICATION EXAMPLE 11

[0036] Application example 11 is directed to a connecting flow channel tube which is detachably attached to a pulsation generating mechanism configured to discharge fluid from an outlet flow channel in a pulsed manner being in communication with the fluid chamber by changing the volume of the fluid chamber, being configured to be communicatable with the outlet flow channel and having a fluid ejecting opening having a smaller cross-sectional area in the vertical direction with respect to the direction of flow of the fluid than the cross-sectional area of the outlet flow channel at an end opposite to the side which communicates with the outlet flow channel.

[0037] In this configuration, since the fluid discharged from the pulsation generating mechanism in a pulsed manner is ejected from the fluid ejecting opening reduced in cross-sectional area than the outlet flow channel, so that the fluid is ejected as high-speed pulsed liquid drops having a high removing performance.

[0038] Also, there is an effect that the shape of the connecting flow channel tube may be selected and used as needed according to the object of usage by preparing a plurality of shapes of the connecting flow channel tube. In addition, by configuring the connecting flow channel tube to be detachably attached to the pulsation generating mechanism, the convenience may be further enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] The invention will be described with reference to the accompanying drawings where like numbers reference like elements;

[0040] FIG. **1** is an explanatory drawing showing a schematic configuration of a fluid ejecting system;

[0041] FIG. **2** is a cross-sectional view of a principal configuration of a pulsation generating mechanism according to a first embodiment taken along the direction of flow channel of liquid;

[0042] FIG. **3** is a side view of the pulsation generating mechanism viewed from the right side;

[0043] FIG. **4** is a side view of the pulsation generating mechanism viewed from the left side;

[0044] FIG. **5** is a cross-sectional view showing a joint portion between a first machine frame and a second machine frame according to the first embodiment in detail;

[0045] FIG. **6** is a plan view showing the first machine frame in a state of viewing from the side of a piezoelectric element according to the first embodiment;

[0046] FIG. **7** is a cross-sectional view showing an inlet port portion in an enlarged scale according to the first embodiment;

[0047] FIG. **8** is a cross-sectional view showing a joint structure between a nozzle and a connecting flow channel tube according to the first embodiment;

[0048] FIG. **9** is a cross-sectional view showing part of a fluid ejecting apparatus according to a second embodiment;

[0049] FIG. **10**A is a cross-sectional view showing part of the fluid ejecting apparatus according to a third embodiment; and

[0050] FIG. **10**B is a cross-sectional view taken along the line E-E in FIG. **10**A.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0051] Referring now to the drawings, embodiments of the invention will be described.

[0052] FIG. **1** shows a fluid ejecting system, FIGS. **2** to **8** show a fluid ejecting apparatus according to a first embodiment, FIG. **9** shows a second embodiment, and FIGS. **10**A and **10**B show a third embodiment.

[0053] Drawings referred to in the description given below are schematic drawings in which vertical and lateral reduction scales of members or portions are different from reality for the sake of convenience.

[0054] The fluid ejecting system and the fluid ejecting apparatus in the invention may be employed in various applications such as drawing using ink or the like, washing of precise substances or structures, surgical knife, and so on. In the embodiments described below, a fluid ejecting apparatus suitable for incising or removing anatomy is exemplified for description. Therefore, fluid used in the embodiments is liquid such as water or physiologic saline and the fluid is sometimes expressed as the liquid.

Fluid Ejecting System

[0055] FIG. **1** is an explanatory drawing showing a schematic configuration of the fluid ejecting system. In FIG. **1**, a fluid ejecting system **1** includes a control device **20** having a liquid container configured to store the liquid and a pump (not shown) as a pressure generating unit as a basic configuration, a fluid ejecting apparatus **10** configured to eject the liquid supplied from the pump with pulsation, and a connecting tube **25** configured to communicate the fluid ejecting apparatus **10** with the pump.

[0056] The fluid ejecting apparatus **10** includes a pulsation generating mechanism **30** configured to discharge supplied liquid at a high pressure and a high frequency in a pulsed manner, a connecting flow channel tube **90** connected to the pulsation generating mechanism **30**, and a nozzle **95** having a fluid ejection opening **97** reduced in cross-section of a flow channel is attached to a distal end of the connecting flow channel tube **90**.

[0057] Subsequently, the flow of the liquid in the fluid ejecting system **1** will be described. The liquid stored in the liquid container provided in the control device **20** is supplied to the pulsation generating mechanism **30** via the connecting tube **25** at a constant pressure by the pump.

[0058] The pulsation generating mechanism **30** includes a fluid chamber **120** (see FIG. **2**), and a volume changing device for the fluid chamber **120**, and ejects the liquid from the fluid ejection opening **97** at a high speed in a pulsed manner by driving the volume changing device and generating pulses. Detailed description of the pulsation generating mechanism **30** will be described later in conjunction with FIG. **2** to FIG. **7**.

[0059] The pressure generating unit is not limited to the pump, and a configuration in which an infusion solution bag as the liquid container is held at a position higher than the pulsation generating mechanism **30** by a stand or the like is also applicable. In this case, the pump is not necessary and hence the configuration is simplified, and in addition, sterilization of a liquid flow channel is easily achieved.

