

DESCRIPTION

HIGH-PRESSURE EJECTION NOZZLE APPARATUS AND GROUND
IMPROVEMENT APPARATUS IN WHICH HIGH-PRESSURE EJECTION
5 NOZZLE APPARATUS IS MOUNTED

Technical Field

[0001] The present invention is a high-pressure ejection nozzle apparatus and a
ground improvement apparatus in which the high-pressure ejection nozzle apparatus
10 is mounted, the high-pressure ejection nozzle apparatus being in communication with
the interior of a hardening material liquid supply pipe in an injection rod and being
provided on a side surface of a monitor that is coupled to the leading end of the
injection rod.

15 Background Art

[0002] A ground improvement apparatus that inserts an injection rod into a borehole
drilled into the ground and ejects a hardening material liquid in a direction orthogonal
to the axial direction of the injection rod from a nozzle attached to the side surface at
the leading end of the injection rod has conventionally been known.

20 [0003] As shown in FIG. 32, the ground improvement apparatus is provided with an
ejection port 107 on a lower end portion side wall 101a of an injection rod 101 with a
double-layer pipe structure composed of a hardening material supply pipe 108 and a
compressed air supply pipe 109. The ejection port 107 is constituted by a discharge
port of the hardening material liquid ejection nozzle 110 that is in communication with
25 the hardening material liquid supply pipe 108 of the injection rod 101, and a
compressed air ejection nozzle 111 that surrounds the hardening material liquid
ejection nozzle 110 and is in communication with the compressed air pressure feed
pipe 109. Also, the hardening material liquid is supplied from the upper portion of
the injection rod 101 via the hardening material liquid supply pipe 108 and the
30 hardening material liquid is ejected from the hardening material liquid nozzle 110
(e.g., Patent Document 1). Here, FIG. 32 is a front cross-sectional view of a
conventional injection rod.

Prior Art Document

Patent Document

[0004]

5 [Patent Document 1] JP H10-331151A

Summary of Invention

Problem to be Solved by the Invention

[0005] However, with the conventional ground improvement apparatus, the
10 hardening material liquid is sent out from the hardening material liquid supply pipe
108 in the axial direction of the injection rod 101 to the hardening material liquid
ejection nozzle 110 that is approximately perpendicular to the axis of the injection rod
101, and therefore part of the flow of the hardening material liquid becomes a
rotational flow at the portion at which the hardening material liquid is emitted from
15 the hardening material liquid supply pipe 108 to the hardening material liquid
ejection nozzle 10, that is, the bent portion of the pipe path, and part of the flow of the
hardening material liquid enters a turbulent flow state in front of the hardening
material liquid ejection nozzle 110. Also, motive force loss of the hardening material
liquid ejected from the hardening material liquid ejection nozzle 110 is incurred due to
20 turbulence in the flow of the hardening material liquid flowing inside of the hardening
material liquid ejection nozzle 110 and due to the difference in flow rate between the
inner circumferential portion and the central portion of the hardening material liquid
ejection nozzle 110. Thus, there has been a problem in that when motive force loss of
the hardening material liquid ejected from the hardening material liquid ejection
25 nozzle 110 occurs, the cutting ability of the hardening material liquid ejected from the
hardening material liquid ejection nozzle 110 declines, and the ejection distance
shortens.

[0006] As described above, with the conventional ground improvement apparatus,
the ejection distance shortened due to the occurrence of motive force loss of the
30 hardening material liquid ejected from the hardening material liquid ejection nozzle,
and therefore in order to solve this problem, ground in a wide range was improved by
increasing the ejection time of the hardening material liquid ejected from the

hardening material liquid ejection nozzle and shortening the interval of pulling up the injection rod. However, if the ground in a wide range is improved with such a method, the execution period of the ground improvement work will increase in length and the execution efficiency will also decrease, and as a result, there has been a problem in

5 that the work cost of the ground improvement work also increases. Although a method of increasing the supply pressure of the hardening material liquid supplied to the hardening material liquid ejection nozzle is also an example of a method for ejecting the hardening material liquid a long distance from the hardening material liquid ejection nozzle, with this method, the hardening material liquid is supplied at a

10 high pressure to the injection rod and the hardening material liquid supply nozzle, and therefore peripheral devices wear more rapidly, and there has also been a possibility that wearing of these peripheral devices will cause defects in the ground improvement. [0007] Also, as shown in later-described FIG. 7, it is known that if the following relational expressions are satisfied, where d is the exit diameter of the ejection nozzle,

15 L is the length of the equal-diameter portion of the leading end of the ejection nozzle, LL is the overall length of the ejection nozzle, and B is the restriction angle from the rear end portion of the ejection nozzle to the equal-diameter portion of the leading end of the ejection nozzle, the hardening material liquid will be ejected a long distance from the ejection nozzle. Here, FIG. 7 is a drawing of the first embodiment of the present

20 invention, and description will be given herein with attention given to only the ejection nozzle.

Equation 1

$$L = 3d \sim 4d \quad (\text{Equation 1})$$

Equation 2

25 $LL = 15d \sim 20d \quad (\text{Equation 2})$

Equation 3

$$B = 12 \text{ degrees} \sim 13 \text{ degrees} \quad (\text{Equation 3})$$

[0008] In recent years, there has been much demand for creation of a large-diameter underground consolidated body, and in order to create such a large-diameter

30 underground consolidated body, it is necessary to increase the exit diameter d of the ejection nozzle. However, if the exit diameter d of the ejection nozzle increases, the length L of the equal-diameter portion of the leading end of the ejection nozzle and the

overall length LL of the ejection nozzle will inevitably need to be increased in order to satisfy the relational expressions of Equations 1 to 3 above, and a problem will occur in that the outer shape of the monitor will increase in size. Furthermore, if the outer shape of the monitor increases in size, the injection rod will also increase in size, the
5 entire injection rod will increase in weight, and a boring machine and the like supporting the injection rod will also increase in size, and therefore the execution cost of ground improvement will also increase, which is problematic.

[0009] The present invention was made in view of the above-described problems, and it is an object thereof to provide a high-pressure ejection nozzle apparatus that can
10 eject a hardening material liquid a long distance from a high-pressure ejection nozzle, and a ground improvement apparatus in which the high-pressure ejection nozzle is mounted.

Means for Solving the Problems

15 Summary

[0010] In order to solve the above-described problems and achieve the above-described object, a first aspect of the present disclosure is a high-pressure ejection nozzle apparatus that communicates with an interior of a hardening material liquid supply pipe formed in an axial direction in an injection rod, and is provided on a
20 side surface of a monitor coupled to a leading end of the injection rod, the high-pressure ejection nozzle apparatus including a nozzle main body portion in which a hollow shape is formed, the hollow shape including: an intermediate inner diameter portion having a tapered surface shape with an inner circumferential surface formed with a diameter that decreases in the leading end direction; a leading end inner
25 diameter portion that communicates with a leading end of the intermediate inner diameter portion and has approximately the same diameter as the leading end of the intermediate inner diameter portion; and a rear end inner diameter portion that

communicates with a rear end of the intermediate inner diameter portion and is formed with a diameter that is approximately the same as the diameter of the rear end of the intermediate inner diameter portion, or with a diameter that increases in the rear end direction from being approximately the same. A flow path division portion
5 that divides a cross section of the hollow shape into a plurality of spaces is formed in the rear end inner diameter portion of the nozzle main body portion. At an

approximately central portion of the hollow-shaped rear end inner diameter portion near the flow path division portion, the flow path division portion includes a portion having an area that is 2% to 20% of a cross-sectional area of the hollow shape of the rear end inner diameter portion near the flow path division portion. A hardening material liquid flowing in the rear end inner diameter portion of the nozzle main body portion is more finely laminarized by the spaces divided by the flow path division portion, and thereafter is sent in the leading end direction with the diameter reduced by the hollow-shaped space of the intermediate inner diameter portion in which there is no concrete object, and therefore a cutting ability of the hardening material liquid ejected from the leading end inner diameter portion of the nozzle main body portion is increased, and the hardening material liquid can be ejected a longer distance.

[0011] When the hardening material liquid undergoes a transition in direction from the direction of the hardening material liquid supply pipe in the injection rod to the direction of the hollow shape of the nozzle main body portion in the monitor, a portion of the flow of the hardening material liquid becomes a rotational flow at the bent portion of the pipe path and a portion of the flow of the hardening material liquid enters a turbulent flow state in front of the nozzle main body portion. However, according to the present invention, the hardening material liquid flowing in the approximate central portion of the rear end inner diameter portion of the nozzle main body portion collides with the approximate central portion of the flow path division portion, and the hardening material liquid in the approximate central portion of the rear end inner diameter portion that was subjected to collision flows into the flow paths divided by the flow path division portion and is sent to the inner circumferential surface of the intermediate inner diameter portion formed with a decreasing diameter, while the speed of the hardening material liquid is increased. Therefore, the thickness of the boundary layer of the turbulent flow that occurs at the inner circumferential surface of the intermediate inner diameter portion can be reduced, and finer laminarization can be achieved. Accordingly, by increasing the cutting ability of the hardening material liquid ejected from the material liquid ejection nozzle at the leading end of the nozzle main body portion, the compositional structure of the ground can be broken and the hardening material liquid can be ejected a longer distance. That is, since the thickness of the boundary layer of the turbulent flow that occurs at

the inner circumferential surface of the intermediate inner diameter portion can be reduced, the hardening material liquid ejected from the ejection port of the material liquid ejection nozzle at the leading end of the nozzle main body portion is ejected at approximately the same speed at approximately the entire surface of the ejection port.

5 Accordingly, it is possible to lengthen the region (potential core region) in which the speed of the hardening material liquid ejected from the ejection port of the material liquid ejection nozzle at the leading end of the nozzle main body portion does not wane, and the hardening material liquid can be ejected a longer distance.

[0012] A first example of the present disclosure is the high-pressure ejection nozzle
10 apparatus according to the first aspect, wherein the total cross-sectional area of the flow path divided by the flow path division portion is 40% to 60% of the cross-sectional area of the hollow shape of the rear end inner diameter portion near the flow path division portion.

[0013] According to the present disclosure, the total cross-sectional area of the flow
15 path divided by the flow path division portion is 40% to 60% of the cross-sectional area of the hollow shape of the rear end inner diameter portion near the flow path division portion, and therefore the hardening material liquid that flows in the rear end inner diameter portion of the nozzle main body portion is split in the spaces divided by the flow path division portion, and is sent in the leading end direction while being
20 compressed by a suitable compression force. Accordingly, finer laminarization of the hardening material liquid can be achieved while further increasing the speed in the spaces divided by the flow path division portion 31, and by increasing the cutting ability of the hardening material liquid ejected from the material liquid ejection nozzle
21 at the leading end of the nozzle main body portion, the compositional structure of
25 the ground can be broken and the hardening material liquid can be ejected a longer distance.

[0014] A second example of the present disclosure is the high-pressure ejection nozzle
according to the first aspect or the first example, wherein the cross-sectional area of
the hollow shape near the flow path division portion is the cross-sectional area of the
30 hollow shape directly in front of the

flow path division portion.

[0015] A third example of the present disclosure is the high-pressure ejection nozzle according to the first aspect or the first example, wherein the cross-sectional area of

the hollow shape near the flow path division portion is the cross-sectional area of the hollow shape directly behind the flow path division portion.

[0016] A fourth example of the present disclosure is the high-pressure ejection nozzle according to any one of the first aspect and the first to third examples, wherein the
5 flow path division portion is formed in a cross shape.

[0017] According to the present disclosure, the flow path division portion is formed in a cross shape, and therefore the hardening material liquid that flows in the approximate central portion of the rear end inner diameter portion of the nozzle main body portion collides with the approximate central portion of the cross shape of the
10 flow path division portion, the hardening material liquid in the approximate central portion of the rear end inner diameter portion that was subjected to collision flows uniformly into the flow paths divided by the cross-shaped flow path division portion, and is sent to the inner circumferential surface of the intermediate inner diameter portion formed with a decreasing diameter, while the speed of the hardening material
15 liquid is increased. Accordingly, the thickness of the boundary layer of the turbulent flow that occurs at the inner circumferential surface of the intermediate inner diameter portion can be reduced, and finer laminarization can be achieved. Accordingly, by increasing the cutting ability of the hardening material liquid ejected from the material liquid ejection nozzle on the leading end of the nozzle main body
20 portion, the compositional structure of the ground can be broken and the hardening material liquid can be ejected a longer distance.

