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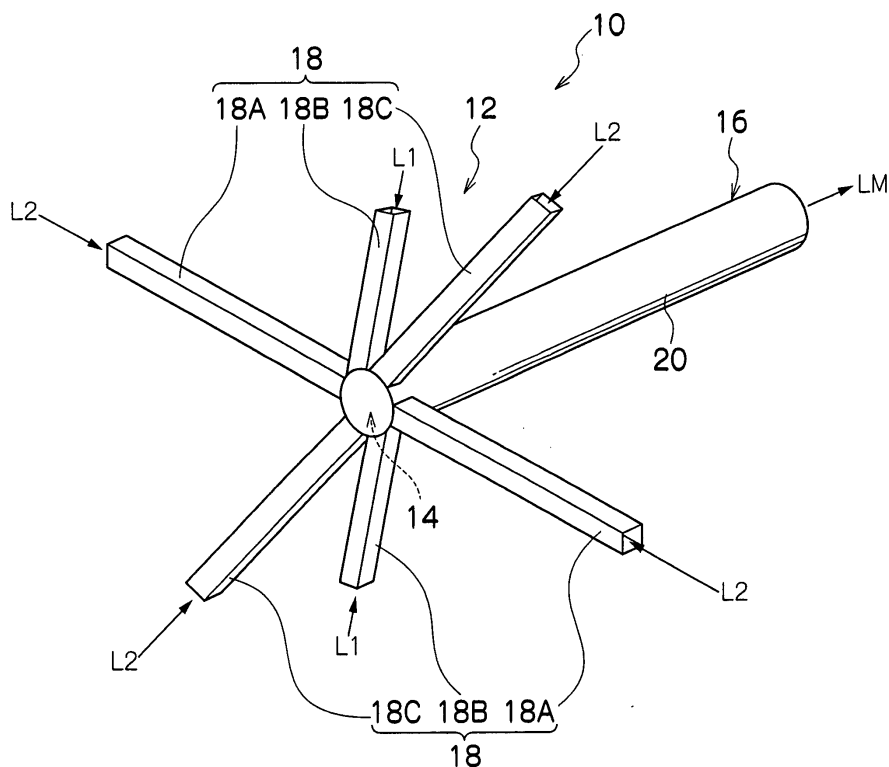
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(54) **Micro device and liquid mixing method**

(57) A micro device (10) includes: a supply channel portion (12); a confluent part (14) into which multiple kinds of liquids (L1, L2) flow from the supply channel portion to join flows of the liquids from the supply channel portion; and a discharge channel portion (16) through which a confluent liquid obtained by joining the flows of liquids is discharged, wherein the supply channel portion includes

one or more channel units (18) arranged around the confluent part, each of the channel units including three supply channels (18A, 18B, 18C) for joining the multiple kinds of liquids so as to sandwich one flow of liquid (L1) between two flows of liquid (L2), and a flow-in direction of the liquids flowing from each of the channel units into the confluent part is offset from the center (14C) of the confluent part.

FIG.1



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a micro device and a liquid mixing method, and more particularly to a micro device and a liquid mixing method for passing multiple kinds of liquids through independent supply channels to be joined into a confluent part and mixing the liquids (including reaction by mixing).

Description of the Related Art

[0002] A so-called micro device (also referred to as a microreactor or a micromixer) for performing mixing or reaction while precisely controlling liquids in a minute space has recently received attention. A specific surface area of the micro device is increased by a scale-down, and thus molecules are moved by only diffusion. This allows collision between molecules to be precisely controlled.

[0003] There is a two-stage reaction process in which, for example, all molecules are reacted in a first stage and agglomeration of the reacted molecules is prevented in a second stage. In this case, mixing needs to be instantaneously completed in the first stage. However, in the conventional micro device, only molecule diffusion contributes to velocity components perpendicular to a main-stream direction, and thus such reaction is difficult to handle.

[0004] Thus, Japanese Patent Application Laid-Open No. 2006-167600 discloses a micromixer that supplies liquids to a mixing vessel so as to generate a swirling flow of the liquids in the mixing vessel as one example of devices for efficiently mixing multiple kinds of liquids.

[0005] Also, "Chemical Micro Process Engineering", V. Hessel et al., WILEY-VCH Verlag GmbH & Co. KGaA discloses a cyclone mixer including a plurality of nozzles for injecting liquids into a confluent part.

SUMMARY OF THE INVENTION

[0006] However, the micromixer described in Japanese Patent Application Laid-Open No. 2006-167600 has a structure in which a power portion such as an actuator is provided in a mixing portion, and has a problem of a cost increase of the device and a reduction in reaction controllability due to a size increase of the mixing portion. The cyclone mixer described in Hessel et al. is necessary to design a large confluent part, and thus a shearing force applied between the liquids is reduced to make it difficult to efficiently convert kinetic energy of the liquids into swirling energy.

[0007] For instantaneously mixing multiple kinds of liquids in a confluent part, it is preferable that a diameter of the confluent part is reduced and the multiple liquids are

brought into contact with each other in thin film form. Thus, reducing (narrowing) a diameter of a confluent part inlet of a supply channel has been proposed. However, reducing the diameter of the confluent part inlet of the supply channel increases pressure loss.

[0008] The present invention is achieved in view of such circumstances, and provides a micro device and a liquid mixing method that can quickly and efficiently mix multiple kinds of liquids without increasing pressure loss.

[0009] To achieve the above described object, a first aspect of the present invention provides a micro device including: a supply channel portion; a confluent part into which multiple kinds of liquids flow from the supply channel portion to join flows of the liquids from the supply channel portion; and a discharge channel portion through which a confluent liquid obtained by joining the flows of liquids is discharged, wherein the supply channel portion includes one or more channel units arranged around the confluent part, each of the channel units including three supply channels for joining the multiple kinds of liquids so as to sandwich one flow of liquid between two flows of liquid, and a flow-in direction of the liquids flowing from each of the channel units into the confluent part is offset from the center of the confluent part.

[0010] According to the micro device of the aspect of the present invention, one or more channel units are arranged around the confluent part, and each channel includes the three supply channels for joining the multiple kinds of liquids so as to sandwich one liquid between two liquids. Therefore, a contracted liquid constituted by a contracted thin middle liquid sandwiched between liquids on opposite sides is formed in the confluent part. Thus, the three liquids that constitute the contracted liquid are joined in thin film form to increase mixing efficiency. Therefore, instantaneous mixing of the three liquids is achieved. In the aspect of the present invention, a diameter of the supply channel is not narrowed to form the contraction, but the two liquids sandwich the middle liquid to form the contracted liquid. Therefore, mixing efficiency can be increased without increasing pressure loss in the supply channel.

[0011] Further, the flow-in direction of the liquid flowing from the channel unit into the confluent part, that is, the contracted liquid is offset from the center of the confluent part. Therefore, a swirling flow of the contracted liquid is generated in the confluent part. The swirling flow can apply a high shearing force between the liquids that constitute the contracted liquid, and also generates a suction flow of the contracted liquid sucked from the center of the confluent part into the discharge channel portion. Thus, the contracted liquid formed by the channel unit is pulled by the swirling flow, and the middle liquid sandwiched between the two liquids in the contracted liquid is contracted to be tapered. Thus, the three liquids that constitute the contracted liquid are further made into thinner film form, thereby further increasing mixing efficiency and allowing instantaneous mixing.