[0060] A discharge pressure of the pump is set to approximately three atmospheric pressure (0.3 MPa) or lower. When the infusion solution bag is used, the difference in height between the pulsation generating mechanism **30** and a liquid level of the infusion solution bag corresponds to the pressure, so that the height difference is preferably set to be approximately 0.1 to 0.15 pressure (0.01 to 0.015 MPa).

[0061] When performing a surgical operation using the fluid ejecting system **1**, a principal portion where the personnel performing the surgical operation grips is the pulsation generating mechanism **30**. Therefore, the connecting tube **25** to be connected to the pulsation generating mechanism **30** is preferably flexible as much as possible. In order to do so, a soft and thin tube is used, and the pressure of the liquid is preferably as low as possible within a range which allows delivery of the liquid to the pulsation generating mechanism **30**.

[0062] Also, as in the case of a brain operation in particular, when the failure of the fluid ejecting system **1** might cause a critical accident, outburst of high-pressure fluid due to the breakage of the connecting tube **25** must be avoided. From this reason, keeping the liquid at a low pressure is required.

First Embodiment

[0063] Subsequently, the structure of the fluid ejecting apparatus **10** according to the first embodiment will be described.

[0064] FIG. **2** is a cross-sectional view showing a principal structure of a pulsation generating mechanism according to the first embodiment taken along the direction of the flow channel of the liquid, FIG. **3** is a side view showing the pulsation generating mechanism from the right side, and FIG. **4** is a side view showing the pulsation generating mechanism from the left side.

[0065] Referring now to FIG. **2** to FIG. **4**, a schematic configuration of the fluid ejecting apparatus **10** will be described. The fluid ejecting apparatus **10** includes the pulsation generating mechanism **30** including a pulsation generating device which generates the pulsation of the liquid and the connecting flow channel tube **90** having an outlet connecting flow channel **92** and the nozzle **95** configured to discharge the liquid.

[0066] The pulsation generating mechanism **30** includes the fluid chamber **120** configured by tightly clamping a ring-shaped spacer **60** and a peripheral edge of a diaphragm **70** formed of a disk-shaped metallic thin plate by opposed surfaces of a first machine frame **80** and a second machine frame **50** as a machine frame and being surrounded by a wall surface **82** on the second machine frame **50** side of the first machine frame **80**, the diaphragm **70**, and an inner peripheral wall surface of the spacer **60**.

[0067] A tube connecting pipe **81** is formed on an outer side surface of the first machine frame **80** so as to project therefrom, and an inflow connecting flow channel **84** is opened in the tube connecting pipe **81**. A connecting flow channel **85** which communicates with the fluid chamber **120** is connected to the inflow connecting flow channel **84**, and is in communication with an inlet flow channel **83** formed on the wall surface **82**. The inlet flow channel **83** will be described in detail in conjunction with FIGS. **5** and **6**.

[0068] The connecting tube **25** is fitted to the tube connecting pipe **81**, and the connecting tube **25** is connected to the pump provided in the interior of the control device **20** (see FIG. **1**), so that the liquid is supplied to the fluid chamber **120** via the inlet flow channel **83**.

[0069] The connecting flow channel tube **90** is inserted into the first machine frame **80** at the substantially center of the wall surface **82** thereof substantially vertically with respect to the diaphragm **70** (that is, the wall surface **82**). The connecting flow channel tube **90** includes an outlet flow channel **91** in communication with the fluid chamber **120** and the outlet connecting flow channel **92** in communication with the outlet flow channel **91**, and the nozzle **95** is fitted to an end opposite to the outlet flow channel **91**.

[0070] The nozzle **95** includes a nozzle flow channel **96** in communication with the outlet connecting flow channel **92** and the fluid ejection opening **97**.

[0071] Here, the outlet connecting flow channel **92** and the nozzle flow channel **96** have the same cross-sectional area, and this cross-sectional area is larger than the cross-sectional area of the outlet flow channel **91**. Then, the cross-sectional area of the fluid ejection opening **97** is reduced to be smaller than the cross-sectional area of the outlet connecting flow channel **92**.

[0072] The above-described cross-sectional area means the cross-sectional area of the flow channel when it is cut vertically with respect to the direction of flow of the liquid.

[0073] The second machine frame **50** is a cylindrical member having an outer flange portion **56** and a cylindrical portion **51**, and the outer shapes of the outer flange portion **56** and the cylindrical portion **51** are both square. Then, a cylindrical hole **51***a* penetrating through the second machine frame **50** is formed.

[0074] An opening of the hole **51***a* on the opposite side to the first machine frame **80** is sealed by a lower panel **100**. A piezoelectric element **40** as a drive source is provided inside the hole **51***a*. The piezoelectric element **40** is a laminated piezoelectric element and constitutes a column shaped actuator.

[0075] One end of the piezoelectric element **40** is secured to the diaphragm **70** via an upper panel **110** and the other end thereof is secured to the inner surface of the lower panel **100**.