[0018] A fifth example of the present disclosure is the high-pressure ejection nozzle according to any one of the first aspect and the first to fourth examples, wherein the rear end inner diameter portion of the nozzle main body portion is formed protruding
25 into a hardening material liquid flow path formed in the axial direction in the monitor.

[0019] According to the present disclosure, the rear end inner diameter portion of the nozzle main body portion is provided protruding into the hardening material liquid flow path in the monitor, and therefore the linear distance that the hardening material in the inner portion of the nozzle main body portion flows can be

made longer, the occurrence of turbulent flow is significantly reduced, the cutting ability of the hardening material liquid ejected from the leading end of the nozzle main body portion can be increased, and the hardening material liquid can be ejected a long distance.

[0020] A second aspect of the present disclosure is a ground improvement apparatus having a monitor in which the high-pressure ejection nozzle apparatus according to any one of the first aspect and the first to fifth examples is mounted.

5 Effects of the Invention

[0021] According to the present invention, the hardening material liquid in the approximate central portion of the rear end inner diameter portion of the nozzle main body portion collides with the approximate central portion of the flow path division portion, and the hardening material liquid in the approximate central portion of the rear end inner diameter portion that was subjected to collision flows into the flow paths divided by the flow path division portion and is sent to the inner circumferential surface of the intermediate inner diameter portion formed with a decreasing diameter, while the speed of the hardening material liquid is increased. Therefore, the thickness of the boundary layer of the turbulent flow that occurs at the inner circumferential surface of the intermediate inner diameter portion can be reduced, and finer laminarization can be achieved. Accordingly, by increasing the cutting ability of the hardening material liquid ejected from the material liquid ejection nozzle at the leading end of the nozzle main body portion, the compositional structure of the ground can be broken and the hardening material liquid can be ejected a longer distance.

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Brief Description of Drawings

[0022] FIG. 1 is a diagram showing an execution state of a ground improvement apparatus in which a high-pressure ejection nozzle apparatus is mounted, according to a first embodiment of the present invention.

25 FIG. 2(a) is a perspective view of the exterior of a monitor in which the high-pressure ejection nozzle apparatus is mounted. FIG. 2(b) is a diagram showing a joining pin that joins an insertion rod and the monitor.

FIG. 3 is a cross-sectional view taken along line A-A in FIG. 2.

30 FIG. 4(a) is an enlarged view of a P-P portion shown in FIG. 3. FIG. 4(b) is a diagram showing a nozzle main body portion attachment hole of the monitor.

FIG. 5 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus of the first embodiment of the present invention.

FIG. 6 shows cross-sectional views of the constituent components.

FIG. 7 is a diagram showing dimensions of the high-pressure ejection nozzle apparatus of the first embodiment of the present invention.

FIG. 8 is a cross-sectional view taken along line B-B in FIG. 3.

5 FIG. 9 is a cross-sectional view taken along line C-C in FIG. 3.

FIG. 10 is a diagram showing a method for assembling the high-pressure ejection nozzle apparatus and peripheral instruments thereof, according to the first embodiment of the present invention.

10 FIG. 11 is a diagram showing a method for mounting the high-pressure ejection nozzle apparatus.

FIG. 12(a) is an enlarged diagram of the P-P portion shown in FIG. 3 of the high-pressure ejection nozzle apparatus according to a second embodiment of the present invention. FIG. 12(b) is a diagram showing the nozzle main body portion attachment hole of the monitor.

15 FIG. 13 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus according to the second embodiment of the present invention.

FIG. 14 shows cross-sectional views of the constituent components.

20 FIG. 15 is a cross-sectional view of the high-pressure ejection nozzle apparatus mounted in the monitor.

FIG. 16(a) is an enlarged diagram of the P-P portion shown in FIG. 3 of the high-pressure ejection nozzle apparatus according to a third embodiment of the present invention. FIG. 16(b) is a diagram showing the nozzle main body portion attachment hole of the monitor.

25 FIG. 17 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus according to the third embodiment of the present invention.

FIG. 18 is a cross-sectional view of the constituent components.

FIG. 19 is a cross-sectional view of the high-pressure ejection nozzle apparatus mounted in the monitor.

30 FIG. 20 is a diagram showing the nozzle main body portion mounted in a downward-facing nozzle main body portion attachment hole of a first variation of the present invention.

FIG. 21 is a diagram showing the nozzle main body portion mounted in an upward-facing nozzle main body portion attachment hole of a second variation of the present invention.

FIG. 22 is a diagram showing a flow path division portion formed in a rear end inner diameter portion inside of a nozzle main body extended portion of a third variation of the present invention.

FIG. 23(a) is a diagram showing an attachment position of the high-pressure ejection nozzle apparatus of a fourth variation of the present invention. FIG. 23(b) is a cross-sectional view of a monitor attachment position of the high-pressure ejection nozzle apparatus of the fourth variation of the present invention.

FIG. 24 is a diagram showing a flow path closing tool mounted in a nozzle main body portion attachment hole 23 of a fifth variation of the present invention.

FIG. 25(a) is an enlarged diagram of the P-P portion shown in FIG. 3 of a sixth variation of the present invention. FIG. 25(b) is a diagram showing the nozzle main body portion attachment hole of the monitor.

FIG. 26 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus according to the sixth variation of the present invention.

FIG. 27 shows cross-sectional views of the constituent components.

FIG. 28(a) is an enlarged diagram of the P-P portion shown in FIG. 3 of the high-pressure ejection nozzle apparatus according to an eighth variation of the present invention. FIG. 28(b) is a diagram showing the nozzle main body portion attachment hole of the monitor.

FIG. 29 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus.

FIG. 30 shows cross-sectional views of the constituent components.

FIG. 31 is a diagram showing a method for mounting the high-pressure ejection nozzle apparatus.

FIG. 32 is a front cross-sectional view of a conventional injection rod.

30 Modes for Carrying out the Invention

First Embodiment

[0023] Hereinafter, a first embodiment of a high-pressure ejection nozzle apparatus 1

of the present invention will be described with reference to the drawings. FIG. 1 is a diagram showing an execution state of a ground improvement apparatus in which the high-pressure ejection nozzle apparatus according to the first embodiment of the present invention is mounted.

5 [0024] As shown in FIG. 1, a monitor 3 is attached by being joined to the leading end of an injection rod 2. Water (liquid) supplied via the injection rod 2 and the inside of the monitor 3 is ejected from a leading end nozzle 4 provided at the leading end of the monitor 3, and cement milk (hardening material liquid) and air that are supplied via the injection rod 2 and the inside of the monitor 3 are ejected from the high-pressure
10 ejection nozzle apparatus 1 provided on the side surface of the monitor 3.

[0025] A work machine 5 is a machine that supports the injection rod 2, moves the injection rod 2 up and down, and rotates and swings the injection rod 2. Accordingly, the injection rod 2 and the monitor 3 can not only move up and down, but also rotate and swing due to the work machine 5.

15 [0026] A swivel 6 is attached to the rear end portion of the injection rod 2. Also, the injection rod 2 is constituted by a double-layer pipe, cement milk or water (liquid) is supplied to a cement milk/water supply path 7 inside of the injection rod 2, and air is supplied to an air supply path 8 on the outer side inside of the injection rod 2 (see FIG. 3). Note that in the first embodiment, the cement milk (hardening material liquid)
20 supply pipe and the water supply pipe are formed as one supply pipe using the cement milk/water supply path 7, but there is no limitation to this, and the cement milk (hardening material liquid) supply pipe and the water supply pipe may also be formed as separate supply pipes. Also, in this manner, if the cement milk (hardening material liquid) supply pipe and the water supply pipe are formed as separate supply
25 pipes, a porous pipe or a multi-layer pipe such as a triple-layer pipe that divides the cement milk (hardening material liquid) and the water may also be used. Also, in the first embodiment, the inside of the injection rod 2 constituted by a double-layer pipe is the cement milk/water supply path 7 and the outer side is the air supply pipe 8, but there is no limitation to this, and the inside of the injection rod 2 constituted by the
30 double-layer pipe may also be the air supply path and the outer side may also be the cement milk/water supply path.

[0027] The monitor 3 is attached by being joined to the leading end of the injection

rod 2 as described above. Also, a cement milk/water flow path 9 that communicates with the cement milk/water supply path 7 of the injection rod 2 is formed in the axial direction in the center of the inner portion of the monitor 3, and four air flow paths 10 that communicate with the air supply path 8 of the injection rod 2 are formed in the axial direction in the outer periphery of the cement milk/water flow path 9 (see FIGS. 3 and 8). The air flow paths 10 will be described later in detail. Note that in the first embodiment, the cement milk (hardening material liquid) flow path and the water flow path are formed as one flow path using the cement milk/water flow path 9, but there is no limitation to this, and the cement milk (hardening material liquid) flow path and the water flow path may also be constituted as separate flow paths.

[0028] The swivel 6 is coupled to supply hoses 14, 15, and 16 for the water, air, and cement milk supplied from a water supply source 11, an air supply source 12, and a cement milk (hardening material liquid) supply source 13, and supplies the water, air, and cement milk to the air supply path 8 and the cement milk/water supply path 7 provided in the injection rod 2 (see FIG. 1). In this manner, the cement milk, air, and water supplied from the supply source 11 of the water, the supply source 12 of the air, and the supply source 13 of the cement milk pass through the following path: supply hoses 14, 15, 16 → swivel 6 → supply paths 7, 8 → flow paths 9, 10, and are ejected from nozzles and the like. Here, the water and cement milk are supplied from the water and cement milk supply hoses 14 and 16 to the cement milk/water supply path 7.

[0029] Next, configurations of the injection rod 2 and the monitor 3 will be described specifically with reference to FIGS. 2 to 9. FIG. 2(a) is a perspective view of the exterior of the monitor in which the high-pressure ejection nozzle apparatus according to the first embodiment of the present invention is mounted, FIG. 2(b) is a diagram showing a joining pin for joining the injection rod and the monitor, FIG. 3 is a cross-sectional view taken along line A-A shown in FIG. 2, FIG. 4(a) is an enlarged view of the P-P portion shown in FIG. 3, and FIG. 4(b) is a diagram showing a nozzle main body portion attachment hole of the monitor. Here, FIGS. 2(a) and 3 do not show the upper side of the insertion rod 2.