[0012] As such, in the present invention, the contracted

liquid formed by the channel unit is further contracted by the swirling flow to maintain a contraction condition in the confluent part, and thus the liquids can be efficiently mixed even with a relatively large diameter of the confluent part. Further, when the two liquids sandwich the middle liquid to form the contracted liquid as in the aspect of the present invention, an imbalance in flow rates of the two sandwiching liquids may reduce a contraction effect to reduce mixing efficiency, but a combination with the swirling flow prevents the reduction in mixing efficiency even with the imbalance in flow rates.

[0013] In the aspect of the present invention, the three liquids that constitute the contracted liquid preferably include two kinds of liquids: two sandwiching liquids A and one sandwiched liquid B mixed together, but all the three liquids may be of different kinds. When two channel units are provided, the liquids passed through the channel units preferably have the same kind constitution, but may have different kind constitutions. The same applies to the case with three or more channel units. The aspect of the present invention describes mixing the liquids in the confluent part, but also includes reaction by mixing.

[0014] In the micro device of the aspect of the present invention, among the three supply channels that constitute the channel unit, the two supply channels for sandwiching preferably form an obtuse angle (the second aspect). This can increase contribution of kinetic energy of the two sandwiching liquids to the contraction of the middle liquid, thereby increasing the degree of contraction and further increasing mixing efficiency.

[0015] In the micro device of the aspects of the present invention, two channel units are preferably provided in symmetrical positions with respect to the center of the confluent part (the third aspect). Thus, swirling flows of two contracted liquids are generated in the confluent part in symmetrical positions with respect to the center of the confluent part, thereby further increasing mixing efficiency.

[0016] In the micro device of the aspects of the present invention, the confluent part in the micro space preferably has a diameter of 0.1 mm to 10 mm (the fourth aspect). In the aspect of the present invention, as described above, the confluent part may have a relatively large diameter, but a diameter of larger than 10 mm may significantly reduce mixing efficiency.

[0017] To achieve the above described object, a fifth aspect of the present invention provides a liquid mixing method including steps of: joining flows of multiple kinds of liquids flowing from a supply channel portion into a confluent part; forming at least one contracted liquid (S) in the confluent part, and contracting the contracted liquid by joining the flows of multiple kinds of liquids from the supply channel portion into the confluent part so as to sandwich one flow of liquid (L1) between two flows of liquid (L2); generating a swirling flow of the contracted liquid in the confluent part by offsetting a flow-in direction of the contracted liquid into the confluent part from the center of the confluent part; and discharging the contract-

ed liquid obtained by joining the flows of liquids from the confluent part through a discharge channel portion.

[0018] According to the liquid mixing method of the fifth aspect of the present invention, the swirling flow of the contracted liquid is generated in the confluent part, and thus the operation described for the micro device occurs. Thus, multiple kinds of liquids may be quickly and efficiently mixed without increasing pressure loss.

[0019] In the liquid mixing method of the aspect of the present invention, two contracted liquids are preferably formed in symmetrical positions with respect to the center of the confluent part (the sixth aspect). Thus, swirling flows of the two contracted liquids are generated in the confluent part in 180° opposite positions around the confluent part center, thereby mixing efficiency is further increased.

[0020] In the liquid mixing method of the aspects of the present invention, flow rates of the multiple kinds of liquids introduced into the confluent part are preferably controlled so that the center of swirling of the swirling flow matches the center of the confluent part (the seventh aspect). This can increase a pulling force of the contracted liquid sucked by a suction flow from the center of the confluent part into the discharge channel portion, thereby contraction by the swirling flow is provided effectively.

[0021] In the liquid mixing method of the aspects of the present invention, the liquid preferably has viscosity of 30 cp or less (the eighth aspect). The low viscosity of 30 cp or less of the liquid further facilitates mixing of the liquids and further reducing pressure loss.

[0022] According to the micro device and the liquid mixing method of the aspects of the present invention, the multiple kinds of liquids can be quickly and efficiently mixed without increasing pressure loss.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

Fig. 1 is a perspective view of an example of a device body of a micro device according to an embodiment of the present invention;

Fig. 2 is a sectional view illustrating a supply channel and a confluent part in Fig. 1;

Figs. 3A and 3B illustrate an operation of the embodiment of the present invention;

Fig. 4 is a perspective view of a device body of a conventional KM reactor;

Fig. 5 illustrates an example of a mixing rate of the micro device of the embodiment of the present invention as compared with a conventional device;

Fig. 6 illustrates an example of pressure loss of the micro device of the embodiment of the present invention as compared with the conventional device; and

Fig. 7 illustrates an example of pressure loss of the micro device of another embodiment of the present invention as compared with the conventional device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Now, preferred embodiments of a micro device and a liquid mixing method according to the present invention will be described with reference to the accompanying drawings.

[0025] Fig. 1 is a perspective view of a device body 10 of a micro device according to an embodiment of the present invention, and Fig. 2 is a sectional view of a confluent part and therearound in Fig. 1. In this embodiment, the case of mixing two kinds of liquids "A" and "B" will be described. The micro device includes at least a supply device that supplies a liquid in the device body 10.

[0026] As shown in Figs. 1 and 2, the device body 10 of the micro device of the present embodiment includes a supply channel portion 12 for two kinds of liquids "A" and "B", a confluent part 14 in which the two kinds of liquids "A" and "B" are joined through the supply channel portion 12, and a discharge channel portion 16 that discharges a confluent liquid LM obtained by joining. In the supply channel portion 12, two channel units 18 are arranged around a cylindrical confluent part 14 with one end closed, each channel unit 18 including three supply channels 18A, 18B and 18C for joining the liquids so as to sandwich one flow of the liquid "A" between two flows of the liquid "B". An upper limit of a number of the channel units 18 that can be arranged around the confluent part 14 is determined according to a size (sectional area) of the confluent part 14. The number of the channel units 18 is preferably equal to or greater than two and equal to or less than four.

[0027] As such, the channel unit 18 joins the liquids into the confluent part so as to sandwich one flow of liquid L1 between two flows of liquid L2 to form a contracted liquid S constituted by the flow of liquid L1 contracted by the flows of liquid L2. As shown in Fig. 2, among the three supply channels 18A, 18B and 18C that constitute the channel unit 18, the two supply channels 18A and 18C for sandwiching preferably form an obtuse angle α (larger than 90° and smaller than 180°). This can increase the degree of contraction. The two channel units 18 are arranged in symmetrical positions with respect to a confluent part center 14A around the confluent part 14, and a flow-in direction of the contracted liquid S flowing from each of the two channel units 18 into the confluent part 14 is offset from the confluent part center 14A. For example, each channel unit 18 is arranged so that central axes of the supply channels 18A, 18B and 18C do not pass through the confluent part center 14A. The flow-in direction of the contracted liquid S formed by the channel unit 18 is offset to generate a swirling flow in the confluent part 14. The two channel units 18 are arranged in the point-symmetrical positions to generate two swirling energies for generating the swirling flows in two positions which are at 180° opposite positions in the confluent part 14 to increase strength of the swirling flows.