[0076] Opposing side surfaces of the piezoelectric element **40** are each provided with a drive electrode (not shown) and connecting leads **151** and **152** provided with insulating coatings thereon are connected to these drive electrodes. The connecting leads **151** and **152** are respectively drawn to the outside through lead insertion holes **54** and **55** formed on the side surfaces of the cylindrical portion **51** of the second machine frame **50**, and are connected to a drive circuit unit (not shown) of the control device **20** (see FIG. **1**).

[0077] The first machine frame **80** and the second machine frame **50** are fixed to each other at four corners with fixing screws **161** in a state in which the peripheral portion of the diaphragm **70** and the spacer **60** clamped therebetween, and are brought into tight contact with each other (see FIG. **4**).

[0078] In contrast, the second machine frame **50** and the lower panel **100** are fixed at four corners with the fixing screws **160** after dimensions are adjusted so as to prevent the diaphragm **70** to be deformed by the piezoelectric element **40** in an assembled state (see FIG. **3**).

[0079] In this manner, in a state in which the first machine frame **80**, the second machine frame **50**, and the lower panel **100** are fixed to each other, resin **140** is filled in a space defined between the cylindrical portion **51** of the second machine frame **50** and the piezoelectric element **40**. The filling range includes the interior of the lead insertion holes **54** and **55** in which the connecting leads **151** and **152** are inserted.

[0080] The resin **140** to be filled is preferably a material having a low water absorbability (or a material having water repellency). Also, materials having a high coefficient of thermal conductivity by itself, or resin mixed with a material having a high coefficient of thermal conductivity are preferable, and inorganic ceramics powder, carbon powder, and the like having a high coefficient of thermal conductivity are applicable as the material to be mixed. Materials which satisfy both conditions of a low water absorbability and a high coefficient of thermal conductivity are further preferable.

[0081] Furthermore, the resin, being filled to coat the periphery of the piezoelectric element **40**, has flexibility to an extent which does not hinder the drive of the piezoelectric element **40**.

[0082] Referring now to FIG. **5**, a joint portion between the first machine frame **80** and the second machine frame **50** will be described.

[0083] FIG. **5** is a cross-sectional view showing the joint portion between the first machine frame and the second machine frame. Therefore, description is given with the same reference numerals as those in FIG. **2**.

[0084] The first machine frame **80** includes a ring-shaped recess **86** around the wall surface **82**, and the second machine frame **50** is formed with a ring-shaped projection **53** opposing the ring-shaped recess **86**. By inserting the ring-shaped projection **53** into the ring-shaped recess **86**, an accurate positional restraint between the first machine frame **80** and the second machine frame **50** is achieved.

[0085] In this case, the diaphragm **70** and the spacer **60** are interposed between the wall surface **82** at the center portion of the first machine frame **80** and an inner periphery flange portion **52** provided inside the ring-shaped projection **53** of the second machine frame **50** in a compressed state.

[0086] Diameters of an inner peripheral wall **61** of the spacer **60** and the inner periphery flange portion **52** of the second machine frame **50** are set to be substantially the same, and the supporting positions with respect to displacement of the diaphragm **70** are the same.

[0087] A packing **130** as a sealing member is interposed between a bottom portion of the ring-shaped recess **86** of the first machine frame **80** and the distal end portion of the ring-shaped projection **53** of the second machine frame **50**. The packing **130** is deformed by being pressed in a state in which the diaphragm **70** and the spacer **60** are interposed in the compressed state, so that the movement of the liquid between the outside and the fluid chamber **120** is restrained.

[0088] The connecting flow channel tube **90** is press-fitted into the first machine frame **80** to a position where the end portion reaches the fluid chamber **120**, and the outlet flow channel **91** is in communication with the fluid chamber **120**. The end surface of the connecting flow channel tube **90** is machined so as to be flush with the surface of the wall surface **82** in the fluid chamber **120**. In addition, a connecting portion (communicating portion) of the outlet flow channel **91** with respect to the fluid chamber **120** is smoothly connected into a substantially arcuate shape.

[0089] The machining as described above is realized by press-fitting the connecting flow channel tube **90** from the wall surface **82** so as to project slightly into the fluid chamber **120**, then grinding the connecting flow channel tube **90** to be flush with the surface of the wall surface **82**, and then by grinding inner corner of the outlet flow channel **91**.

[0090] The inlet flow channel **83** is configured by a groove formed on the wall surface **82** of the first machine frame **80** and the spacer **60** which seals the opening of the groove.

[0091] Referring now to FIGS. **6** and **7**, the inlet flow channel **83** will be described.

[0092] FIG. **6** is a plan view showing the first machine frame in a state of viewing from the side of the piezoelectric element. The inlet flow channel **83** is formed as the groove on the wall surface **82** of the first machine frame **80**, and is formed into a substantially arcuate shape extending from the connecting portion with respect to the connecting flow channel **85** as a proximal end and to an inlet port portion **83***a* as a distal end which communicates with the fluid chamber **120**.

[0093] This groove extends from the connecting portion with respect to the connecting flow channel **85** to a position A in the drawing as a concentric circle having the outlet flow channel **91** as the center, and extends in the direction of a tangent line of the inner peripheral wall **61** of the spacer **60** (that is, in the direction of the tangent line of the side wall of the fluid chamber **120**) in a range from the positions B to C in the drawing. In addition, in the range from the positions C to D, the groove extends along the inner peripheral wall **61** of the spacer **60**.