[0030] As shown in FIG. 2(a), the injection rod 2 is attached by being joined to the monitor 3 as described above. The joining of the injection rod 2 and the monitor 3 will

be described later. Here, a double-layer pipe constituted by an injection rod outer pipe 17 with an outer diameter of 45 mm and an inner diameter of 37 mm and an injection rod inner pipe 18 with an outer diameter of 24 mm and an inner diameter of 14 mm is used as the injection rod 2. Also, the lower portion of the injection rod outer pipe 17

5 has an inner diameter of 42 mm, joining pin insertion holes 19 are formed on the lower portion, and joining pin injection rod recesses 20a that have approximately the same diameter as half of the outer circumference of the joining pin 36 are formed in the inner surface of the lower portion (see FIG. 10). Also, the outer diameter of the injection rod inner pipe 18 is 22 mm from slightly below the upper end of the lower

10 portion of the insertion rod outer pipe 17, which has an inner diameter of 42 mm. Also, the monitor 3 has a maximum outer diameter DD of 68 mm, the cement milk/water flow path 9, which has a diameter of 14 mm, is formed inside of the monitor 3, the monitor outer pipe 17a, which has an upper portion with an outer diameter of 42 mm and an inner diameter of 37 mm, and the monitor inner pipe 18a,

15 which has an outer diameter of 24 mm and an inner diameter of 14 mm, are formed in the monitor 3, and the air flow paths 10 are formed between the monitor outer pipe 17a and the monitor inner pipe 18a (see FIG. 3). Also, the air flow paths 10 are constituted by a flow path between the monitor outer pipe 17a and the monitor inner pipe 18a and four flow paths formed inside of the monitor 3 that communicate with

20 that flow path (see FIG. 8). Thus, the air supply path 7 in the injection rod 2 and the air flow paths 10 in the monitor 3 are in communication. The side surface of the monitor 3 is provided with the high-pressure ejection nozzle apparatus 1 that ejects cement milk and water as described above, and the joining pin monitor recesses 20b that have the same diameter as half the outer circumference of the joining pin 36 are

25 formed in the upper portion of the side surface (see FIG. 10). Also, the leading end nozzle 4 that ejects the water (liquid) is provided on the leading end portion of the monitor 3. Note that in the first embodiment, the injection rod 2 with a circular cross section having an outer diameter of about 45 mm was used, but there is no limitation to this, and an injection rod with a circular cross section having a diameter of about 50

30 mm to 140 mm (e.g., about 75 mm) may also be used, and the inner diameter of the injection rod inner pipe 18 may be set to 14 mm to 16 mm if an injection rod with a circular cross section having a diameter of about 50 mm to 140 mm (e.g., about 75 mm)

is used. Here, the inner diameter of the injection rod inner pipe 18 is determined by the flow rate of the cement milk that flows in the injection rod inner pipe 18. Furthermore, an injection rod having a hexagonal cross section may also be used. Also, the joining pin 36 is constituted by a spring pin 36a and a spring pin 36b (see FIG. 2(b)). The spring pin 36b of the joining pin 36 is first inserted into the joining pin insertion hole 19 at the lower portion of the insertion rod 2 and then the spring pin 36a is press fit into the hollow portion of the spring pin 36b inserted into the joining pin insertion hole 19.

[0031] As shown in FIG. 3, the material liquid ejection nozzle 21 that ejects the cement milk and the air ejection nozzle 22 that ejects compressed air are formed in the high-pressure ejection nozzle apparatus 1. Specifically, the material liquid ejection nozzle 21 is formed inside of the high-pressure ejection nozzle apparatus 1, and the air ejection nozzle 22 is formed on the outside. In this manner, when the cement milk and the compressed air are ejected at a high pressure from the high-pressure ejection nozzle apparatus 1, the cement milk is ejected from the inside of the high-pressure ejection nozzle apparatus 1, the compressed air is ejected from the outside (outer peripheral portion), and a gaseous layer film is created around the ejection flow of the cement milk, whereby the ejecting distance can be increased compared to a case where there is no gaseous layer film of the compressed air.

[0032] The material liquid ejection nozzle 21 is formed on the leading end of the nozzle main body portion 24 inserted into the nozzle main body portion attachment hole 23 (see FIG. 4). Here, as described above, two nozzle main body portion attachment holes 23 are formed at equal intervals on the circumference at positions with different heights in the axial direction of the monitor 3. Note that in the first embodiment, two nozzle main body portion attachment holes 23 are formed at equal intervals on the circumference at positions with different heights in the axial direction of the monitor 3 at equal intervals, but the positions need not have different heights in the axial direction of the monitor 3 at equal intervals, and the nozzle main body portion attachment holes 23 need not be formed at positions at equal intervals on the circumference. Also, there need not be two nozzle main body portion attachment holes 23, and two, three, four, six, or more (preferably four or more) nozzle main body portion attachment holes 23 may be formed, or one nozzle main body portion

attachment hole 23 may be formed.

[0033] Thus, multiple nozzle main body portion attachment holes 23 are formed at positions with different heights in the axial direction of the monitor 3, and therefore consolidated bodies of various shapes can be created efficiently in a short amount of time due to attaching the nozzle main body portions 24 to the different nozzle main body portion attachment holes 23 according to the application.

[0034] Also, the air ejection nozzle 22 is formed from the outer circumferential surface of the nozzle main body portion 24, the inner circumferential surface of the air cover 25, and the like. Also, compressed air is ejected from the air ejection nozzle 22 at a high speed via the flow path whose cross-sectional area is reduced from the air flow path 10 in the monitor 3 to the leading end. Note that in the first embodiment, the air ejection nozzle 22 is formed from the outer circumferential surface of the nozzle main body portion 24, the inner circumferential surface of the air cover 25, and the like, but there is no limitation to this, and the air ejection nozzle 22 may also be an air ejection nozzle of another form, as long as it is a nozzle that is configured to communicate with the air flow path 10 in the monitor 3 and surround the periphery of the leading end inner diameter portion of the nozzle main body portion 24, and that has a cross-sectional area reduced from the air flow path 10 in the monitor 3 to the leading end and ejects compressed air at a high speed.

[0035] The nozzle main body portion 24 is constituted by a nozzle main body 26 and a nozzle main body extended portion 27 (see FIG. 5). In the first embodiment, the nozzle main body portion 26 and the nozzle main body extended portion 27 are both made of a high-strength material such as a hard metal alloy. The nozzle main body 26 has a circular rod shape whose frontward portion has a reduced diameter and whose rearward portion has a diameter that is slightly larger than that of the frontward portion. Also, the inner portion of the nozzle main body portion 24, which has a hollow shape, is constituted by a rear end inner diameter portion 28, an intermediate inner diameter portion 29, and a leading end inner diameter portion 30 (see FIG. 6). Here, FIG. 5 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus according to the first embodiment of the present invention, and FIG. 6 shows cross-sectional views of the constituent components. The intermediate inner diameter portion 29 and the leading end inner

diameter portion 30 are formed in the nozzle main body 26, and the rear end inner diameter portion 28 is formed in the nozzle main body extended portion 27. Here, in the first embodiment, the length of the rear end inner diameter portion 28 is 9 mm, the length of the intermediate inner diameter portion 29 is 15 mm, and the length L of the leading end inner diameter portion 30 is 8 mm (see FIG. 7). Also, the inner circumferential surface of the intermediate inner diameter portion 29 is formed in a tapered surface shape with a diameter that decreases at a restriction angle β of 12 to 20 degrees (preferably 12 to 15 degrees, and more preferably 12 to 13 degrees) in the leading end direction, and the leading end inner diameter portion 30 communicates with the leading end of the intermediate inner diameter portion 29 and is formed such that the diameter d of the inner portion of the hollow shape is approximately the same as the diameter of the leading end of the intermediate inner diameter portion 29 and the length L is 2 to 4 times (preferably 3 to 4 times) the diameter d of the leading end of the intermediate inner diameter portion 29. Here, in the first embodiment, the diameter d of the leading end inner diameter portion 30 is 2 mm. Also, the rear end inner diameter portion 28 communicates with the rear end of the intermediate inner diameter portion 29 and is formed such that the diameter of the inner portion of the communication portion is approximately the same as the diameter of the rear end of the intermediate inner diameter portion 29. Here, FIG. 7 is a diagram showing dimensions of the high-pressure ejection nozzle apparatus according to the first embodiment of the present invention. Also, when the nozzle main body portion 24 is attached to the monitor 3, the nozzle main body portion 24 protrudes 7 mm into the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3. Here, the length by which the nozzle main body portion 24 protrudes into the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3 is half ($D/2$) of the diameter (D) of the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3 (see FIGS. 7 to 9). Here, FIG. 8 is a cross-sectional diagram taken along line B-B in FIG. 3, and FIG. 9 is a cross-sectional diagram taken along line C-C in FIG. 3. Note that in the first embodiment, the entire length LL (32 mm) of the nozzle main body portion 24 is 16 times the diameter d (2 mm) of the leading end of the intermediate inner diameter portion 29, but there is no limitation to this, and the entire length LL of the nozzle main body portion 24 may also be 15 to 20

times the diameter of the leading end of the intermediate inner diameter portion 29, and if the entire length LL of the nozzle main body portion 24 cannot be increased, the entire length LL of the nozzle main body portion 24 may also be 10 to 20 times the diameter d of the leading end of the intermediate inner diameter portion 29. Also, a

5 flow path division portion 31 that divides the cross section of the hollow-shaped rear end inner diameter portion 28 into multiple spaces is formed in the rear end inner diameter portion 28 inside of the nozzle main body extended portion 27. The flow path division portion 31 is formed in a cross shape with a width of 1.5 mm, a length of 5.5 mm, and a depth of 5.0 mm (see FIG. 5). Note that the depth of the flow path

10 division portion 31 is not limited to 5.0 mm, and need only be formed with a predetermined length. As described above, the hollow-shaped rear end inner diameter portion 28 is provided with the cross-shaped flow path division portion 31, but the area of the portion intersected by the cross shape of the flow path division portion 31 is 2.25 mm², and the area of the portion intersected by the cross shape, the

15 cross-sectional area (diameter 5.5 mm) of the hollow shape of the rear end inner diameter portion 28 near the flow path division portion 31 is 23.7 mm², and therefore the area of the portion intersected by the cross shape is 9.5% of the cross-sectional area of the hollow shape. In this manner, the flow path division portion 31 has a shape with a portion having an area that is approximately 10% of the cross-sectional area of

20 the hollow shape near the flow path division portion 31, at the approximate central portion of the hollow-shaped rear end inner diameter portion 28 near the flow path division portion 31. Note that in the present embodiment, the flow path division portion 31 has a shape with a portion having an area that is approximately 10% of the cross-sectional area of the hollow shape near the flow path division portion 31, but

25 there is no limitation thereto, and the flow path division portion 31 may also have a shape with a portion having an area that is 2% to 25% (preferably 2% to 20% (more preferably 2% to 15%)) of the cross-sectional area of the hollow shape near the flow path division portion 31.

[0036] The total cross-sectional area (9.45 mm²) of the flow path divided by the flow

30 path division portion 31 is 40% of the cross-sectional area (23.7 mm²) of the hollow shape of the rear end inner diameter portion 28 near the flow path division portion 31. Note that although the present embodiment has described that the total

cross-sectional area of the flow path divided by the flow path division portion 31 is 40% of the cross-sectional area of the hollow shape of the rear end inner diameter portion 28 near the flow path division portion 31, there is no limitation to this, and the total cross-sectional area of the flow path divided by the flow path division portion 31 may
 5 also be 40% to 60% of the cross-sectional area of the hollow shape near the flow path division portion 31.

[0037] In the present embodiment, due to the fact that the diameters of the cross-sections of the hollow shape of the rear end inner diameter portion 28 directly in front of and behind the flow path division portion 31 are the same (5.5 mm), the
 10 cross-sectional area of the hollow shape of the rear end inner diameter portion 28 near the flow path division portion 31 is used, but if the diameters of the cross-sections of the hollow shape of the rear end inner diameter portion 28 directly in front of and behind the flow path division portion 31 are different, the phrase “near the flow path division portion 31” may be replaced with the phrase “directly in front of the flow path
 15 division portion 31” or the phrase “directly behind the flow path division portion 31”.

[0038] A nozzle main body support tool 32 is attached from the frontward outer circumferential surface of the nozzle main body 26, the outer circumferential surface of the leading end thereof has a hexagonal shape, and a male screw is formed on the rearward outer circumferential surface thereof. Also, the outer circumferential
 20 surface of the leading end of the air cover 25 has a hexagonal shape, a male screw is formed on the intermediate outer circumferential surface, and notch portions 33 are formed at equal intervals in the circumferential direction on the rear end portion of the intermediate outer circumferential surface (see FIG. 5). The notch portions 33 are provided in order to ensure the flow path of the compressed air when the air cover 25 is
 25 mounted on the monitor 3. Also, the hollow inner portion of the air cover 25 has a diameter that decreases in the leading end direction from the notch portions 33 and thus has a tapered shape (see FIG. 6).

[0039] Also, the cement milk supplied via the cement milk/water supply pipe 7 in the injection rod 2 and the cement milk/water flow path 9 in the monitor 3 is sent into the
 30 nozzle main body portion 24 through the nozzle main body extended portion 27 and the nozzle main body 26, in the stated order, and is ejected from the material liquid ejection nozzle 21 (see FIG. 8). Also, the compressed air supplied via the air supply

path 8 in the injection rod 2 and the air flow path 10 in the monitor 3 is ejected from the air ejection nozzle 22 (see FIG. 8). Here, the air ejection nozzle 22 communicates with two air flow paths 10. In this manner, the high-pressure ejection nozzle apparatus 1 according to the first embodiment is constituted by the nozzle main body portion 24 consisting of the nozzle main body 26 and the nozzle main body extended portion 27, the nozzle main body portion support tool 32, and the air cover 25.