[0028] As such, the swirling flow by the contracted liq-

uid S is generated in the confluent part 14, thereby allowing instantaneous mixing of the liquids L1 and L2 that constitute the contracted liquid S.

[0029] Meanwhile, the discharge channel portion 16 includes one cylindrical discharge channel 20, and is formed continuously with the cylindrical confluent part 14. The discharge channel 20 has such a length L that can ensure a distance for a mixing rate of the confluent liquid LM joined in the confluent part 14 to reach an upper limit and to reach a state of equilibrium. Generally, the length L is preferably about 10 mm. Specifically, mixing of the two kinds of liquids L1 and L2 joined in the confluent part 14 is started in the confluent part 14, and instantaneous mixing is performed in a short time for the liquids to flow through the discharge channel 20 whose length is about 10 mm. Thus, when the liquids L1 and L2 are also reacted, the reaction is completed while the liquids flow through the discharge channel 20.

[0030] As to the size of the channels used in the micro device of the present embodiment, in order to achieve quick mixing and precise control of reaction, an equivalent diameter of the supply channels 18A to 18C is preferably $10\ \mu\text{m}$ or more and $1000\ \mu\text{m}$ or less. In the present embodiment, the equivalent diameter of the cylindrical confluent part 14 may be relatively large and is preferably $0.1\ \text{mm}$ or more and $10\ \text{mm}$ or less. The discharge channel 20 preferably has an equivalent diameter equal to or larger than that of the confluent part 14 so as to quickly discharge the confluent liquid LM joined in the confluent part 14.

[0031] The equivalent diameter is also referred to as equilibrium diameter, and is a term used in the field of machine engineering. When an equivalent circular pipe with respect to a pipe (channel in the present embodiment) having an arbitrary sectional shape is supposed, a diameter of the equivalent circular pipe is referred to as an equivalent diameter. The equivalent diameter (d_{eq}) is defined as $d_{eq} = 4A/p$, where "A" is a sectional area of a pipe and "p" is a wetted perimeter length (perimeter length) of the pipe. When applied to the circular pipe, the equivalent diameter matches the diameter of the circular pipe. The equivalent diameter is used for estimating a flow or heat transfer characteristic of the pipe on the basis of data on the equivalent circular pipe, and the equivalent diameter indicates a spatial scale (representative length) of a phenomenon. The equivalent diameter is $d_{eq} = 4a^2/4a = a$ for a square pipe with each side of "a", $d_{eq} = a/3^{1/2}$ for a regular triangular pipe with each side of "a", and $d_{eq} = 2h$ for a flow between parallel flat plates with a channel height "h" (for example, see "Dictionary of machine engineering", edited by The Japan Society of Mechanical Engineers, 1997, Maruzen Co., Ltd.).

[0032] In Fig. 1, the supply channels 18A to 18C each have a square sectional shape, but not limited to this, and may have various shapes such as a circular, semi-circular, or inversed trapezoidal shape. When the confluent part 14 is formed into the cylindrical shape as described above, the discharge channel 20 preferably has

the same circular sectional shape as the confluent part 14 so as to efficiently transfer the swirling flow generated in the confluent part 14. The discharge channel 20 with a circular shape can also reduce dead space.

[0033] As a supply device that supplies the liquids L1 and L2 to the supply channels 18A to 18C, for example, a micro syringe pump can be suitably used. Also, a heating device (not illustrated) that heats the device body 10 of the micro device is provided as required. As the heating device, there is a method of incorporating a heater structure including a metal resistance wire or polysilicon or the like into the device body. When the heater structure including the metal resistance wire or polysilicon or the like is used, a thermal cycle is performed by using the heater structure for heating and using natural cooling for cooling to control temperature. In this case, generally, when the metal resistance wire is used, one more metal resistance wire which is of the same sort as that included in the heater structure is incorporated to detect the temperature on the basis of a change in resistance value thereof. And when the polysilicon is used, a thermocouple is used to detect the temperature. A temperature control function using a Peltier device may be incorporated into the device body.

[0034] As the specific kinds of the liquids L1 and L2 used in the embodiment, organic solvent such as water, acid solution, alkaline solution, methanol, ethanol or dimethyl sulfoxide, a mixture of these liquids, or a dispersed liquid that is the above described liquids or the mixture having particulates dispersed therein can be suitably used. The particulate refers to a particle having a diameter of 1 μm or less.

[0035] The liquids L1 and L2 preferably have low viscosity in terms of mixing performance and pressure loss, and more specifically, the liquids preferably have viscosity of 30 cp or less. The liquids "A" and "B" are preferably used at a flow rate of 1 to 1000 cc/min.

[0036] In this embodiment, the three liquids that constitute the contracted liquid S include two kinds of liquids: one sandwiched liquid L1 and two sandwiching liquids L2, but all the three liquids that constitute the contracted liquid S may be of different kinds. When two channel units 18 are provided, the liquids passed through the channel units 18 preferably have the same kind constitution, but may have different kind constitutions. Specifically, a liquid passed through one channel unit 18 and a liquid passed through another channel unit 18 may be of different kinds. The same applies to the case with three or more channel units 18.

[0037] Next, an operation of the micro device configured as described above will be described.

[0038] According to the micro device configured as described above, the two channel units 18 arranged around the confluent part 14 each channel unit 18 includes the three supply channels 18A to 18C that join the flows of liquids so as to sandwich one flow of liquid L1 between two flows of liquid L2. Thus, as shown in Figs. 3A and 3B, the contracted liquid S constituted by the middle flow

of liquid L1 sandwiched between the flows of liquid L2 on opposite sides is formed in the confluent part 14. Further, a flow-in direction of the liquids L1 and L2 flowing from the channel unit 18 into the confluent part 14, that is, the contracted liquid S is offset from the confluent part center 14A, and thus the swirling flow of the contracted liquid S is generated in the confluent part 14. Fig. 3A shows the liquids L1 and L2 flowing through the three supply channels 18A to 18C being supplied at the same speed of 1 m/sec, and the swirling flow of the contracted liquid S is formed around the confluent part center 14A. In this case, the center of the swirling flow is substantially identical to the confluent part center 14A. Fig. 3B shows the liquids L1 and L2 flowing through the three supply channels 18A to 18C being supplied at different speeds, and the center of the swirling flow is offset from the confluent part center 14A. In Figs. 3A and 3B, the lightest color shows the flow of the liquid L2, the second lightest color shows the flow of the liquid L1, and the darkest color shows the liquids L1 and L2 being mixed.

[0039] The swirling flow can apply a high shearing force between the flows of liquids L1 and L2 that constitute the contracted liquid S, and also generates a suction flow of the contracted liquid S sucked from the confluent part center 14A into the discharge channel 20. The contracted liquid S is pulled by the suction flow, and the middle flow of liquid L1 in the contracted liquid S is particularly contracted to be tapered.

[0040] When the flow-in direction of the contracted liquid S formed by the channel unit 18 is directed to the confluent part center 14A, the contracted liquid S easily expands in the confluent part 14 having the larger diameter than the supply channels 18A to 18C, thereby preventing the contraction of the contracted liquid S from being maintained. In contrast, when the contracted liquid S is swirled in the confluent part 14 as described in the embodiment, the flow of contracted liquid S is pressed against an inner wall of the confluent part 14, thereby preventing the expansion and further facilitating the contraction.