[0094] The range from the positions A to B is connected as a small arc which changes the direction of flow of the liquid smoothly.

[0095] A most part of an opening of the groove formed in this manner (upper side in the drawing) is sealed by the ring-shaped spacer **60** to define the inlet flow channel **83**, and the inlet port portion **83***a* is in communication with the fluid chamber **120**.

[0096] By forming the inlet flow channel **83** in this manner, the liquid flowing from the connecting tube **25** at a constant pressure assumes a whirling flow along the inner peripheral wall **61** of the spacer **60**.

[0097] The inlet port portion **83***a* of the inlet flow channel **83** into the fluid chamber **120** is continued by an inclined surface **83***d* from the bottom surface to the wall surface **82**.

[0098] FIG. **7** is a cross-sectional view showing the inlet port portion in an enlarged scale. The inlet port portion **83***a* is continued to the wall surface **82** via the inclined surface **83***d* from a groove bottom surface **83***b* substantially within a range from the positions C to D (see also FIG. **6**) of the inlet flow channel **83**.

[0099] Referring now to the drawings, a joint structure between the nozzle and the connecting flow channel tube in this embodiment will be described.

[0100] FIG. **8** is a cross-sectional view showing the joint structure between the nozzle and the connecting flow channel tube. The nozzle **95** includes a distal end flange portion **98** and an insertion portion **99**, and includes the nozzle flow channel **96** which communicates with the outlet connecting flow channel **92** of the connecting flow channel tube **90** and the fluid ejection opening **97**. A groove **99***a* is formed on a mid-section in terms of the longitudinal direction on the outer peripheral surface of the insertion portion **99**, and a smaller-diameter tube portion **99***b* having a smaller outer diameter is formed at the distal end portion on the insertion side.

[0101] A nozzle insertion hole **90***f* is formed at the end portion of the connecting flow channel tube **90**. The nozzle **95** is press-fitted into the nozzle insertion hole **90***f*. In this case, an end surface **99***c* of the nozzle **95** is brought into tight contact with a bottom surface **94** of the nozzle insertion hole **90***f*.

[0102] The nozzle **95** is press-fitted into the connecting flow channel tube **90** after an adhesive agent is applied on the outer peripheral side surface of the insertion portion **99** for reinforcement of the press-fitting strength. At the time of the press-fitting, the adhesive agent is accumulated in the groove **99***a*. Therefore, the groove **99***a* in this embodiment corresponds to the adhesive agent trap, and has a function to enhance the adhesive strength and a function to prevent liquid leakage or entry of air at the joint portion between the nozzle **95** and the connecting flow channel tube **90**.

[0103] The smaller-diameter tube portion **99***b* serves to stop the adhesive agent within the range of the smaller-diameter tube portion **99***b* and prevent the adhesive agent from entering the interior of the outlet connecting flow channel **92** or the nozzle flow channel **96**.

[0104] Referring now to FIGS. **5** and **6**, the operation of the fluid ejecting apparatus **10** in this embodiment will be described. The liquid discharge of the pulsation generating mechanism **30** in this embodiment is performed by the difference between an inertance L**1** on the inlet flow channel side (also referred to as synthetic inertance L**1**) and an inertance L**2** on the outlet flow channel side (also referred to as synthetic inertance L**2**).

[0105] First of all, an inertance will be described.

[0106] An inertance L is expressed by $L=\rho\times h/S$, where **92** is a density of the liquid, S is the cross-sectional area of the flow channel, and h is the length of the flow channel. A relation; $\Delta P=L\times dQ/dt$ is delivered by deforming a dynamic equation in the flow channel using the inertance L, where ΔP is a pressure difference in the flow channel, Q is a flow rate of the liquid flowing in the flow channel, and t is time.

[0107] In other words, the inertance L shows a degree of influence applied to the change of flow rate with time and, the larger the inertance L, the smaller the change of flow rate with time is, and the smaller the inertance L, the larger the change of flow rate with time is.

[0108] Since the cross-sectional areas of the inflow connecting flow channel **84** and the connecting flow channel **85** are set to be sufficiently larger than the cross-sectional area of the inlet flow channel **83**, the synthetic inertance L**1** is calculated within the range of the inlet flow channel **83**. In this case, since the connecting tube **25** has flexibility, it may be eliminated from the calculation of the synthetic inertance L**1**.

[0109] Since the connecting flow channel tube **90** has a sufficient rigidity for propagating pressure waves of the liquid, the synthetic inertance L**2** may be considered to be sum of the outlet flow channel **91** and the outlet connecting flow channel **92**.

[0110] Then, the flow channel length and the cross-sectional area of the inlet flow channel **83**, the flow channel length and the cross-sectional area of the outlet flow channel **91** and the outlet connecting flow channel **92** are set so that the synthetic inertance L**1** is larger than the synthetic inertance L**2** in this embodiment.

[0111] Subsequently, the operation of the pulsation generating mechanism **30** will be described.

