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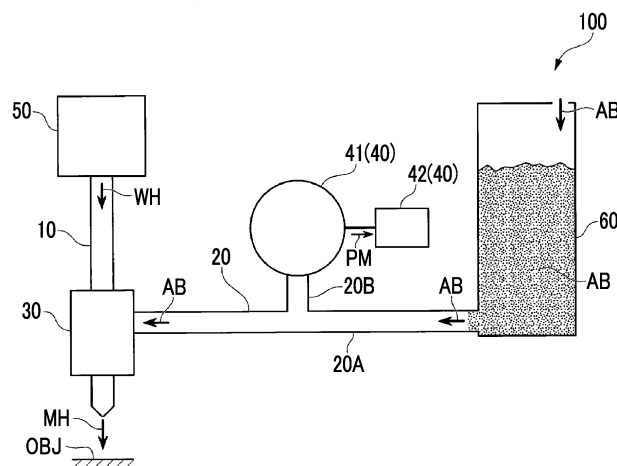
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(54) **MACHINING APPARATUS AND MACHINING METHOD**

(57) A machining apparatus (100) is provided with: high-pressure water piping (10) that is capable of supplying high-pressure water (WH); abrasive grain piping (20) that is capable of supplying abrasive grains (AB); a spraying part (30) having a high-pressure water introduction part by which the high-pressure water (WH) is introduced, an abrasive grain introduction part by which the abrasive grains (AB) are introduced, a mixing part that

mixes the high-pressure water (WH) and the abrasive grains (AB), and a nozzle that sprays the high-pressure water (WH) with which the abrasive grains (AB) have been mixed onto an object to be machined (OBJ); and a detection part (40) that measures the pressure (PM) inside the abrasive grain piping (20) and detects when the pressure (PM) is less than a lower-limit threshold value.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a machining apparatus and a machining method.

[0002] This application claims the priority of Japanese Patent Application No. 2018-014975 filed in Japan on January 31, 2018, the contents of which are incorporated herein by reference.

Background Art

[0003] As one of machining apparatuses, there is an apparatus which vigorously injects high-pressure water mixed with an abrasive from a nozzle to cut or machine an object.

[0004] For example, PTL 1 discloses a cutting device using an abrasive water jet which mixes an abrasive into ultrahigh-pressure jet water.

Citation List

Patent Literature

[0005] [PTL 1] Japanese Unexamined Utility Model Registration Application Publication No. 02-19466

Summary of Invention

Technical Problem

[0006] In the cutting device disclosed in PTL 1, the abrasive introduced from a supply portion is mixed with the ultrahigh-pressure jet water inside the supply portion.

[0007] When the abrasive is abrasive grains, the abrasive grains may be clogged inside the supply portion. When the abrasive grains are clogged inside the supply portion, a supply amount of the abrasive grains decreases, and machining ability decreases.

[0008] However, the cutting device disclosed in PTL 1 cannot detect clogging of the abrasive grains.

[0009] An object of the present invention is to provide a machining apparatus and a machining method capable of detecting the clogging of abrasive grains in consideration of the above-described problems.

Solution to problem

[0010] According to a first aspect, there is provided a machining apparatus including: a high-pressure water pipe through which high-pressure water is supplied; an abrasive grain pipe through which abrasive grains are supplied; an injection unit which includes a high-pressure water introduction portion into which the high-pressure water is introduced, an abrasive grain introduction portion into which the abrasive grains are introduced, a mixing portion in which the high-pressure water and the abrasive

grains are mixed with each other, and a nozzle which injects the high-pressure water having the mixed abrasive grains to an object to be machined; and a detection unit which measures a pressure inside the abrasive grain pipe and detects that the pressure is lower than a lower threshold value.

[0011] According to this aspect, the machining apparatus detects that the measured pressure is lower than the lower threshold value. Accordingly, the machining apparatus can detect that the abrasive grains are clogged on at least a downstream side of a pressure measurement location. Therefore, the machining apparatus can detect the clogging of the abrasive grains.

[0012] Moreover, according to a second aspect, in the machining apparatus according to the first aspect, the detection unit further detects that the pressure is higher than an upper threshold value.

[0013] Further, according to a third aspect, in the machining apparatus according to the first or second aspect, the detection unit specifies that an abnormality is present on an upstream side of a pressure measurement location by the detection unit in a case where the pressure is lower than the lower threshold value.

[0014] In addition, according to a fourth aspect, the machining apparatus of according to any one of the first to third aspects further includes a partition pipe which separates a first space extending in one direction from the high-pressure water introduction portion to the nozzle and a second space around the first space from each other, inside the mixing portion and includes an opening on an introduction straight line extending in an introduction direction of the abrasive grains from the abrasive grain introduction portion; and an exhaust portion which is provided at a position facing the abrasive grain introduction portion across the first space and exhausts air inside the second space.