[0041] As such, the contracted liquid S formed by the channel unit 18 is further contracted by the swirling flow, and thus the middle flow of liquid L1 sandwiched between the two flows of liquid L2 is contracted to be tapered in the confluent part 14 to increase a mixing rate of the liquids L1 and L2. The contracted liquid S is further contracted by the swirling flow to maintain the contraction from the confluent part 14 toward the discharge channel 20, thereby providing high mixing efficiency even with a relatively large diameter of the confluent part 14. The contracted liquid S is further contracted by the swirling flow to prevent the influence on mixing performance even if flow ratios of the three flows of liquids L1 and L2 that constitute the contracted liquid S are not equal to each other, that is, even if a flow balance changes. Further, the channel unit 18 has the structure in which the flows of liquid L2 contracts the flow of liquid L1, and thus there is no need for narrowing confluent part inlets of the supply

channels 18A to 18C to prevent an increase in pressure loss.

[Example]

[0042] Next, simulation tests conducted for evaluating mixing performance and pressure loss of the micro device and the fluid mixing method of the present embodiment will be described. An analysis software used for the simulation tests is "FLUENT: version 6.3" by ANSYS Japan K.K.

[Mixing performance test]

(The present embodiment)

[0043] In the simulation, as shown in Fig. 1, a micro device (also referred to as reactor) was used including two channel units 18, each channel unit 18 including three supply channels 18A to 18C, and one discharge channel 20 in a device body 10.

[0044] The three supply channels 18A to 18C that constitute the channel unit 18 each had a square section with a size of 0.4 mm x 0.4 mm. Among the supply channels 18A to 18C, one supply channel 18B that passes a liquid L1 had a length of 3 mm, and two supply channels 18A and 18C that pass a liquid L2 each had a length of 5.3 mm. An angle α between the two supply channels 18A and 18C for sandwiching was 120°.

[0045] Meanwhile, a confluent part 14 was formed into a cylindrical shape having a diameter of 1.1 mm and a depth of 0.4 mm. The discharge channel 20 was formed into a cylindrical shape having the same diameter of 1.1 mm as the confluent part 14 and a length of 10 mm.

(Comparative example)

[0046] For comparison, a KM reactor 30 was used as a conventional reactor in Fig. 4. As is clear from Fig. 4, in a device body 31 of the KM reactor 30, three supply channels 32A, 32B and 32C that pass a liquid L1 and three supply channels 34A, 34B and 34C that pass a liquid L2 are joined in a confluent part 36, and the liquids are discharged from a discharge channel 38. However, the six channels 32A to 32C and 34A to 34C are radially extended from a center 36A of the confluent part 36, angles between the channels are all 60°, and the liquids L1 and L2 flowing from the six channels 32A to 32C and 34A to 34C into the confluent part 36 collide with each other in the confluent part center 36A. Specifically, the KM reactor 30 is not configured so that a flow-in direction of liquids flowing into a confluent part 14 is offset from the confluent part center 14A as in the present embodiment.

[0047] In the KM reactor 30 used, the three supply channels 32A to 32C that pass the liquid L1 had a size of 0.4 mm x 0.2 mm and a length of 3 mm. The three supply channels 34A to 34C that pass the liquid L2 had a size of 0.4 mm x 0.4 mm and a length of 5.3 mm. The

confluent part 36 was formed into a cylindrical shape having a diameter of 0.8 mm and a depth of 0.4 mm. The discharge channel 38 was formed into a cylindrical shape having the same diameter of 0.8 mm as the confluent part 36 and a length of 10 mm.

(Test condition)

[0048] For both the present embodiment and the comparative example, dimethyl sulfoxide (DMSO) was used as the liquid L1, and a flow rate thereof was set to 500 cc/min (cubic centimeter per minute) as simulation conditions. Also, water was used as the liquid L2, and a flow rate thereof was set to 1000 cc/min.

(Test results)

[0049] The test results are shown in Fig. 5. In the mixing performance test, in addition to comparison between a mixing rate in the use of the micro device 10 of the present embodiment and a mixing rate in the use of the conventional KM reactor 30, a mixing rate when there are flow rate variations in the micro device 10 of the present embodiment was also tested. Specifically, it is checked that whether combination use of two actions, that is, contraction and swirling which are the features of the present embodiment can reduce the influence of the flow rate variations on a mixing rate. The mixing rate is a percentage of a mixing rate when complete mixing of the liquids L1 and L2 is 100%.

[0050] For the reactor of the present embodiment (without flow rate variations) in Fig. 5, the same flow rate of 500 cc/min of the liquid L1 was passed through the two supply channels and the same flow rate of 1000 cc/min of the liquid L2 was passed through the four supply channels so that the liquids L1 and L2 are evenly supplied to the respective supply channels.

[0051] For the reactor of the present embodiment (with flow rate variations), among the two supply channels 18B that pass the liquid L1, a flow rate of one of the supply channels 18B was set to 375 cc/min and a flow rate of the other was set to 625 cc/min so that variations of 25% occur. Also, among the two supply channels 18A and 18C for the liquids L2 for sandwiching the flow of liquid L1, a flow rate of one of the supply channels was set to 500 cc/min and a flow rate of the other was set to 1500 cc/min so that variations of 50% occur.

[0052] Thus, as is clear from Fig. 5, the reactor of the present embodiment (without flow rate variations) could achieve a mixing rate equal to or higher than that of the conventional KM reactor. It could be also confirmed that there is little influence on the mixing rate even if there are flow rate variations as the reactor of the present embodiment (with flow rate variations).

[Pressure loss test]

[0053] Also, a pressure loss test for checking a reduc-

tion in pressure loss as the feature of the micro device of the present embodiment was conducted and compared with the conventional KM reactor. The configuration of the reactor used in the pressure loss test was the same as in the mixing performance test for both the present embodiment and the comparative example.

[0054] Dimethyl sulfoxide (DMSO) was used as the liquid L1 in the test, and a flow rate thereof was set to 100 cc/min. Also, water was used as the liquid L2, and a flow rate thereof was set to 200 cc/min, and the liquids were actually supplied to measure pressure loss.

[0055] The test results are shown in Fig. 5. Fig. 6 shows results of pressure loss when only the liquid L2 is passed and immediately before the liquid L1 is passed. Fig. 7 shows results of pressure loss when only the liquid L1 is passed and immediately before the liquid L2 is passed.

[0056] As is clear from Figs. 6 and 7, it was confirmed that the pressure loss is remarkably reduced in the micro device of the present embodiment as compared with the conventional KM reactor. Specifically, it is supposed that the micro device of the present embodiment joins the flows of liquids into the confluent part so as to sandwich one flow of liquid between two flows of liquid to form the contracted liquid in the confluent part, thereby effectively preventing an increase in pressure loss.

[0057] As described above, it became apparent that the micro device of the present embodiment can maintain higher mixing performance, prevent the mixing performance from being influenced by flow rate variations, and further reduce pressure loss, as compared with the conventional KM reactor.