[0112] The liquid at an always constant pressure is supplied to the inlet flow channel **83** by the pump. Consequently, when the piezoelectric element **40** is not operated, the liquid flows into the fluid chamber **120** due to the difference between the discharge pressure of the pump and a fluid resistance value of the entire inlet flow channel side.

[0113] Here, assuming that a drive signal is inputted to the piezoelectric element **40**, and the piezoelectric element **40** is expanded abruptly, the pressure in the fluid chamber **120** rises quickly to several tens atmospheric pressure if the synthetic inertances L**1** and L**2** on the inlet flow channel side and the outlet flow channel side have a sufficient magnitude. Since this pressure is larger than the pressure by the pump applied to the inlet flow channel **83** by far, inflow of the liquid from the inlet flow channel **83** into the fluid chamber **120** is reduced by the pressure, and outflow of the liquid from the outlet flow channel **91** is increased.

[0114] However, the synthetic inertance L**1** on the inlet flow channel side is larger than the synthetic inertance L**2** on the outlet flow channel side, the amount of increase of the liquid discharged from the outlet flow channel **91** is larger than the amount of decrease of the flow rate of the liquid flowing into the fluid chamber **120** from the inlet flow channel **83**. Therefore, a fluid discharge in a pulsed manner, that is, a pulsation flow is generated in the outlet flow channel **91**.

[0115] Pressure variations at the time of discharge propagate in the interior of the connecting flow channel tube **90**, and the liquid is ejected from the fluid ejection opening **97** of the nozzle **95** at the distal end (see FIG. **2** for both). Since the diameter of the fluid ejection opening **97** is smaller than the diameter of the outlet flow channel **91**, the liquid is ejected as further high-pressure and high-speed pulsed liquid drops.

[0116] In contrast, the interior of the fluid chamber **120** is brought into a vacuum state immediately after the pressure rise because of the mutual action of the reduction of an amount of inflow liquid from the inlet flow channel **83** and the increase of the amount of liquid outflow from the outlet flow channel **91**. Consequently, the liquid in the inlet flow channel **83** is restored to flow toward the fluid chamber **120** at a speed similar to that before the operation of the piezoelectric element **40** after having elapsed a certain period of time by the pressure from the pump and the vacuum state in the fluid chamber **120**. If the expansion of the piezoelectric element **40** occurs after having restored the flow of the liquid in the inlet flow channel **83**, the liquid from the nozzle **95** may be continuously ejected in a pulsed manner.

[0117] This embodiment has a structure to form the inlet flow channel **83** on the wall surface **82** of the first machine frame **80** as a groove and seal the opening by the spacer **60**. Accordingly, the synthetic inertance L**1** on the inlet flow channel side may be set to a value sufficiently larger than the synthetic inertance L**2** on the outlet flow channel side from both facts that a long flow channel length of the inlet flow channel **83** is secured, and that the cross sectional area in the vertical direction with respect to the direction of flow of the liquid can be set to be small. Therefore, a simple structure in which a check valve is not provided is realized.

[0118] Consequently, an operation to supply the liquid from the inlet flow channel **83** into the fluid chamber **120** at a constant pressure, and convert the same to a strong pulsation by the pulsation generating mechanism **30** is enabled. Therefore, a priming action is no longer necessary and, since the inflow of the liquid is continued even though air bubbles are generated, they are discharged in a certain time period and hence the normal operation may be restored.

[0119] Also, the inlet flow channel **83** extends along an arcuate portion extending from the connecting portion (proximal end) with respect to the connecting flow channel **85**, in the direction of the tangent line of an inner peripheral wall **93** of the spacer **60** from the arcuate portion, and along the inner peripheral wall **93**, and finally communicates with the fluid chamber **120** from the inlet port portion **83***a*. Therefore, the whirling flow is generated in the fluid chamber **120**.

[0120] By the generation of the whirling flow, the liquid is directed outward from the fluid chamber **120** by a centrifugal force, and the air bubbles get together at the center portion and are discharged to the outside in association with discharge of the liquid from the outlet flow channel **91**. Therefore, the air bubbles are prevented from staying in the fluid chamber **120**, and the pressure in the interior of the fluid chamber **120** may be raised sufficiently, so that a high-pressure pulsation discharge is achieved.

[0121] Also, at the inlet port portion **83***a* where the inlet flow channel **83** is connected to the fluid chamber **120**, the groove bottom surface **83***b* which defines the inlet flow channel **83** is continued to the wall surface **82** via the inclined surface **83***d*, the fluid resistance at the connecting portion between the inlet port portion **83***a* and the fluid chamber **120** is reduced, and the turbulence of the whirling flow due to a vortex flow generated by the sudden change of the flow channel is restrained.

[0122] The space in the cylindrical portion **51** of the second machine frame **50** in which the piezoelectric element **40** is disposed is filled with the resin **140**. Since the resin **140** has a low absorbability, entry of the water content into the space is prevented, so that inter-electrode short circuit due to attachment of the water content to the piezoelectric element **40** is prevented.