[0040] A differential pressure valve 34 is provided below the monitor 3 (see FIG. 3). Also, during drilling, low-pressure water is supplied to the cement milk/water flow path 7 of the injection rod 2, the low-pressure water is ejected from the leading end nozzle 4 via the differential pressure valve 34, and after the drilling is complete, the cement milk is supplied to the cement milk/water flow path 7 of the injection rod 2, whereby the differential pressure valve 34 is closed and the cement milk is ejected from the material liquid ejection nozzle 21 (high-pressure ejection nozzle apparatus 1).

[0041] Next, a method for assembling the injection rod 2, the monitor 3, and the high-pressure ejection nozzle apparatus 1 will be described with reference to FIGS. 10 and 11. Here, FIG. 10 is a diagram showing a method for assembling the high-pressure ejection nozzle apparatus and its peripheral instruments according to the first embodiment of the present invention, and FIG. 11 is a diagram showing a method for mounting the high-pressure ejection nozzle apparatus.

[0042] As shown in FIG. 10, first, the upper portion of the monitor upper portion pipe 35 is inserted into the lower end of the injection rod 2. Upon the insertion of the injection rod 2, a semicircular monitor upper portion pipe inner protrusion portion 45 formed on the upper portion of the monitor upper portion pipe 35 is fit together with a semicircular injection rod protrusion portion 44 formed on the lower end of the injection rod outer pipe 17, and thus positioning of the monitor upper portion pipe 35 and the injection rod 2 in the circumferential direction is performed, and attachment is achieved. Also, the joining pins 36 are inserted from the joining pin insertion holes 19 in the lower portion of the insertion rod 2, the joining pins 36 are fit into the joining pin injection rod recesses 20a in the lower portion of the injection rod inner pipe 18 and the joining pin monitor recesses 20b in the upper portion of the monitor upper portion pipe 35, whereby the monitor 3 is joined to the injection rod 2. Note that in the first embodiment, it was described that the lower portions and the upper portions of the

upper ends of the four air flow paths 10 formed in the monitor upper portion pipe 35 are integrated, but there is no limitation to this, and the lower portions and the upper portions of the upper ends of the four air flow paths 10 formed in the monitor upper portion pipe 35 may also be separate. Due to being formed separately in this manner,
5 it is easier to form the four air flow paths 10 in the monitor upper portion pipe 35.

[0043] Next, the high-pressure ejection nozzle apparatus 1 is attached to the nozzle main body portion attachment hole 23 formed on the side surface of the monitor upper portion pipe 35 (see FIG. 11). Specifically, the high-pressure ejection nozzle apparatus 1 is attached to the nozzle main body portion attachment hole 23 of the monitor upper
10 portion pipe 35 through the following procedures (1) to (3).

[0044] (1) The nozzle main body extended portion 27 is inserted from the rear portion of the nozzle main body 26, and the male screw formed on the outer circumference of the leading end of the nozzle main body extended portion 27 is screwed into a female screw formed on the inner circumference of the rear end of the nozzle main body 26,
15 whereby the nozzle main body extended portion 27 is attached to the nozzle main body 26.

[0045] (2) Next, the nozzle main body support tool 32 is fit from the leading end direction of the nozzle main body 26 to which the nozzle main body extended portion 27 is attached, and in this state, insertion into the nozzle main body portion attachment hole 23 is performed. When the nozzle main body support tool 32 is inserted into the nozzle main body portion attachment hole 23, the nozzle main body support tool 32 (also includes the nozzle main body 26 and the nozzle main body extended portion 27) is attached to the monitor 3 by screwing the male screw formed on the outer circumference of the rear end of the nozzle main body support tool 32 into
20 the female screw formed on the nozzle main body portion attachment hole 23 of the monitor 3. The nozzle main body extended portion 27 attached in this manner is attached protruding to the approximate central portion of the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3 (see FIG. 7). In other words, the rear end inner diameter portion 28 of the nozzle main body portion 24
25 attached to the monitor 3 is attached protruding to the approximate central portion (D/2) of the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3. Note that in the first embodiment, the rear end inner diameter portion 28
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of the nozzle main body portion 24 attached to the monitor 3 is attached protruding to the approximate central portion of the cement milk/water flow path 9 in the monitor 3, but there is no limitation to this, and the rear end inner diameter portion 28 may also protrude to at least approximately $1/3$ of the lateral cross section of the cement milk/water flow path 9 in the monitor 3, and if multiple nozzle main body portion attachment holes 23 are formed at positions with different heights in the axial direction of the monitor 3 as in the first embodiment, the rear end inner diameter portion 28 may also protrude to at least approximately $1/2$ to approximately $2/3$ (preferably, approximately $2/3$) of the cross section of the cement milk/water flow path 9 in the monitor 3.

[0046] (3) Next, the air cover 25 is fit from the leading end direction of the nozzle main body 26, and the air cover 25 is attached to the monitor 3 by screwing the male screw formed on the outer circumference of the air cover 25 into the female screw formed on the air cover attachment hole 43 on the inner circumference on the side surface of the monitor 3.

[0047] Next, the monitor lower portion pipe 39 built into the differential pressure valve 34 is attached below the monitor upper portion pipe 35. Specifically, the monitor lower portion pipe 39 is attached to the monitor upper portion pipe 35 by screwing the male screw on the outer circumference of the upper portion of the monitor lower portion pipe 39 into the female screw on the inner circumference of the lower portion of the monitor upper portion pipe 35.

[0048] In this manner, the rear end inner diameter portion 28 of the nozzle main body portion 24 is provided protruding to the approximate central portion of the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3, whereby it is possible to ensure a sufficiently long linear distance of the inner portion of the nozzle main body portion 24, the occurrence of turbulent flow of the cement milk flowing in the nozzle main body portion 24 can be reduced, and by increasing the cutting ability of the cement milk ejected from the leading end of the nozzle main body portion 24, the compositional structure of the ground can be broken and the cement milk can be ejected a longer distance. Furthermore, the total cross-sectional area of the flow path divided by the flow path division portion 31 has a shape that is 40% of the cross-sectional area of the hollow shape of the rear end inner diameter portion 28

near the flow path division portion 31, and therefore the cement milk that flows in the rear end inner diameter portion 28 of the nozzle main body portion 24 is divided into the spaces divided by the flow path division portion 31 and is sent in the leading end direction while being compressed with a suitable compression force. For this reason, the cement milk can be finely laminarized while further increasing the speed with the spaces divided by the flow path division portion 31, and by increasing the cutting ability of the cement milk ejected from the material liquid ejection nozzle 21 at the leading end of the nozzle main body portion 24, the compositional structure of the ground can be broken and the cement milk can be ejected a longer distance. The same also applies to the case where the total cross-sectional area of the flow path divided by the flow path division portion 31 is 40% to 60% of the cross-sectional area of the hollow shape near the flow path division portion 31.

[0049] Also, the cement milk that flows in the rear end inner diameter portion 28 of the nozzle main body portion 24 is divided into the spaces divided by the flow path division portion 31 and is sent in the leading end direction, and therefore the cement milk can be more finely laminarized by the spaces divided by the flow path division portion 31, and by increasing the cutting ability of the cement milk ejected from the material liquid ejection nozzle 21 at the leading end of the nozzle main body portion 24, the compositional structure of the ground can be broken and the cement milk can be ejected a longer distance. To describe this in more detail, the cement milk that flows in the approximate central portion of the rear end inner diameter portion 28 of the nozzle main body portion 24 collides with the approximate central portion of the flow path division portion 31, and the cement milk in the approximate central portion of the rear end inner diameter portion 28 that was subjected to collision flows into spaces divided by the flow path division portion 31 and is sent to the inner circumferential surface of the intermediate inner diameter portion formed with a decreasing diameter, while the speed of the hardening material liquid is increased. For this reason, it is possible to reduce the thickness of the boundary layer of the turbulent flow that occurs at the inner circumferential surface of the intermediate inner diameter portion, and finer laminarization can be achieved. Accordingly, the cutting ability of the cement milk ejected from the material liquid ejection nozzle 21 at the leading end of the nozzle main body portion 24 is increased, whereby the compositional structure of the ground

can be broken and the cement milk can be ejected a longer distance.

[0050] As described above, the male screw formed on the outer side of the outer circumferential surface of the nozzle main body portion 24 is screwed into the female screw formed on the inner side of the inner circumferential surface of the nozzle main body portion attachment hole 23 of the monitor 3, whereby the nozzle main body portion 24 is detachably attached to the monitor 3, and therefore the nozzle main body portion 24 can be freely switched according to the application, and the nozzle main body portion 24 can be attached to the monitor 3 with a simple method.

[0051] Next, a procedure executed by the ground improvement apparatus including the monitor in which the high-pressure ejection nozzle apparatus according to the first embodiment of the present invention is mounted will be described simply.

[0052] First, after the injection rod 2 is positioned at the position at which drilling is to be subsequently performed, water (liquid) is ejected from the leading end nozzle 4 of the injection rod 2 at that position, and drilling is performed to a predetermined depth.

Then, after drilling is performed to a predetermined depth, cement milk is ejected from the material liquid ejection nozzle 21 and compressed air is ejected from the air ejection nozzle 22 while the injection rod 2 is swung. Specifically, the injection rod 2 is swung 30 degrees (a predetermined angle) while the cement milk and the compressed air are ejected from the ejection nozzle (material liquid ejection nozzle 21, air ejection nozzle 22).

[0053] Next, when the injection rod 2 is swung 30 degrees, the injection rod 2 is pulled up by a predetermined length (e.g., 5 cm or less (preferably 2.5 cm)). Then, until the ejecting from the ejection nozzles (material liquid ejection nozzle 21, air ejection nozzle 22) is complete, the following procedure is repeated: clockwise swinging ejection → pulling up injection rod 2 → counterclockwise swinging ejection → pulling up injection rod 2 → clockwise swinging ejection → pulling up injection rod 2. Note that in the first embodiment, the injection rod 2 was swung, but there is no limitation to this, and it is also possible to rotate the injection rod 2 in a direction (right rotation and left rotation are possible).

[0054] Next, the injection rod 2 is pulled up from the drilling hole and taken out of the drilling hole by a crane. By doing so, a fan-shaped consolidated body is created in the ground.

Second Embodiment

[0055] Next, a second embodiment of the high-pressure ejection nozzle apparatus of the present invention will be described with reference to the drawings. Here, FIG. 12(a) is an enlarged view of the P-P portion shown in FIG. 3 of the high-pressure ejection nozzle apparatus according to the second embodiment of the present invention, FIG. 12(b) is a diagram showing a nozzle main body portion attachment hole of the monitor, and FIG. 13 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus according to the second embodiment of the present invention. FIG. 14 shows cross-sectional views of the constituent components.

[0056] The main differences between the second embodiment and the first embodiment of the present invention are that in the first embodiment, the nozzle main body 26 and the nozzle main body extended portion 27 constituting the nozzle main body portion 24 are formed separately, whereas in the second embodiment, the nozzle main body and the nozzle main body extended portion constituting the nozzle main body portion of the first embodiment are formed integrally, and that in the first embodiment, the nozzle main body portion 24 protrudes to the approximate central portion of the cement milk/water flow path 9 in the monitor 3, whereas in the second embodiment, a configuration is used in which the nozzle main body portion 24x protrudes into the cement milk/water flow path 9 of the monitor 3x. Note that in the second embodiment, differences from the first embodiment will mainly be described. Also, in the second embodiment, configurations that are the same as in the first embodiment (including similar configurations) are denoted by the same reference numerals thereas and exhibit the same effects thereas, and thus description thereof is omitted.