Claims

1. A micro device (10) comprising:

a supply channel portion (12);
a confluent part (14) into which multiple kinds of liquids (L1, L2) flow from the supply channel portion to join flows of the liquids from the supply channel portion; and
a discharge channel portion (16) through which a confluent liquid obtained by joining the flows of liquids is discharged,
wherein the supply channel portion includes one or more channel units (18) arranged around the confluent part, each of the channel units including three supply channels (18A, 18B, 18C) for joining the multiple kinds of liquids so as to sandwich one flow of liquid (L1) between two flows of liquid (L2), and
a flow-in direction of the liquids flowing from each of the channel units into the confluent part is offset from the center (14C) of the confluent part.

2. The micro device according to claim 1, wherein

among the three supply channels that constitute the channel unit, two supply channels (18A, 18C) for sandwiching one supply channel (18B) form an obtuse angle.

3. The micro device according to claim 1 or 2, wherein two channel units are provided in point-symmetrical positions with respect to the center of the confluent part.

4. The micro device according to any one of claims 1 to 3, wherein the confluent part is a micro space, and has an equivalent diameter of 0.1 mm to 10 mm.

5. A liquid mixing method comprising steps of:

joining flows of multiple kinds of liquids (L1, L2) flowing from a supply channel portion (12) into a confluent part (14);

forming at least one contracted liquid (S) in the confluent part, and contracting the contracted liquid by joining the flows of multiple kinds of liquids from the supply channel portion into the confluent part so as to sandwich one flow of liquid (L1) between two flows of liquid (L2);

generating a swirling flow of the contracted liquid in the confluent part by offsetting a flow-in direction of the contracted liquid into the confluent part from the center (14A) of the confluent part; and

discharging the contracted liquid obtained by joining the flows of liquids (L1, L2) from the confluent part through a discharge channel portion (16).

6. The liquid mixing method according to claim 5, wherein the forming step includes step of forming two contracted liquids in point-symmetrical positions with respect to the center of the confluent part.

7. The liquid mixing method according to claim 5 or 6, further comprising step of controlling flow rates of the multiple kinds of liquids introduced into the confluent part so that the center of swirling of the swirling flow matches the center of the confluent part.

8. The liquid mixing method according to any one of claims 5 to 7, wherein the liquid (L1, L2) has viscosity of 30 cp or less.