[0123] Since the resin **140** is filled in the lead insertion holes **54** and **55** (see FIG. **2**) which allow insertion of the connecting leads **151** and **152**, reinforcement of the connecting portion with respect to the piezoelectric element **40** and the connecting leads **151** and **152** in the second machine frame **50** is achieved.

[0124] In addition, by employing a material having a high coefficient of thermal conductivity as the resin **140**, heat generated from the piezoelectric element **40** by continuous driving for a long time is diverged to the outside via the second machine frame **50**, the piezoelectric element **40** is effectively prevented from being deteriorated in performance due to the temperature rise.

[0125] Also, since the joint portion with respect to the wall surface **82** of the outlet flow channel **91** is connected by a substantially arcuate shape and rounded smoothly, reduction of the fluid resistance at the joint portion between the fluid chamber **120** and the outlet flow channel **91** is achieved and, in addition, generation of the vortex flow at the joint portion is restrained, and the pressure waves generated when reducing the volume of the fluid chamber **120** is propagated to the nozzle **95** without being attenuated.

[0126] Also, the groove **99***a* as the adhesive agent trap is formed on the joint surface between the nozzle **95** and the connecting flow channel tube **90**. The nozzle **95** and the connecting flow channel tube **90** are coupled by press-fitting and the coupled portion between these members is reinforced by the adhesive agent. In this case, with the provision of the adhesive agent trap, the reinforcement of the strength and the hermeticity are secured.

Second Embodiment

[0127] Subsequently, referring to the drawings, the second embodiment will be described. The second embodiment is different from the first embodiment in that the outlet flow channel is provided on the first machine frame, and the outlet connecting flow channel provided in the connecting flow channel tube is in communication with the outlet flow channel. Therefore, the points different from the first embodiment will mainly be described.

[0128] FIG. **9** is a cross-sectional view showing part of the fluid ejecting apparatus according to the second embodiment. In FIG. **9**, an outlet flow channel **88** in communication with the fluid chamber **120** is formed on the first machine frame **80**, and a connecting flow channel insertion portion **80***a* is formed on the opposite side to the fluid chamber **120** so as to project therefrom, and the center portion is formed with an insertion hole **80***c*.

[0129] Then, the connecting flow channel tube **90** is fitted to the connecting flow channel insertion portion **80***a*. The outlet connecting flow channel **92** is formed in the connecting flow channel tube **90**, so that the outlet flow channel **88** and the outlet connecting flow channel **92** are communicated.

[0130] The flow channel lengths and the cross-sectional areas (diameters) of the outlet flow channel **88** and the outlet connecting flow channel **92** are set to similar values as those in the first embodiment.

[0131] The connecting flow channel tube **90** is press-fitted until a distal end portion **90***g* comes into tight contact with a bottom portion **80***b* of the insertion hole **80***c*.

[0132] Also a groove portion **90***d* is provided at a midsection of a range of the connecting flow channel tube **90** which is joined with the insertion hole **80***c* and a smaller-diameter tube portion **90***e* having a smaller outer diameter is provided at a distal end portion thereof.

[0133] The connecting flow channel tube **90** is press-fitted into the insertion hole **80***c* after the adhesive agent is applied on the outer peripheral surface for reinforcement of the press-fitting strength. At the time of the press-fitting of the connecting flow channel tube **90**, the adhesive agent is accumulated in the groove portion **90***d*. Therefore, the groove portion **90***d* in this embodiment corresponds to the adhesive agent trap, and has a function to enhance the adhesive strength and a function to prevent liquid leakage or entry of air at the joint portion between the connecting flow channel tube **90** and the first machine frame **80**.

[0134] The smaller-diameter tube portion **90***e* serves to stop the adhesive agent within the range of the smaller-diameter tube portion **90***e* and prevent the adhesive agent from entering the interior of the outlet flow channel **88** or the outlet connection flow channel **92**.

[0135] In this configuration, the outlet flow channel **88** is formed in the first machine frame **80**. Therefore, since the outlet flow channel **88** continues with the same surface of the wall surface **82** which constitutes part of the fluid chamber **120**, the joint portion between the connecting flow channel tube **90** and the wall surface **82** is not formed in the fluid chamber **120**, so that generation of the air bubbles caused by the existence of a joint surface is restrained.

Third Embodiment

[0136] Referring now to the drawings, the fluid ejecting apparatus according to the third embodiment will be described. While the connecting flow channel tube **90** is press-fitted into and fixed to the pulsation generating mechanism **30** (first machine frame **80**) in the first and second embodiment, the connecting flow channel tube **90** is detachable with respect to the pulsation generating mechanism **30** in the third embodiment. Therefore, the different points from the above-described first and second embodiments will mainly be described.

[0137] FIGS. **10**A and **10**B show the fluid ejecting apparatus according to the third embodiment. FIG. **10**A is a cross-sectional view showing part of the fluid ejecting apparatus, and FIG. **10**B is a cross-sectional view showing a cross section taken along the line E-E in FIG. **10**A. In FIGS. **10**A and **10**B, the fluid ejecting apparatus **10** is configured in such a manner that the connecting flow channel tube **90** is fixedly screwed to the pulsation generating mechanism **30** with screw portions of the partner members.