[0057] In the present embodiment, the inner surface portion of the nozzle main body portion 24x and the entire nozzle main body rearward member 48x are constituted by a high-strength material such as a hard metal alloy. Here, the frontward portion of the nozzle main body rearward member 48x has a hollow circular rod shape with a diameter larger than that of the rearward portion of the nozzle main body portion 24x, and the rearward portion of the nozzle main body rear member 48x has a hollow

circular rod shape with a diameter smaller than that of the frontward portion. Note that in the present embodiment, the inner surface portion of the nozzle main body portion 24x is made of a high-strength material such as a hard metal alloy, but there is no limitation to this, and the entire nozzle main body portion 24x may also be made of a high-strength material such as a hard metal alloy. The frontward portion of the outer shape of the nozzle main body portion 24x is a circular rod shape whose leading end has a smaller diameter, the intermediate portion is a circular rod shape with a diameter that is slightly larger than that of the front portion, and the rearward portion is a circular rod shape with a diameter that is slightly larger than that of the intermediate portion. Also, the O-ring attachment recess 47x is formed on the rear end surface of the nozzle main body portion 24x (see FIG. 14(b)).

[0058] The inner portion of the nozzle main body portion 24x, which has a hollow shape, is constituted by the rear end inner diameter portion 28x, the intermediate inner diameter portion 29x, and the leading end inner diameter portion 30x (see FIG. 14(b)). Here, in the second embodiment, the length of the rear end inner diameter portion 28x is 5.0 mm, the length of the intermediate inner diameter portion 29x is 5.5 mm, and the length of the leading end inner diameter portion 30x is 8.0 mm. Also, the inner circumferential surface of the intermediate inner diameter portion 29x is formed into a tapered surface with a diameter that decreases at a restriction angle β of 12 to 20 degrees (preferably 12 to 15 degrees, and more preferably 12 to 13 degrees) in the leading end direction, and the leading end inner diameter portion 30x communicates with the leading end of the intermediate inner diameter portion 29x, and is formed such that the diameter d of the inner portion of the hollow shape is approximately the same as the diameter of the leading end of the intermediate inner diameter portion 29x and the length L is two to four times (preferably three to four times) the diameter d of the leading end of the intermediate inner diameter portion 29x. Here, in the second embodiment, the diameter of the leading end inner diameter portion 30x is 4.0 mm (see FIG. 14(b)). Note that in the second embodiment, the overall length LL (18.5 mm) of the nozzle main body portion 24x is 4.625 times the diameter d (4 mm) of the leading end of the intermediate inner diameter portion 29x, but there is no limitation to this, and the overall length of the nozzle main body portion 24x may also be 4 to 20 times the diameter of the leading end of the intermediate inner

diameter portion 29x. Also, the rear end inner diameter portion 28x communicates with the rear end of the intermediate inner diameter portion 29x, and the diameter of the inner portion of the communication portion is approximately the same as the diameter of the rear end of the intermediate inner diameter portion 29x. Also, when
5 the nozzle main body portion 24x is attached to the monitor 3x, the nozzle main body portion 24x does not protrude inside of the cement milk/water flow path 9 (hardening material liquid flow path) of the monitor 3x, but is stored in the nozzle main body portion attachment hole 23x of the monitor 3x. Also, the flow path division portion 31x that divides the cross section of the hollow-shaped rear end inner diameter portion
10 28x into multiple spaces is formed in the rear end inner diameter portion 28x at the rearward portion of the nozzle main body portion 24x. The flow path division portion 31x is formed in a cross shape with a width of 2.0 mm, a length of 10.0 mm, and a depth of 3.5 mm (see FIG. 13(b)). Note that the depth of the flow path division portion 31x is not limited to 3.5 mm, and need only be formed with a predetermined length.
15 Also, the length of the nozzle main body rear member 48x is 6.5 mm, the nozzle main body rearward member 48x communicates with the rear end of the intermediate inner diameter portion 29x, and the diameter of the inner portion of the hollow shape is approximately the same as the diameter of the rear end of the intermediate inner diameter portion 29x. Also, the air cover 25x and the nozzle main body support tool
20 32x are approximately the same as in the first embodiment, and therefore description thereof will be omitted.

[0059] As described above, the cross-shaped flow path division portion 31x is provided in the hollow-shaped rear end inner diameter portion 28x, but due to the fact that the area of the portion intersected by the cross shape of the flow path division
25 portion 31x is 4.00 mm² and the cross-sectional area (diameter 10.0 mm) of the hollow shape of the rear end inner diameter portion 28x near the flow path division portion 31x is 78.5 mm², the area of the portion intersected by the cross shape is 5.1% of the cross-sectional area of the hollow shape. In this manner, the flow path division portion 31x is a shape that has a portion having an area that is approximately 5.0% of
30 the cross-sectional area of the hollow shape near the flow path division portion 31x at the approximate central portion of the hollow-shaped rear end inner diameter portion 28x near the flow path division portion 31x. Note that in the present embodiment,

the flow path division portion 31x is a shape that has a portion having an area of approximately 5.0% of the cross-sectional area of the hollow shape near the flow path division portion 31x, but there is no limitation to this, and as described above, the flow path division portion 31x may also be a shape that has a portion having an area of 2% to 25% (preferably 2% to 20% (more preferably 2% to 15%)) of the cross-sectional area of the hollow shape near the flow path division portion 31x.

[0060] Also, the total cross-sectional area (42.5 mm²) of the flow path divided by the flow path division portion 31x is 54.1% of the cross-sectional area (78.5 mm²) of the hollow shape near the flow path division portion 31x. Note that in the present embodiment, it was described that the total cross-sectional area of the flow path divided by the flow path division portion 31x is 54.1% of the cross-sectional area of the hollow shape near the flow path division portion 31x, but as described above, the total cross-sectional area of the flow path divided by the flow path division portion 31x may also be 40% to 60% of the cross-sectional area of the hollow shape near the flow path division portion 31x.

[0061] In the present embodiment, due to the fact that the diameters of the cross-sections of the hollow shape of the rear end inner diameter portion 28x directly in front of and behind the flow path division portion 31x are the same (10.0 mm), the cross-sectional area of the hollow shape of the rear end inner diameter portion 28x near the flow path division portion 31x was used, but if the diameters of the cross sections of the hollow shape of the rear end inner diameter portion 28x directly in front of and behind the flow path division portion 31x are different, the phrase “near the flow path division portion 31x” can be replaced with the phrase “directly in front of the flow path division portion 31x” or the phrase “directly behind the flow path division portion 31x”.

[0062] Next, a method for attaching the high-pressure ejection nozzle apparatus 1x to the monitor 3x will be described. Note that differences from the method for attaching the nozzle main body portion 24 of the first embodiment will be described. Here, FIG. 15 is a cross-sectional view of the high-pressure ejection nozzle apparatus mounted in the monitor according to the second embodiment of the present invention.

[0063] First, the nozzle main body rearward member 48x is inserted into the nozzle main body portion attachment hole 23x formed on the side surface of the monitor 3x

(see FIGS. 12(b) and 15). Here, a nozzle main body extended portion stopping protrusion 38x is formed at the nozzle main body portion attachment hole 23x formed on the side surface of the monitor 3x of the present embodiment (see FIGS. 12(b) and 15), and therefore the rear end of the nozzle main body rearward member 48x comes into contact with the nozzle main body extended portion stopping protrusion 38x and the nozzle main body rearward member 48x is supported by the nozzle main body extended portion stopping protrusion 38x.

[0064] Next, the nozzle main body portion 24x is inserted into the nozzle main body portion attachment hole 23x. Then, the rear end of the nozzle main body portion 24x comes into contact with the leading end of the nozzle main body rearward member 48x and is sealed by the O-ring 46x inserted into the O-ring attachment recess 47x at the rear end of the nozzle main body portion 24x. The nozzle main body rearward member 48x (including the nozzle main body portion 24x) attached in this manner does not protrude into the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3x, but is stored in the nozzle main body portion attachment hole 23x of the monitor 3x (see FIG. 15).

[0065] Next, the high-pressure ejection nozzle apparatus 1x including the nozzle main body portion 24x is attached to the nozzle main body portion attachment hole 23x using a procedure similar to the attachment procedure of the first embodiment, such as fitting the air cover 25x from the leading end direction of the nozzle main body portion 24x. The nozzle main body rearward member 48x (including the nozzle main body portion 24x) attached in this manner is attached in a state of being stored in the nozzle main body portion attachment hole 23 formed in the monitor 3x, unlike in the first embodiment.

[0066] In this manner, according to the present embodiment, the turbulent flow state of the cement milk is disrupted due to the cement milk being more finely divided by the flow path division portion 31x of the rear end inner diameter portion 28x of the nozzle main body portion 24x, and thus the cement milk is more finely laminarized while the flow rate distribution is made uniform by the divided spaces. Also, the flow rate of the laminarized cement milk is significantly increased while the flow of the cement milk is straightened by the intermediate inner diameter portion 29x of the nozzle main body portion 24x formed such that the diameter of the inner

circumferential surface decreases in the leading end direction, and the straightness of the cement milk with the increased flow rate is significantly increased by the leading end inner diameter portion 30x of the nozzle main body portion 24x, which has the same diameter as the leading end portion of the intermediate inner diameter portion 29x of the nozzle main body portion 24x. Accordingly, due to the cutting ability of the cement milk ejected from the leading end of the nozzle main body 24x being significantly increased, the compositional structure of the ground can be broken and the cement milk can be ejected a longer distance. To describe this in detail, the cement milk that flows in the approximate central portion of the rear end inner diameter portion 28x of the nozzle main body portion 24x collides with the approximate central portion of the flow path division portion 31x, and the cement milk in the approximate central portion of the rear end inner diameter portion 28x that was subjected to collision flows to the spaces divided by the flow path division portion 31x and is sent to the inner circumferential surface of the intermediate inner diameter portion that is formed with a decreasing diameter, while the speed of the hardening material liquid is increased, and therefore it is possible to reduce the thickness of the boundary layer of the turbulent flow that occurs in the inner circumferential surface of the intermediate inner diameter portion, and finer laminarization is possible. Furthermore, a shape is used in which the total cross-sectional area of the flow path divided by the flow path division portion 31x is 54.1% of the cross-sectional area of the hollow shape of the rear end inner diameter portion 28x near the flow path division portion 31x, and therefore the cement milk that flows in the rear end inner diameter portion 28x of the nozzle main body portion 24x is divided into the spaces divided by the flow path division portion 31x and is sent in the leading end direction while being compressed with a suitable compression force. For this reason, it is possible to more finely laminarize the cement milk while further increasing its speed with the spaces divided by the flow path division portions 31x, and by increasing the cutting ability of the cement milk ejected from the material liquid ejection nozzle 21x of the nozzle main body portion 24x, the compositional structure of the ground can be broken and the cement milk can be ejected a longer distance. Accordingly, the cutting ability of the cement milk ejected from the material liquid ejection nozzle 21x at the leading end of the nozzle main body portion 24x is increased, whereby the compositional structure of

the ground can be broken and the cement milk can be ejected a longer distance. The same also applies to the case where the total cross-sectional area of the flow path divided by the flow path division portion 31x is 40% to 60% of the cross-sectional area of the hollow shape near the flow path division portion 31x. Here, the variations
5 below are applied to the second embodiment as well.

Third Embodiment

[0067] Next, a third embodiment of the high-pressure ejection nozzle apparatus 1y of the present invention will be described with reference to the drawings. Here, FIG.
10 16(a) is an enlarged view of a P-P portion shown in FIG. 3 of the high-pressure ejection nozzle apparatus according to the third embodiment of the present invention, FIG. 16(b) is a diagram showing a nozzle main body portion attachment hole of the monitor, and FIG. 17 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus according to the third embodiment of the present invention.
15 FIG. 18 shows cross-sectional views of the constituent components.

[0068] The difference between the third embodiment and the first embodiment of the present invention is that in the first embodiment, the nozzle main body extended portion 27 protrudes to the approximate central portion of the cement milk/water flow path 9 in the monitor 3, whereas in the third embodiment, the nozzle main body
20 extended portion 27y does not protrude in the cement milk/water flow path 9 of the monitor 3y. Note that in the third embodiment, differences from the first embodiment will mainly be described. Also, in the third embodiment, configurations that are the same as in the first embodiment (including similar configurations) are denoted by the same reference numerals thereas and exhibit the same effects thereas,
25 and thus description thereof is omitted.