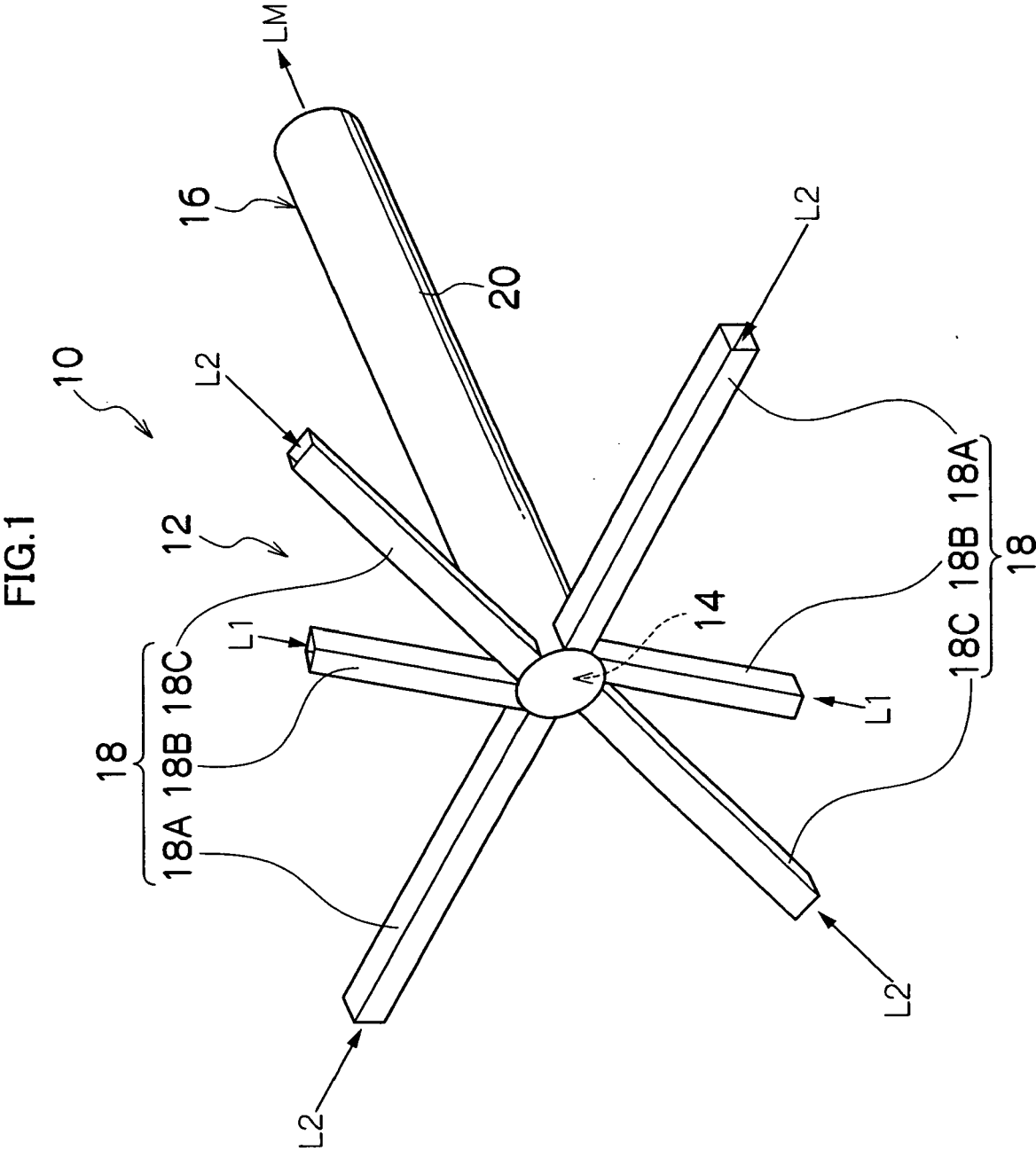


FIG.2

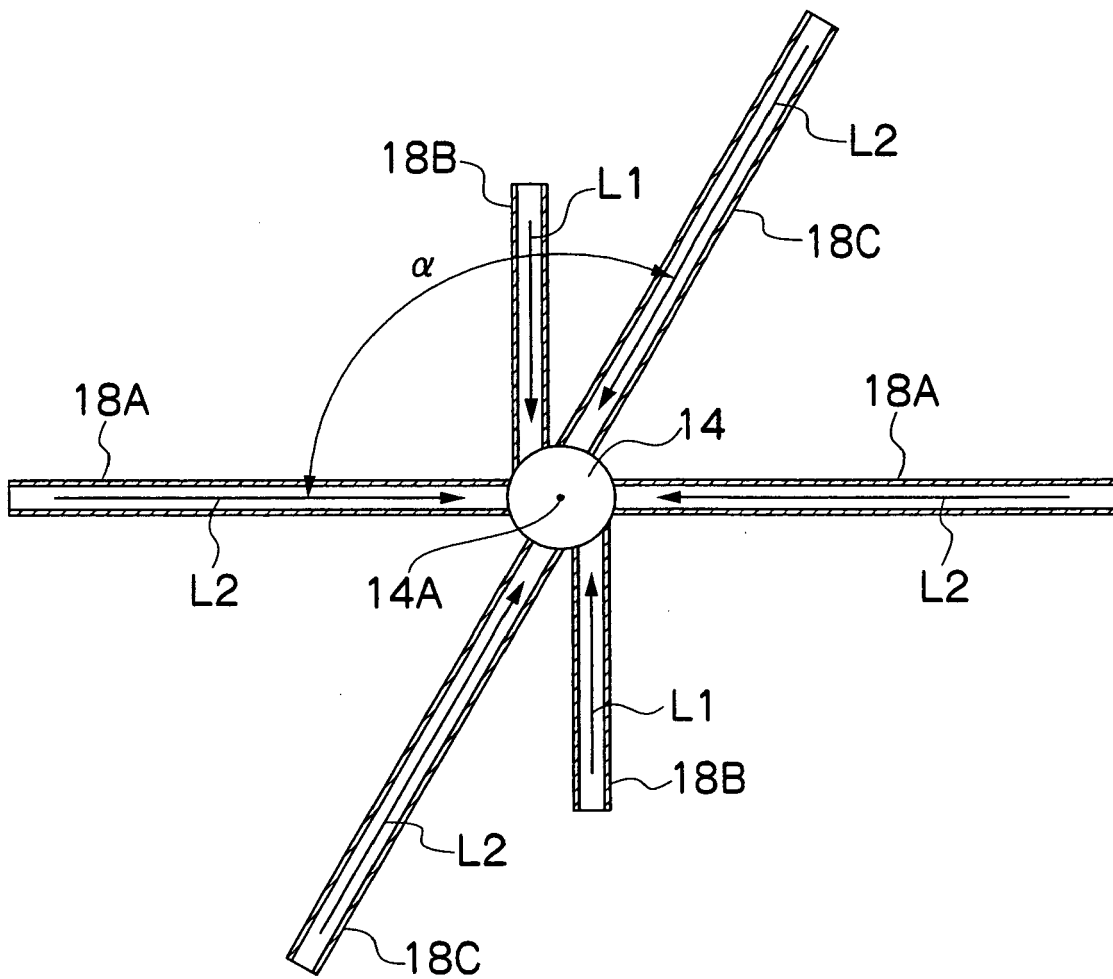


FIG.3A

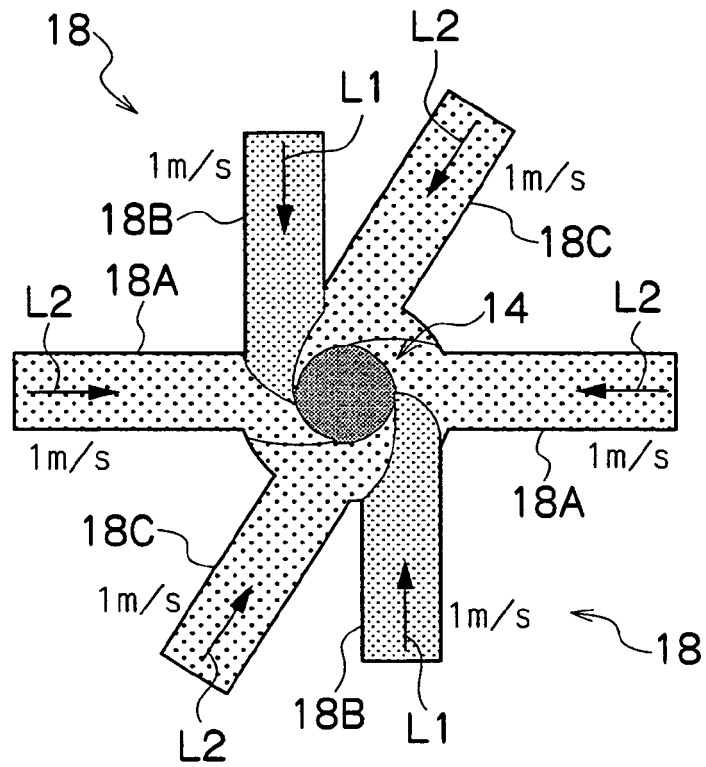


FIG.3B