[0138] More specifically, the connecting flow channel insertion portion **80***a* is provided on the first machine frame **80** which constitutes the pulsation generating mechanism **30** opposite to the fluid chamber **120** so as to project therefrom, and the outlet flow channel **88** and a connecting flow channel **89** which are in communication with the fluid chamber **120** are formed in the connecting flow channel insertion portion **80***a*. In addition, a female screw **80***d* is formed in the range from the distal end portion of the connecting flow channel insertion portion **80***a* to the connecting flow channel **89**.

[0139] The outlet connecting flow channel **92** is formed in the connecting flow channel tube **90**, and a male screw **90***a* is formed on the outer periphery of the distal end portion. By screwing these screw portions, the connecting flow channel tube **90** is fixed to the pulsation generating mechanism **30**. Therefore, the connecting flow channel tube **90** has a configuration which is detachable with respect to the pulsation generating mechanism **30** (that is, the first machine frame **80**).

[0140] The connecting flow channel tube **90** is screwed in until the distal end portion **90***g* comes into tight contact with the bottom portion **80***b* of the female screw **80***d*.

[0141] The diameters of the connecting flow channel **89** and the outlet connecting flow channel **92** are the same, and the flow channel length and the cross-sectional area (diameter) of the outlet flow channel **88**, the connecting flow channel **89**, and the outlet connecting flow channel **92**, that is, the synthetic inertance L**2** on the outlet flow channel side is set in the same manner as in the first embodiment 1.

[0142] A cut portion **90***b* is formed on the outer peripheral portion at a midsection of the connecting flow channel tube **90** in terms of the longitudinal direction. As shown in FIG. **10**B, the cut portion **90***b* is formed by cutting the outer periphery of the connecting flow channel tube **90** into plane surfaces opposing to each other. The cut portion **90***b* is used for mounting to and demounting from the pulsation generating mechanism **30** of the connecting flow channel tube **90** by rotating the same by a jig or the like.

[0143] Therefore, in this configuration, easy replacement of the connecting flow channel tube **90** as well as removal for cleaning or sterilization of the connecting flow channel tube **90** in the unlikely event that the nozzle **95** is clogged is achieved.

[0144] Also, there is also an effect that the shape of the connecting flow channel tube **90** may be selected and attached as needed according to the object of usage by preparing a plurality of shapes of connecting flow channel tube **90**.

Fourth Embodiment

[0145] Subsequently, a fourth embodiment will be described. The fourth embodiment is characterized in that a coating layer is formed on an inner wall surface of the fluid chamber. Although not shown, description will be given on the basis of FIG. **5**.

[0146] The fluid chamber **120** is defined by a space surrounded by the wall surface **82** of the first machine frame **80**, the inner peripheral wall **61** of the spacer **60**, and the diaphragm **70**. In this case, a joint portion and corners of the first machine frame **80** and the wall surface **82**, a joint portion and corners of the inner peripheral wall **61** of the spacer **60** and the diaphragm **70**, and a joint portion between the connecting flow channel tube **90** and the wall surface **82** are formed.

[0147] Small gaps might be formed at these joint portions due to the machining reasons, and the inner angle of the corners is 90 degrees.

[0148] The coating layer is formed over the entire periphery of the inner wall surface of the fluid chamber **120**. As an example of the coating layer, a metal plated layer may be employed. Although the material of the plated layer is not specifically limited, a material having a resistance against the liquid to be used is selected.

[0149] Formation of the plated layer is achieved by inserting the connecting flow channel tube **90** into the pulsation generating mechanism **30** and then immersing the same in plating solution, and by forcing the plating solution to flow from the inflow connecting flow channel **84** through the inlet flow channel **83** to the outlet connecting flow channel **92**, the plating solution is circulated to minute portions in the respective flow channels, so that the plated layer may be formed over the entire flow channels.

[0150] The coating layer is also formed at the corners formed between the bottom portion and the side walls of the groove of the inlet flow channel **83** and the corners of the joint portion between the groove and the spacer **60** which seals the groove. The coating layer is formed also at the joint portions between the nozzle **95** and the connecting flow channel tube **90**.

[0151] Therefore, the continuous thin coating layer is formed over the entire flow channel for the liquid.

[0152] As described above, the gas contained in the flowing liquid gets together to small gaps or corners at the joint portions of the components gradually to generate air bubbles. If the air bubbles exist in the fluid chamber **120**, the internal pressure might not rise sufficiently when reducing the volume of the fluid chamber **120** by the diaphragm **70**.

[0153] Therefore, by embedding the small gap at the joint portions of the respective components by forming the continuous thin coating layer over the entire flow channel for the liquid including the fluid chamber **120** and rounding the corners with the coating layer, generation of the air bubbles caused by the existence of the small gaps or corners is restrained, so that the internal pressure in the fluid chamber **120** may be raised to a predetermined level.

[0154] Although this embodiment has been described on the basis of the first embodiment described above, it may also be applied to the second and third embodiments.