[0069] The nozzle main body portion 24y of the present embodiment is constituted by the nozzle main body 26y and the nozzle main body extended portion 27y (see FIG. 18). In the third embodiment, the inner surface portion of the nozzle main body portion 26y and the nozzle main body extended portion 27y are both made of a high-strength
30 material such as a hard metal alloy. Note that the inner surface portion of the nozzle main body 26y is made of the high-strength material such as the hard metal alloy, but there is no limitation to this, and the entire nozzle main body 26y may also be made of

the high-strength material such as the hard metal alloy. The frontward portion of the nozzle main body 26y has an approximately circular rod shape whose leading end has a small diameter, the intermediate portion has a circular rod shape with a diameter that is slightly larger than that of the frontward portion, and the rearward portion has a circular rod shape with a diameter that is slightly larger than that of the intermediate portion. An O-ring attachment recess 47y is formed on the rear end surface of the nozzle main body 26y (see FIG. 18(b)). Also, the frontward portion of the nozzle main body extended portion 27y has a circular rod shape with a diameter larger than that of the rearward portion of the nozzle main body 26y, and the rearward portion of the nozzle main body extended portion 27y has a circular rod shape with a diameter larger than that of the frontward portion.

[0070] The inner portion of the nozzle main body portion 24y, which has a hollow shape, is constituted by the rear end inner diameter portion 28y, the intermediate inner diameter portion 29y, and the leading end inner diameter portion 30y (see FIG. 18). The intermediate inner diameter portion 29y and the leading end inner diameter portion 30y are formed in the nozzle main body 26y, and the rear end inner diameter portion 28y is formed in the nozzle main body extended portion 27y. Here, in the third embodiment, the length of the rear end inner diameter portion 28y is 7.0 mm, the length of the intermediate inner diameter portion 29y is 10.0 mm, and the length of the front end inner diameter portion 30 is 8.0 mm. Also, the inner circumferential surface of the intermediate inner diameter portion 29y is formed into a tapered surface with a diameter that decreases at a restriction angle β of 12 to 20 degrees (preferably 12 to 15 degrees (more preferably 12 to 13 degrees)) in the leading end direction, the leading end inner diameter portion 30y communicates with the leading end of the intermediate inner diameter portion 29y, the diameter of the inner portion of the hollow shape is approximately the same as the diameter of the leading end of the intermediate inner diameter portion 29y, and the length L is two to four times (preferably three to four times) the diameter d of the leading end of the intermediate inner diameter portion 29y (see FIG. 18). Here, in the third embodiment, the diameter of the leading end diameter portion 30y is 4.0 mm. Note that in the third embodiment, the entire length LL (25 mm) of the nozzle main body portion 24y is 6.25 times the diameter d (4 mm) of the leading end of the intermediate inner diameter

portion 29y, but there is no limitation to this, and the entire length of the nozzle main body portion 24y may also be 6 to 20 times the diameter of the leading end of the intermediate inner diameter portion 29y. Also, the rear end inner diameter portion 28y communicates with the rear end of the intermediate inner diameter portion 29y, and is formed such that the diameter of the inner portion of the communication portion is approximately the same as the diameter of the rear end of the intermediate inner diameter portion 29y. Also, when the nozzle main body portion 24y is attached to the monitor 3y, the nozzle main body portion 24y does not protrude into the cement milk/water flow path 9 (hardening material liquid flow path) of the monitor 3y, but is stored in the nozzle main body portion attachment hole 23y of the monitor 3y. Also, the flow path division portion 31y that divides the cross section of the hollow-shaped rear end inner diameter portion 28y is formed in the rear end inner diameter portion 28y in the inner portion of the nozzle main body extended portion 27y. The flow path division portion 31y is formed in a cross shape with a width of 2.0 mm, a length of 10.0 mm, and a depth of 4.5 mm (see FIG. 17)). Note that the depth of the flow path division portion 31y is not limited to 4.5 mm, and need only be formed with a predetermined length. Here, the nozzle main body supporting tool 32y and the air cover 25y are almost the same as in the first embodiment, and therefore description thereof is omitted.

[0071] As described above, the cross-shaped flow path division portion 31y is provided in the hollow-shaped rear end inner diameter portion 28y, but the area of the portion intersected by the cross shape of the flow path division portion 31y is 4.00 mm², and the cross-sectional area (diameter 10.0 mm) of the hollow shape of the rear end inner diameter portion 28y near the flow path division portion 31y is 78.5 mm², whereby the area of the portion intersected by the cross shape is 5.1% of the cross-sectional area of the hollow shape. In this manner, the flow path division portion 31y has a shape with a portion having an area that is approximately 5.0% of the cross-sectional area of the hollow shape near the flow path division portion 31y, at the approximate central portion of the hollow-shaped rear end inner diameter portion 28y near the flow path division portion 31y. Note that in the present embodiment, although the flow path division portion 31y has a shape with a portion having an area that is approximately 5.0% of the cross-sectional area of the hollow shape near the flow

path division portion 31y, there is no limitation to this, and as described above, it is also possible to have a shape with a portion having an area that is 2% to 25% (preferably 2% to 20% (more preferably 2% to 15%)) of the cross-sectional area of the hollow portion near the flow path division portion 31.

5 [0072] Also, the total cross-sectional area (42.5 mm²) of the flow path divided by the flow path division portion 31y is 54.1% of the cross-sectional area (78.5 mm²) of the hollow shape near the flow path division portion 31y. Note that in the present embodiment, it was described that the total cross-sectional area of the flow path divided by the flow path division portion 31y is 54.1% of the cross-sectional area of the
10 hollow shape near the flow path division portion 31y, but as described above, the total cross-sectional area of the flow path divided by the flow path division portion 31y may also be 40% to 60% of the cross-sectional area of the hollow shape near the flow path division portion 31y.

[0073] In the present embodiment, due to the fact that the diameters of the cross
15 sections of the hollow shape of the rear end inner diameter portion 28y directly in front of and behind the flow path division portion 31y are the same (10.0 mm), the cross-sectional area of the hollow shape of the rear end inner diameter portion 28y near the flow path division portion 31y is used, but if the diameters of the cross sections of the hollow shape of the rear end inner diameter portion 28y directly in front
20 of and behind the flow path division portion 31y are different, it is possible to replace the phrase “near the flow path division portion 31y” with the phrase “directly in front of the flow path division portion 31y” or the phrase “directly behind the flow path division portion 31y”.

[0074] Next, a method for attaching the high-pressure ejection nozzle apparatus 1y to
25 the monitor 3y will be described with reference to FIG. 19. Note that differences from the method for attaching the nozzle main body portion 24 of the first embodiment will be described. Here, FIG. 19 is a cross-sectional view of the high-pressure ejection nozzle apparatus mounted in the monitor.

[0075] First, the nozzle main body extended portion 27y is inserted into the nozzle
30 main body portion attachment hole 23y formed on the side surface of the monitor 3y (see FIG. 19). Here, the nozzle main body extended portion stopping protrusion 38y is formed on the nozzle main body portion attachment hole 23y formed on the side

surface of the monitor 3y of the present embodiment (see FIGS. 16(b) and 19), and therefore the rear end of the nozzle main body extended portion 27y comes into contact with the nozzle main body extended portion stopping protrusion 38y and the nozzle main body extended portion 27y is supported by the nozzle main body extended portion stopping protrusion 38y.

[0076] Next, the nozzle main body 26y is inserted into the nozzle main body portion attachment hole 23y. Then, the rear end of the nozzle main body 26y comes into contact with the rear end side of the nozzle main body extended portion 27y, and is sealed by the O-ring 46y inserted into the O-ring attachment recess 47y on the rear end of the nozzle main body 26y. The nozzle main body extended portion 27y attached in this manner is stored in the nozzle main body portion attachment hole 23y of the monitor 3y (see FIG. 19).

[0077] Next, the high-pressure ejection nozzle apparatus 1y including the nozzle main body portion 24y is attached to the nozzle main body portion attachment hole 23y through a procedure similar to the attachment procedure of the first embodiment, such as fitting the air cover 25y from the leading end direction of the nozzle main body 26y. The nozzle main body extended portion 27y attached in this manner is attached stored in the nozzle main body portion attachment hole 23y in the monitor 3y, unlike in the first embodiment.

[0078] In this manner, according to the present embodiment, the turbulent flow state of the cement milk is disrupted due to the cement milk being more finely divided by the flow path division portion 31y of the rear end inner diameter portion 28y of the nozzle main body portion 24y, and thus the cement milk is more finely laminarized while the flow rate distribution is made uniform by the divided spaces. Also, the flow rate of the laminarized cement milk is significantly increased while the flow of the cement milk is straightened by the intermediate inner diameter portion 29y of the nozzle main body portion 24y formed such that the diameter of the inner circumferential surface decreases in the leading end direction, and the straightness of the cement milk with the increased flow rate is significantly increased by the leading end inner diameter portion 30y of the nozzle main body portion 24y, which has the same diameter as the leading end portion of the intermediate inner diameter portion 29y of the nozzle main body portion 24y. To describe this in detail, the cement milk

that flows in the approximate central portion of the rear end inner diameter portion 28y of the nozzle main body portion 24y collides with the approximate central portion of the flow path division portion 31y, and the cement milk in the approximate central portion of the rear end inner diameter portion 28y that was subjected to collision flows to the spaces divided by the flow path division portion 31y and is sent to the inner circumferential surface of the intermediate inner diameter portion that is formed with a decreasing diameter, while the speed of the hardening material liquid is increased, and therefore it is possible to reduce the thickness of the boundary layer of the turbulent flow that occurs at the inner circumferential surface of the intermediate inner diameter portion, and finer laminarization is possible. Furthermore, a shape is used in which the total cross-sectional area of the flow path divided by the flow path division portion 31y is 54.1% of the cross-sectional area of the hollow shape of the rear end inner diameter portion 28y near the flow path division portion 31y, and therefore the cement milk that flows in the rear end inner diameter portion 28y of the nozzle main body portion 24y is divided into the spaces divided by the flow path division portion 31y and is sent in the leading end direction while being compressed with a suitable compression force. For this reason, it is possible to more finely laminarize the cement milk while further increasing its speed with the spaces divided by the flow path division portions 31y, and by increasing the cutting ability of the cement milk ejected from the material liquid ejection nozzle 21y of the nozzle main body portion 24y, the compositional structure of the ground can be broken and the cement milk can be ejected a longer distance. The same also applies to the case where the total cross-sectional area of the flow path divided by the flow path division portion 31y is 40% to 60% of the cross-sectional area of the hollow shape near the flow path division portion 31y. Accordingly, due to the cutting ability of the cement milk ejected from the leading end of the nozzle main body 24y being significantly increased, the compositional structure of the ground can be broken and the cement milk can be ejected a longer distance. Here, the variations below are applied to the third embodiment as well.

[0079] The embodiments disclosed herein are to be considered exemplary and non-limiting in all respects. The scope of the present invention is indicated not by the above description, but by the claims, and all changes within the scope and meanings

equivalent to the claims are intended to be encompassed therein.

[0080] Hereinafter, variations of the present invention will be described.

First Variation

5 [0081] The difference between the first variation and the first embodiment of the present invention is that in the first embodiment, the nozzle main body portion attachment hole 23 of the monitor 3 is formed in a direction orthogonal to the axis of the monitor 3 and the nozzle main body portion 24 is mounted on the nozzle main body portion attachment hole 23, whereas in the first variation, the nozzle main body portion attachment hole 23a (including the air cover attachment hole 43a) of the
10 monitor 3 is formed facing downward 30 degrees and the nozzle main body portion 24 is mounted on the nozzle main body portion attachment hole 23a (see FIG. 20). Here, FIG. 20 is a diagram showing the nozzle main body portion mounted in the downward-facing nozzle main body portion attachment hole of the first variation of the present invention. Detailed description will be given hereinafter.