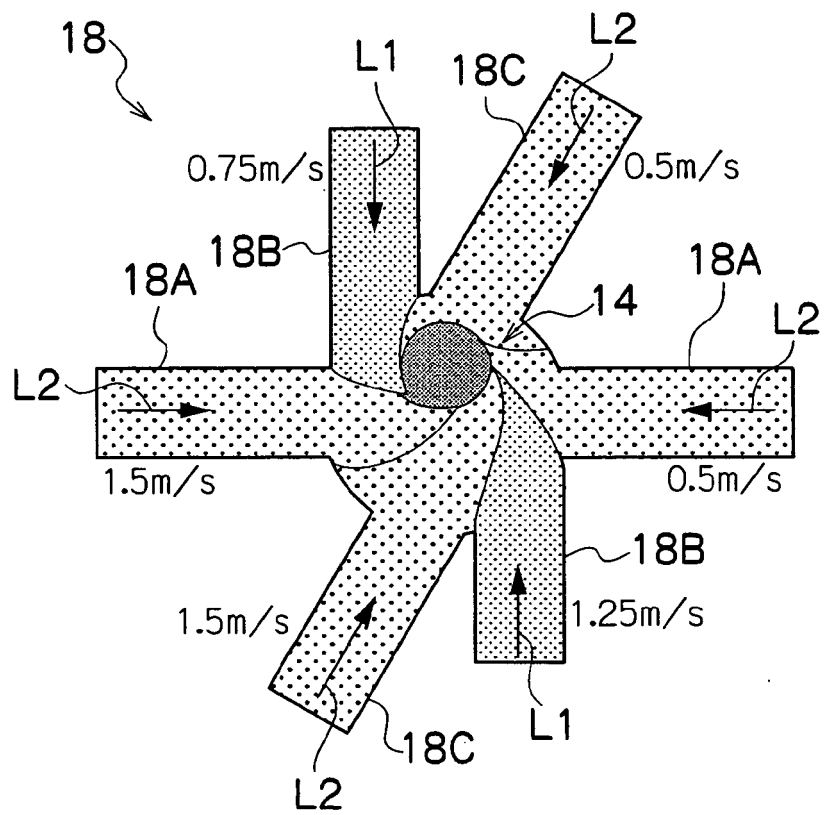


FIG.4

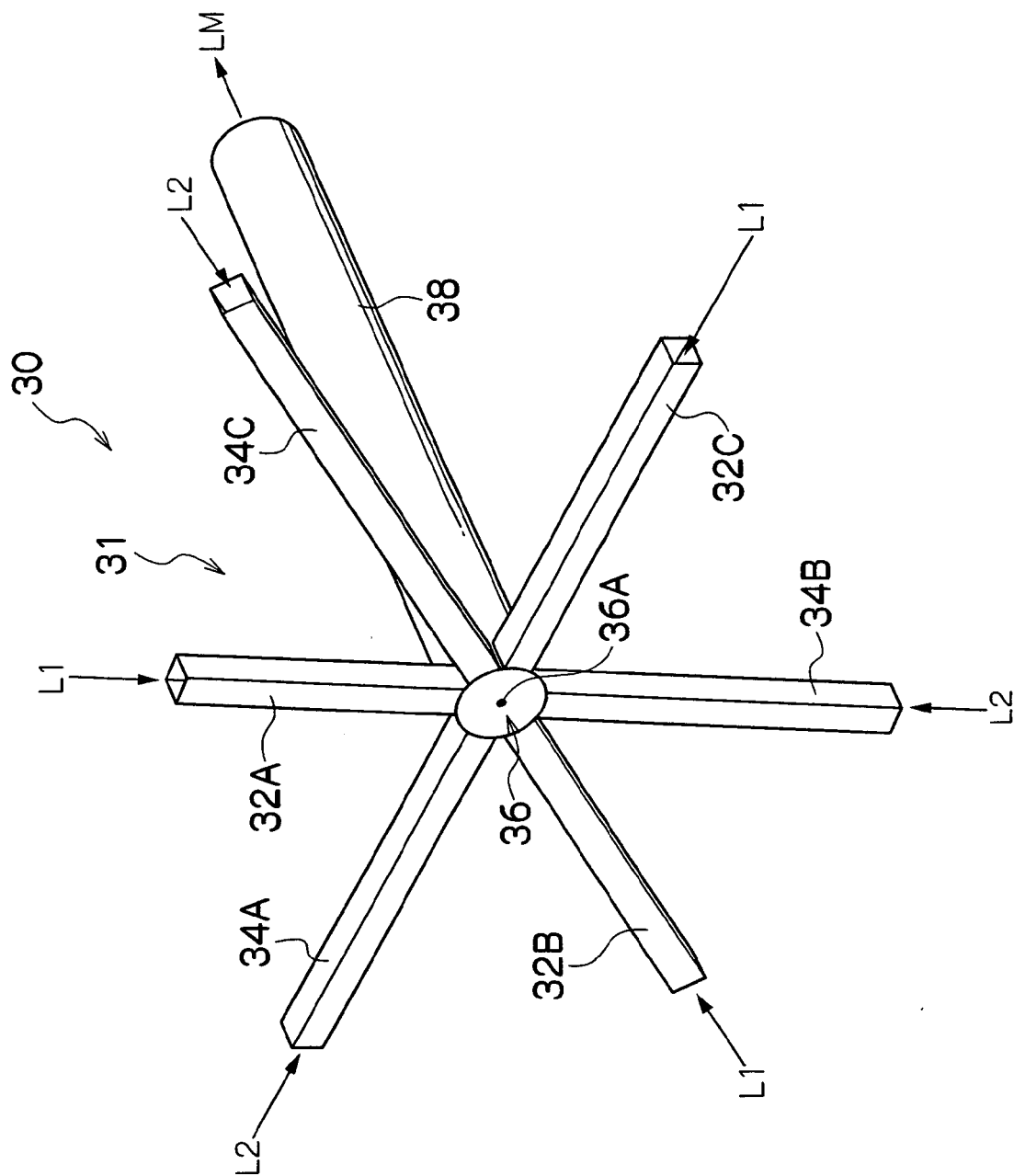


FIG.5

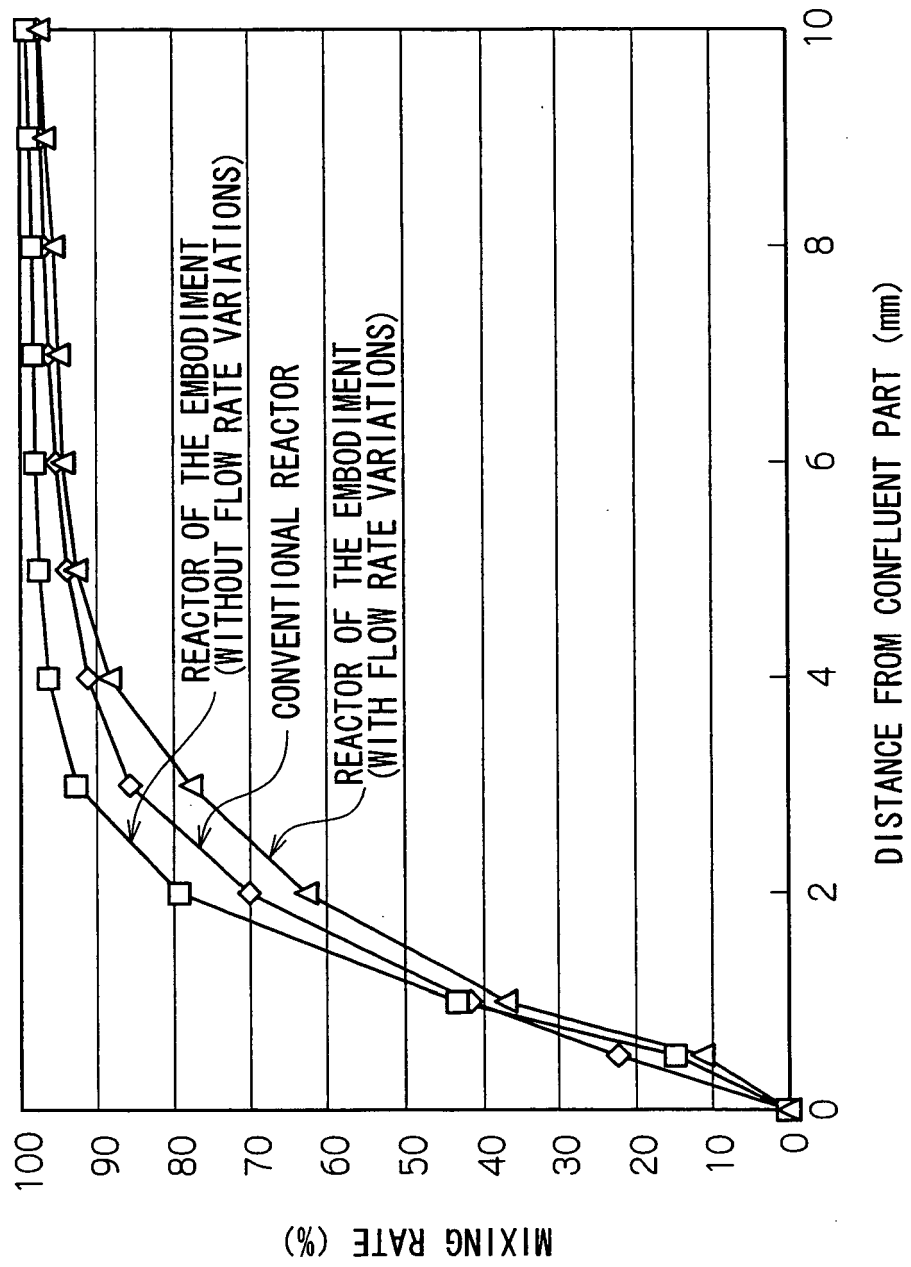


FIG.6

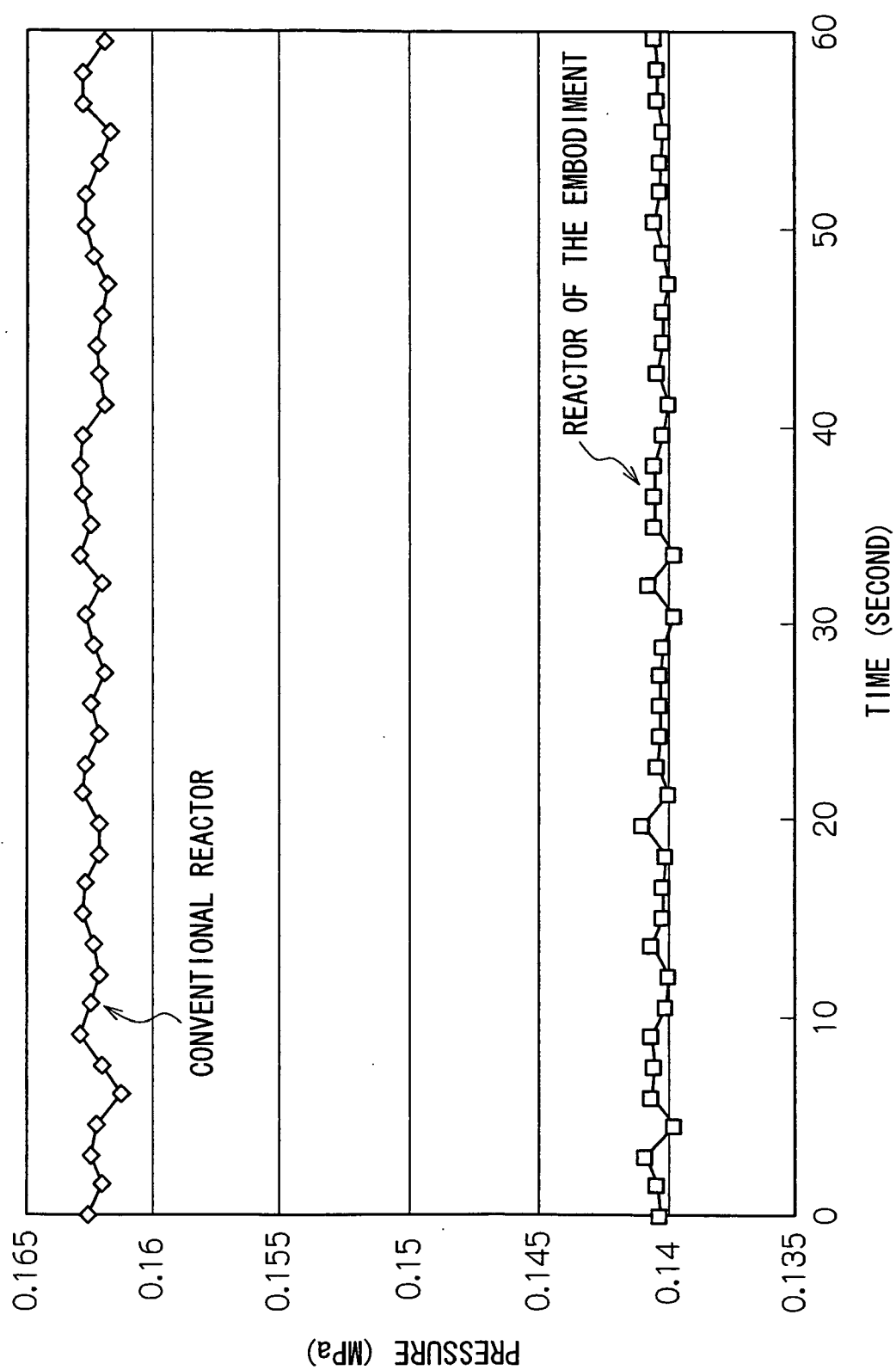