What is claimed is:

1. A fluid ejecting apparatus comprising:
a diaphragm;
a wall surface provided so as to oppose the diaphragm;
a spacer being provided between the diaphragm and the wall surface and having a cylindrical through hole;
a piezoelectric element configured to displace the diaphragm;
a fluid chamber defined by the diaphragm, the wall surface, and an inner surface of the through hole of the spacer;
a connecting flow channel tube communicated with the fluid chamber;
an inlet flow channel defined by a groove provided on the wall surface and the spacer, and in communication with the fluid chamber; and
a nozzle provided at an end of the connecting flow channel tube opposite to the fluid chamber that is configured to eject fluid from the fluid chamber in a pulsed manner by changing the volume of the fluid chamber.

2. The fluid ejecting apparatus according to claim **1**,

the groove of the wall surface including:

a first end portion provided with a hole through which the fluid is supplied into the groove of the wall surface,

a first middle portion extending from the first end portion in an arcuate shape along the wall surface,

a second middle portion extending from the first middle portion to the inner surface of the spacer along a direction of a line tangent to the inner surface of the spacer, and

a second end portion extending from the second middle portion along an edge of the inner surface of the spacer.

3. The fluid ejecting apparatus according to claim **2**, is the second end portion being formed into an inclined surface continuing from a bottom surface of the groove on the wall surface which defines the inlet flow channel to the wall surface.

4. The fluid ejecting apparatus according to claim **1**, the fluid chamber being formed with a coating layer on an inner wall surface thereof.

5. The fluid ejecting apparatus according to claim **1**,

the fluid ejecting apparatus including a holding portion configured to hold a peripheral edge portion of the diaphragm, and

the piezoelectric element being disposed in the interior of the holding portion and resin being filled in a space between the piezoelectric element and the holding portion.

6. The fluid ejecting apparatus according to claim **5**, the resin having thermal conductivity.

7. The fluid ejecting apparatus according to claim **1**, a connecting portion between the inner wall of the connecting flow channel tube and the inner wall of the fluid chamber having a substantially arcuate shape.

8. The fluid ejecting apparatus according to claim **1**, the nozzle being inserted into the connecting flow channel tube and an adhesive groove being provided along a joint surface of the nozzle with respect to the connecting flow channel tube.

9. The fluid ejecting apparatus according to claim **1**, the connecting flow channel tube being detachably attached.

10. A pulsation generating mechanism comprising:

a diaphragm;

a wall surface provided so as to oppose the diaphragm;

a spacer being provided between the diaphragm and the wall surface and having a cylindrical through hole;

a piezoelectric element configured to displace the diaphragm;

a fluid chamber defined by the diaphragm, the wall surface, and an inner surface of the through hole of the spacer; and

an inlet flow channel defined by a groove provided on the wall surface and the spacer that is in communication with the fluid chamber,

the fluid ejecting apparatus being configured to discharge fluid supplied from the inlet flow channel to the fluid chamber in a pulsed manner from a flow channel that is in communication with the fluid chamber by changing the volume of the fluid chamber.

11. A connecting flow channel tube which is detachably attached to a pulsation generating mechanism configured to discharge fluid from an outlet flow channel in a pulsed manner by changing the volume of a fluid chamber that is in communication with the outlet flow channel, the connection flow channel tube comprising:

a first end configured to be communicatable with the outlet flow channel; and

a second end opposite to the first end and having a fluid ejecting opening with a smaller cross-sectional area in the vertical direction with respect to a direction of flow of the fluid than a cross-sectional area of the outlet flow channel.

12. A fluid ejecting apparatus comprising:

a fluid chamber;

an inlet flow channel that supplies fluid to the fluid chamber; and

an outlet flow channel in communication with the fluid chamber, the outlet flow channel having an inertance less than an inertance of the inlet flow channel,

the fluid ejecting apparatus ejecting the fluid supplied to the fluid chamber from the outlet flow channel by changing a volume of the fluid chamber.

13. The fluid ejecting apparatus according to claim **12**, the inlet flow channel being formed to supply the fluid to the fluid chamber so as to create a whirling flow of the fluid within the fluid chamber.

14. The fluid ejecting apparatus according to claim **13**, the inlet flow channel including:

a first end portion provided with a hole through which the fluid is supplied to the inlet flow channel,

a first middle portion extending from the first end portion in an arcuate shape around an outside of the fluid chamber,

a second middle portion extending from the first middle portion to an inner surface of the fluid chamber along a direction of a line tangent to the inner surface of the fluid chamber, and

a second end portion extending from the second middle portion along the inner surface of the fluid chamber.

15. The fluid ejecting apparatus according to claim **12**, further comprising:

an outlet flow channel tube including the outlet flow channel and an outlet connecting flow channel in communication with the outlet flow channel; and

a nozzle in communication with the outlet flow channel tube, a fluid ejection opening of the nozzle having a diameter smaller than a diameter of the output flow channel.

16. A method for ejecting fluid comprising:

supplying fluid from an inlet flow channel to a fluid chamber at a constant pressure; and

changing a volume of the fluid chamber to eject the fluid from the fluid chamber and through an outlet flow channel having an inertance less than an inertance of the inlet flow channel.

17. The method for ejecting fluid according to claim **16**, the fluid being supplied to the fluid chamber so as to create a whirling flow of the fluid within the fluid chamber.

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