[0082] The nozzle of the monitor 3 is normally installed slightly above the leading end of the monitor 3, and therefore if a structural object is present in front of the leading end of the monitor 3, which has been inserted into the ground, the cement milk (hardening material liquid) cannot be ejected near the structural object. However, as
20 described above, by mounting the nozzle main body portion 24 in the nozzle main body portion attachment hole 23a (including the air cover attachment hole) formed facing downward 30 degrees, even if a structural object is present in front of the leading end of the monitor 3 inserted into the ground and the monitor 3 cannot be inserted downward due to the structural object, the cement milk (hardening material liquid)
25 can be ejected from the leading end inner diameter portion of the nozzle main body portion 24 to near the structural object, and a consolidated body that is closely adhered to the structural body can be created. Note that in the first variation, the nozzle main body portion attachment hole 23a was formed facing downward 30 degrees, but there is no limitation to this, and the nozzle main body portion attachment hole 23a may
30 also be formed facing downward 45 degrees, or another angle. Also, in the first variation, the nozzle main body portion attachment hole may be formed on the leading end of the monitor without mounting the leading end nozzle 4 on the leading end of the

monitor 3, and the high-pressure ejection nozzle apparatus 1 such as the nozzle main body portion 24 may be mounted in the nozzle main body portion attachment hole.

Second Variation

- 5 [0083] The difference between the second variation and the first embodiment of the present invention is that in the first embodiment, the nozzle main body portion attachment hole 23 of the monitor 3 is formed in a direction orthogonal to the axis of the monitor 3 and the nozzle main body portion 24 is mounted in the nozzle main body portion attachment hole 23, whereas in the second variation, the nozzle main body portion attachment hole 23b (including the air cover attachment hole 43b) of the
10 monitor 3 is formed facing upward and the nozzle main body portion 24 is mounted in the nozzle main body portion attachment hole 23b (see FIG. 21). Here, FIG. 21 is a diagram showing the nozzle main body portion mounted in the upward-facing nozzle main body portion attachment hole of the second variation of the present invention.
- 15 [0084] If the high-pressure air is ejected from the air ejection nozzle 22 of the monitor 3, the ejected high-pressure air rises to the upper portion in the ground and forms an air layer in the ground. As described above, the nozzle main body portion 24 is mounted in the nozzle main body portion attachment hole 23b formed facing upward, and the cement milk (hardening material liquid) is ejected upward from the material
20 liquid ejection nozzle 21 at the leading end of the nozzle main body portion 24, and thus the air layer can be used to eject the cement milk (hardening material liquid) a longer distance.

Third Variation

- 25 [0085] The difference between the third variation and the first embodiment of the present invention is that in the first embodiment, one side of the flow path division portion 31 that divides the cross section of the hollow shape of the rear end inner diameter portion 28 of the nozzle main body portion 24 into multiple spaces is formed into a cross shape with a width of 1.5 mm, a length of 5.5 mm, and a depth of 5.0 mm,
30 whereas in the third variation, the cross section of the hollow shape of the rear end inner diameter portion has a diameter of 10.0 mm and is formed into (four) circular shapes each with a diameter of 3.2 mm and a depth of 5.0 mm (see FIG. 22(a)). By

forming the outside of the circular shape into the flow path division portion 31a in this manner, it is possible to obtain a greater width of the flow path division portion 31a outside of the circular shape, and it is possible to increase the strength of the flow path division portion 31a. Also, the flow path division portion 31v may also be formed with the shapes from FIG. 22(b) to 22(g). FIG. 22 shows diagrams showing the flow path division portions formed in the rear end inner diameter portion in the nozzle main body extended portion of the third variation of the present invention. Here, the total cross-sectional area (3.22 mm^2) of the flow path divided by the flow path division portion 31a is 41.0% of the cross-sectional area (78.5 mm^2) of the hollow shape near the flow path division portion 31a.

Fourth Variation

[0086] The difference between the fourth variation and the first embodiment of the present invention is that in the first embodiment, two air ejection nozzles 22 are provided and communicate with two air flow paths 10 corresponding to the air ejection nozzles 22, whereas in the fourth variation, six air ejection nozzles are provided, and may each communicate with two air flow paths 10 (10a and 10b, 10b and 10c, 10c and 10d, 10d and 10e, 10e and 10f, 10f and 10a) corresponding to the air ejection nozzles 22. That is, the air flow paths 10 between the air ejection nozzles 22 that are provided adjacent to the air flow paths of the monitor 3 at equal intervals circumferentially may also be shared (see FIG. 23). In this manner, by sharing the adjacent air flow paths 10, it is possible to reduce the number of air flow paths in the monitor 3, and many air ejection nozzles 22 that perform ejection in many directions can be attached to the monitor 3 (see FIG. 23). Here, FIG. 23(a) is a diagram showing the attachment position of the high-pressure ejection nozzle apparatus of the fourth variation of the present invention, and FIG. 23(b) is a cross-sectional view of the monitor attachment position of the high-pressure ejection nozzle apparatus of the fourth variation of the present invention.

Fifth Variation

[0087] The difference between the fifth variation and the first embodiment of the present invention is that in the first embodiment, two (multiple) nozzle main body

portion attachment holes 23 are formed at positions with different heights in the axial direction of the monitor 3 and the nozzle main body portions 26 are attached to the nozzle main body portion attachment holes 23, whereas in the fifth variation, the nozzle main body portion attachment holes 23 are closed using flow path closing tools 40, whereby the cement milk and the compressed air cannot be ejected (see FIG. 24). Here, FIG. 24 is a diagram showing a flow path closing tool mounted in the nozzle main body portion attachment hole 23 of the fifth variation of the present invention.

[0088] The flow path closing tool 40 is constituted by a nozzle main body portion attachment hole closing tool 41 and an air flow path closing tool 42 (see FIG. 24). The outer circumferential surface of the leading end of the nozzle main body portion attachment hole closing tool 41 has a hexagonal shape and a male screw is formed on the rearward outer circumferential surface. Also, the leading end portion of the air flow path closing tool 42 protrudes slightly outward in the circumferential direction and a male screw is formed on the rearward outer circumferential surface. Also, the nozzle main body portion attachment hole closing tool 41 is attached to the monitor 3 by screwing the male screw formed on the outer circumference of the nozzle main body portion attachment hole closing tool 41 into a female screw formed on the inner circumference of the leading end of the nozzle main body portion attachment hole 23 of the monitor 3. Accordingly, the flow path of the cement milk from the cement milk/water flow path 9 can be closed. Also, the air flow path closing tool 42 is attached to the monitor 3 by screwing the male screw formed on the outer circumference of the air flow path closing tool 42 into the female screw formed on the inner circumference of the air cover attachment hole 43 of the monitor 3. Accordingly, the flow path of the air from the air flow path 10 can be closed.

[0089] In this manner, by attaching the flow path closing tools 40 to the flow paths of the cement milk and the compressed air that are not to be used, the attachment position of the nozzle main body portion 24 that is suitable for creating the consolidated body can be selected according to the application.

Sixth Variation

[0090] The difference between the sixth variation and the first embodiment of the present invention is that in the first embodiment, the nozzle main body portion 24 is

constituted by the nozzle main body 26 and the nozzle main body extended portion 27, which can be joined through screwing to the nozzle main body 26, whereas in the sixth variation, the nozzle main body portion 24w of the high-pressure ejection nozzle apparatus 1w is constituted by the nozzle main body 26w and the nozzle main body extended portion 27w that is completely separate from and cannot be joined to the nozzle main body 26w. Here, FIG. 25(a) is an enlarged view of the P-P portion shown in FIG. 3 of the sixth variation of the present invention. FIG. 25(b) is a diagram showing the nozzle main body portion attachment hole of the monitor, FIG. 26 is a diagram showing constituent components of the high-pressure ejection nozzle apparatus of the sixth variation of the present invention, and FIG. 27 shows cross-sectional views of the constituent components. Hereinafter, the nozzle main body portion 24w will be described specifically.

[0091] The frontward portion of the nozzle main body 26w has a circular rod shape with a smaller radius, and the rearward portion has a circular rod shape with a slightly larger radius than the frontward portion. Furthermore, an O-ring attachment recess 47 is formed on the rear end surface of the nozzle main body 26w (see FIG. 27(b)). Also, the frontward portion of the nozzle main body extended portion 27w has a circular rod shape with a larger radius, and the rearward portion has a circular rod shape with a slightly smaller radius than the frontward portion. Note that in the sixth variation, similarly to the first embodiment, the nozzle main body 26w and the nozzle main body extended portion 27w are constituted by a high-strength material such as a hard metal alloy.

[0092] The inner portion of the nozzle main body portion 24w, which has a hollow shape, is constituted by the rear end inner diameter portion 28w, the intermediate inner diameter portion 29w, and the leading end inner diameter portion 30w (see FIG. 27). The intermediate inner diameter portion 29w and the leading end inner diameter portion 30w are formed in the nozzle main body 26w and the rear end inner diameter portion 28w is formed in the nozzle main body extended portion 27w. Here, in the sixth variation, similarly to the first embodiment, the length of the rear end inner diameter portion 28w is 9 mm, the length of the intermediate inner diameter portion 29w is 15 mm, and the length L of the leading end inner diameter portion 30w is 8 mm (see FIG. 7). Also, the inner circumferential surface of the intermediate inner

diameter portion 29w is formed into a tapered surface whose diameter decreases at a restriction angle θ of 12 to 20 degrees (preferably 12 to 15 degrees and more preferable 12 to 13 degrees) in the leading end direction, the leading end inner diameter portion 30w communicates with the leading end of the intermediate inner diameter portion 29w, the diameter d of the hollow-shaped inner portion is approximately the same as the diameter of the leading end of the intermediate inner diameter portion 29w, the length L is two to four times (preferably three to four times) the diameter d of the leading end of the intermediate inner diameter portion 29w, and the diameter d of the leading end inner diameter portion 30w is 2 mm. Also, the rear end inner diameter portion 28w communicates with the rear end of the intermediate inner diameter portion 29w and the diameter of the inner portion of the communication portion is approximately the same as the diameter of the rear end of the intermediate inner diameter portion 29w. Then, when the nozzle main body portion 24w is attached to the monitor 3, the nozzle main body portion 24w protrudes 7 mm into the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3. Here, similarly to the first embodiment, the length by which the nozzle main body portion 24w protrudes into the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3 is half ($D/2$) of the diameter (D) of the cement milk/water flow path 9 in the monitor 3. Note that in the sixth variation, similarly to the first embodiment, the entire length LL (32 mm) of the nozzle main body portion 24w is 16 times the diameter d (7 mm) of the leading end of the intermediate inner diameter portion 29w, but there is no limitation to this, and the entire length of the nozzle main body portion 24w may also be 15 to 20 times the diameter of the leading end of the intermediate inner diameter portion 29w, and if the entire length LL of the nozzle main body portion 24w cannot be increased, the entire length LL of the nozzle main body portion 24w may also be 10 to 20 times the diameter d of the leading end of the intermediate inner diameter portion 29w. Also, the flow path division portion 31w that divides the cross section of the hollow-shaped rear end inner diameter portion 28w into multiple spaces is formed in the rear end inner diameter portion 28w inside of the nozzle main body extended portion 27w. Similarly to the first embodiment, the flow path division portion 31w is formed into a cross shape with a width of 1.5 mm and a length of 5.5 mm. The flow path division portion 31w can also be changed to the

shape of the third embodiment.

[0093] Next, differences between the method for attaching the nozzle main body portion 24w to the nozzle main body portion attachment hole 23w formed on the side surface of the monitor upper portion pipe 35 and the method for attaching the nozzle main body portion 24 of the first embodiment will be described. Here, the nozzle main body extended portion stopping protrusion 38 is formed on the nozzle main body portion attachment hole 23w formed on the side surface of the monitor upper portion pipe 35 of the sixth embodiment (see FIG. 25(b)).

[0094] (1) First, the nozzle main body extended portion 27w is inserted into the nozzle main body portion attachment hole 23w. Accordingly, the circular rod shape formed on the leading end of the nozzle main body extended portion 27w comes into contact with the nozzle main body extended portion stopping protrusion 38, and the nozzle main body extended portion 27w is supported by the nozzle main body extended portion stopping protrusion 38.

(2) Next, the nozzle main body 26w is inserted into the nozzle main body portion attachment hole 23w. Accordingly, the rear end of the nozzle main body 26w comes into contact with the rear end side of the nozzle main body extended portion 27w, and is sealed by the O-ring 46 inserted into the O-ring attachment recess 47 at the rear end of the nozzle main body 26w.