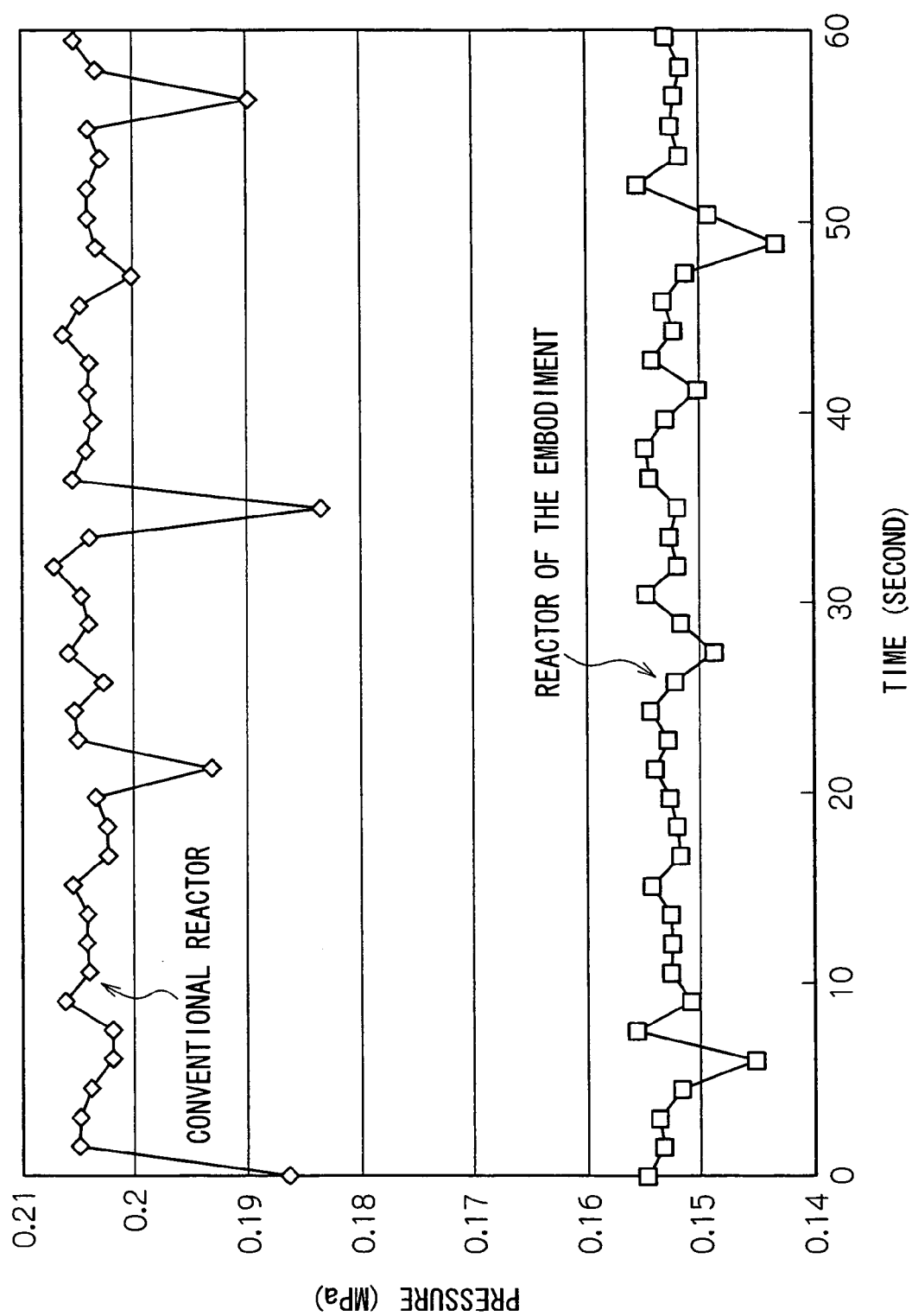


FIG. 7



REFERENCES CITED IN THE DESCRIPTION

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