[0095] (3) Next, the high-pressure ejection nozzle apparatus 1 including the nozzle main body portion 24w is attached to the nozzle main body portion attachment hole 23w through a procedure similar to the attachment procedure of the first embodiment, such as fitting the nozzle main body supporting tool 32 from the leading end direction of the nozzle main body 26w. Similarly to the first embodiment, the nozzle main body extended portion 27w attached in this manner is attached protruding to the approximate central portion of the cement milk/water flow path 9 (hardening material liquid flow path) in the monitor 3. Note that in the sixth variation as well, similarly to the first embodiment, the nozzle main body portion 27w may also protrude to at least approximately 1/3 of the lateral cross section of the cement milk/water flow path 9 in the monitor 3, and if multiple nozzle main body portion attachment holes 23w are formed at positions with different heights in the axial direction of the monitor 3 as in the first embodiment, the nozzle main body portion 27w may also protrude to at least

approximately 1/2 (preferable, approximately 2/3) of the cross section of the cement milk/water flow path 9 in the monitor 3.

Seventh Variation

5 [0096] The difference between the seventh variation and the first embodiment (including the first variation to the sixth variation) of the present invention is that in the first embodiment, the rear end inner diameter portion 28 of the nozzle main body portion 24 communicates with the rear end of the intermediate inner diameter portion 29 and all of the diameters are approximately the same as the diameter of the rear end
10 of the intermediate inner diameter portion 29, whereas in the seventh variation, the rear end inner diameter portion 28 of the nozzle main body portion 24 communicates with the rear end of the intermediate inner diameter portion 29, the diameter of the communication portion between the rear end inner diameter portion 28 and the intermediate inner diameter portion 29 is approximately the same as the diameter of
15 the rear end of the intermediate inner diameter portion 29, and the diameter increases in the rear end direction of the rear end inner diameter portion 28 from the communication portion between the rear end inner diameter portion 28 and the intermediate inner diameter portion 29. In this case, the diameter may also be increased toward the rear end of the rear end inner diameter portion 28 by 12 to 20
20 degrees (preferably 12 to 15 degrees and more preferably 12 to 13 degrees), which is the same angle as the intermediate inner diameter portion, or by 13 degrees or more or 18 degrees or more, which are larger angles.

[0097] By increasing the diameter to the rear end of the rear end inner diameter portion 28 from the communication portion between the rear end inner diameter
25 portion 28 and the intermediate inner diameter portion 29, a greater amount of cement milk can enter the nozzle main body portion 24 in a laminarized state, the cement milk can be ejected without attenuating the cutting power from the material liquid ejection nozzle 21 formed on the leading end of the nozzle main body portion 24, and the cement milk can be ejected a longer distance.

30

Eighth Variation

[0098] The eighth variation of the present invention is obtained by applying the

above-described seventh variation to the third embodiment, and the difference between the eighth variation and the third embodiment is that in the third embodiment, the rear end inner diameter portion 28y of the nozzle main body portion 24y communicates with the rear end of the intermediate inner diameter portion 29y and the diameters are all approximately the same as the diameter of the rear end of the intermediate inner diameter portion 29y, whereas in the eighth variation, the rear end inner diameter portion 28z of the nozzle main body portion 24z communicates with the rear end of the intermediate inner diameter portion 29z, the diameter of the communication portion between the rear end inner diameter portion 28z and the intermediate inner diameter portion 29z is approximately the same as the diameter of the rear end of the intermediate inner diameter portion 29z, and the diameter increases in the rear end direction of the rear end inner diameter portion 28z from the communication portion between the rear end inner diameter portion 28z and the intermediate inner diameter portion 29z (see FIGS. 28 to 31). In this case, the diameter may also be increased toward the rear end of the rear end inner diameter portion 28z by 12 to 20 degrees (preferably 12 to 13 degrees), which is the same angle as the intermediate inner diameter portion 29z, or by 13 degrees or more or 18 degrees or more, which are greater angles. Here, FIG. 28(a) is an enlarged view of the P-P portion shown in FIG. 3 of the high-pressure ejection nozzle apparatus according to the eighth apparatus of the present invention, FIG. 28(b) is a diagram showing the nozzle main body portion attachment hole of the monitor, FIG. 29 is a diagram showing the constituent components of the high-pressure ejection nozzle apparatus, FIG. 30 shows cross-sectional views of the constituent components, and FIG. 31 is a diagram showing a method for mounting the high-pressure ejection nozzle apparatus.

[0099] In this manner, by increasing the diameter toward the rear end of the rear end inner diameter portion 28z from the communication portion between the rear end inner diameter portion 28z of the intermediate inner diameter portion 29z, a greater amount of the cement milk is laminarized and enters the nozzle main body portion 24z, the laminarized cement milk can exhibit a greater ejection force due to the frontward portion at which the diameter decreases, the cement eject can be ejected without attenuating the cutting ability from the material liquid ejection nozzle 21z formed at the leading end of the nozzle main body portion 24z, and the cement milk can be

ejected a longer distance.

Ninth Variation

[0100] In the above-described embodiment, it was described that “the total
 5 cross-sectional area of the flow path divided by the flow path division portion 31 (31x,
 31y) may also be 40% to 60% of the cross-sectional area of the hollow shape near the
 flow path division portion 31 (31x, 31y)”, but there is no limitation to this, and the total
 cross-sectional area of the flow path divided by the flow path division portion 31 (31x,
 31y) may also be 50% to 60% of the cross-sectional area of the hollow shape near the
 10 flow path division portion 31 (31x, 31y). In particular, it has been demonstrated that
 the effect is significant when the eject pressure from the high-pressure ejection nozzle
 apparatus 1 (1x, 1y) is 20 MPa or more.

Description of Reference Numerals

15	[0101]	
	1	High-pressure ejection nozzle apparatus
	1w	High-pressure ejection nozzle apparatus
	1x	High-pressure ejection nozzle apparatus
	1y	High-pressure ejection nozzle apparatus
20	2	Injection rod
	3	Monitor
	3x	Monitor
	3y	Monitor
	4	Leading end nozzle
25	5	Work machine
	6	Swivel
	7	Cement milk/water supply path
	8	Air supply path
	9	Cement milk/water flow path
30	10	Air flow path
	11	Water supply source
	12	Air supply source

	13	Cement milk supply source
	14	Water supply hose
	15	Air supply hose
	16	Cement milk supply hose
5	17	Injection rod outer pipe
	17a	Monitor outer pipe
	18	Injection rod inner pipe
	18a	Monitor inner pipe
	19	Joining pin insertion hole
10	20a	Joining pin injection rod recess
	20b	Joining pin monitor recess
	21	Material liquid ejection nozzle
	22	Air ejection nozzle
	23	Nozzle main body portion attachment hole
15	23a	Nozzle main body portion attachment hole
	23b	Nozzle main body portion attachment hole
	23w	Nozzle main body portion attachment hole
	23x	Nozzle main body portion attachment hole
	23y	Nozzle main body portion attachment hole
20	24	Nozzle main body portion
	24w	Nozzle main body portion
	24x	Nozzle main body portion
	24y	Nozzle main body portion
	25	Air cover
25	25x	Air cover
	25y	Air cover
	26	Nozzle main body
	26w	Nozzle main body
	26y	Nozzle main body
30	27	Nozzle main body extended portion
	27w	Nozzle main body extended portion
	27y	Nozzle main body extended portion

	27z	Nozzle main body extended portion
	28	Rear end inner diameter portion
	28w	Rear end inner diameter portion
	28x	Rear end inner diameter portion
5	28y	Rear end inner diameter portion
	28z	Rear end inner diameter portion
	29	Intermediate inner diameter portion
	29w	Intermediate inner diameter portion
	29x	Intermediate inner diameter portion
10	29y	Intermediate inner diameter portion
	30	Leading end inner diameter portion
	30w	Leading end inner diameter portion
	30x	Leading end inner diameter portion
	30y	Leading end inner diameter portion
15	31	Flow path division portion
	31a	Flow path division portion
	31w	Flow path division portion
	31x	Flow path division portion
	31y	Flow path division portion
20	31z	Flow path division portion
	32	Nozzle main body portion support tool
	32x	Nozzle main body portion support tool
	32y	Nozzle main body portion support tool
	33	Notch portion
25	34	Differential pressure valve
	35	Monitor upper portion pipe
	36	Joining pin
	37	Injection rod inner pipe connection pipe
	38	Nozzle main body extended portion stopping protrusion
30	38x	Nozzle main body extended portion stopping protrusion
	38y	Nozzle main body extended portion stopping protrusion
	39	Monitor lower portion pipe

	40	Flow path closing tool
	41	Nozzle main body portion attachment hole closing tool
	42	Air flow path closing tool
	43	Air cover attachment hole
5	43a	Air cover attachment hole
	43b	Air cover attachment hole
	44	Injection rod protrusion portion
	45	Monitor upper portion pipe inner protrusion portion
	46	O ring
10	46x	O ring
	46y	O ring
	47	O ring attachment recess
	47x	O ring attachment recess
	47y	O ring attachment recess
15	48x	Nozzle main body rearward member

CLAIMS

1. A high-pressure ejection nozzle apparatus that communicates with an interior of a hardening material liquid supply pipe formed in an axial direction in an injection
5 rod, and is provided on a side surface of a monitor coupled to a leading end of the injection rod, the high-pressure ejection nozzle apparatus comprising

a nozzle main body portion in which a hollow shape is formed, the hollow shape including: an intermediate inner diameter portion having a tapered surface shape with an inner circumferential surface formed with a diameter that decreases in
10 the leading end direction; a leading end inner diameter portion that communicates with a leading end of the intermediate inner diameter portion and has approximately the same diameter as the leading end of the intermediate inner diameter portion; and a rear end inner diameter portion that communicates with a rear end of the intermediate inner diameter portion and is formed with a diameter that is
15 approximately the same as the diameter of the rear end of the intermediate inner diameter portion, or with a diameter that increases in the rear end direction from being approximately the same,

wherein a flow path division portion that divides a cross section of the hollow shape into a plurality of spaces is formed in the rear end inner diameter portion of the
20 nozzle main body portion,

at an approximately central portion of the hollow-shaped rear end inner diameter portion near the flow path division portion, the flow path division portion includes a portion having an area that is 2% to 20% of a cross-sectional area of the hollow shape of the rear end inner diameter portion near the flow path division portion,
25 and

a hardening material liquid flowing in the rear end inner diameter portion of the nozzle main body portion is more finely laminarized by the spaces divided by the flow path division portion, and thereafter is sent in the leading end direction with the diameter reduced by the hollow-shaped space of the intermediate inner diameter
30 portion in which there is no concrete object, and therefore a cutting ability of the hardening material liquid ejected from the leading end inner diameter portion of the nozzle main body portion is increased, and the hardening material liquid can be

ejected a longer distance.

2. The high-pressure ejection nozzle apparatus according to claim 1, wherein the total cross-sectional area of the flow path divided by the flow path division portion is
5 40% to 60% of the cross-sectional area of the hollow shape of the rear end inner diameter portion near the flow path division portion.
3. The high-pressure ejection nozzle apparatus according to claim 1 or 2, wherein the cross-sectional area of the hollow shape near the flow path division portion is the
10 cross-sectional area of the hollow shape directly in front of the flow path division portion.
4. The high-pressure ejection nozzle apparatus according to claim 1 or 2, wherein the cross-sectional area of the hollow shape near the flow path division portion is the
15 cross-sectional area of the hollow shape directly behind the flow path division portion.
5. The high-pressure ejection nozzle apparatus according to any one of claims 1 to 4, wherein the flow path division portion is formed in a cross shape.
- 20 6. The high-pressure ejection nozzle apparatus according to any one of claims 1 to 5, wherein the rear end inner diameter portion of the nozzle main body portion is formed protruding into a hardening material liquid flow path formed in the axial direction in the monitor.
- 25 7. A ground improvement apparatus according to any one of claims 1 to 6, provided with the monitor in which the high-pressure nozzle apparatus is mounted.