[0015] Further, according to a fifth aspect, there is provided a machining apparatus including: a high-pressure water pipe through which high-pressure water is supplied; an abrasive grain pipe through which abrasive grains are supplied; an injection unit which includes a high-pressure water introduction portion into which the high-pressure water is introduced, an abrasive grain introduction portion into which the abrasive grains are introduced, a mixing portion in which the high-pressure water and the abrasive grains are mixed with each other, and a nozzle which injects the high-pressure water having the mixed abrasive grains to an object to be machined; and a partition pipe which separates a first space extending in one direction from the high-pressure water introduction portion to the nozzle and a second space around the first space from each other, inside the mixing portion and includes an opening on an introduction straight line extending in an introduction direction of the abrasive grains from the abrasive grain introduction portion; and an exhaust portion which is provided at a position facing the abrasive grain introduction portion across the first space and exhausts air inside the second space.

[0016] According to this aspect, in the machining apparatus, the exhaust portion is provided at the position facing the abrasive grain introduction portion across the first space and exhausts the air inside the second space. Therefore, the machining apparatus can keep a flow rate of the abrasive grains in the injection unit large. Accordingly, it is possible to suppress the clogging of the abrasive grains.

[0017] Moreover, according to a sixth aspect, there is provided a machining method including: a step of measuring a pressure inside an abrasive grain pipe of a machining apparatus including a high-pressure water pipe through which high-pressure water is supplied, the abrasive grain pipe through which abrasive grains are supplied, and a nozzle which is connected to the high-pressure water pipe and the abrasive grain pipe and injects the high-pressure water mixed with the abrasive grains to an object to be machined; and a step of detecting that the pressure is lower than a lower threshold value.

[0018] According to this aspect, the machining method detects that the measured pressure is lower than the lower threshold value. Accordingly, the machining method can detect that the abrasive grains are clogged on at least a downstream side of a pressure measurement location. Therefore, the machining method can detect the clogging of the abrasive grains.

Advantageous Effects of Invention

[0019] According to an aspect of the present invention, it is possible to detect clogging of abrasive grains.

Brief Description of Drawings

[0020]

Fig. 1 is an overall schematic diagram of a machining apparatus according to a first embodiment.

Fig. 2 is a cross-sectional diagram of an injection unit according to the first embodiment.

Fig. 3 is a diagram for explaining an operation of the machining apparatus of the first embodiment.

Fig. 4 is a diagram for explaining an operation of a detection unit according to the first embodiment.

Fig. 5 is a diagram for explaining an operation of a modification example of the detection unit of the first embodiment.

Fig. 6 is an overall schematic diagram of a machining apparatus according to a second embodiment.

Fig. 7 is a cross-sectional diagram of an injection unit according to the second embodiment.

Fig. 8 is a flowchart of a machining method in each embodiment.

Description of Embodiments

[0021] Hereinafter, various embodiments according to the present invention will be described with reference to

the drawings.

<First Embodiment>

[0022] Hereinafter, a machining apparatus according to a first embodiment of the present invention will be described with reference to Figs. 1 to 5.

[0023] A machining apparatus 100 of the present embodiment is a cutting apparatus using an abrasive water jet and cuts an object to be machined OBJ.

(Constitution)

[0024] As illustrated in Fig. 1, the machining apparatus 100 includes a high-pressure water pipe 10, an abrasive grain pipe 20, an injection unit 30, a detection unit 40, a high-pressure pump 50, and a hopper 60. The machining apparatus 100 injects high-pressure mixed water MH containing abrasive grains AB to the object to be machined OBJ.

[0025] The high-pressure water pipe 10 connects the high-pressure pump 50 and the injection unit 30 to each other.

[0026] The high-pressure pump 50 pressurizes water into high-pressure water WH and supplies the high-pressure water WH to the injection unit 30 via the high-pressure water pipe 10.

[0027] Therefore, the high-pressure water WH can be supplied to the injection unit 30 through the high-pressure water pipe 10.

[0028] The abrasive grain pipe 20 connects a lower portion of the hopper 60 and the injection unit 30 to each other.

[0029] An inside of the hopper 60 is filled with the abrasive grains AB. The abrasive grains AB are supplied into the hopper 60 from an opening on an upper portion of the hopper 60 by another device or an operator.

[0030] In the abrasive grains AB in the hopper 60, the abrasive grains AB located in a lower portion of the hopper 60 are pressurized by the gravity and extruded to the abrasive grain pipe 20 connected to the lower portion of the hopper 60. Thereby, the hopper 60 supplies the extruded abrasive grains AB to the injection unit 30 via the abrasive grain pipe 20.

[0031] Therefore, the abrasive grains AB can be supplied to the injection unit 30 through the abrasive grain pipe 20.

[0032] The abrasive grain pipe 20 has a main pipe 20A and a branch pipe 20B. The main pipe 20A extends from the hopper 60 toward the injection unit 30. The branch pipe 20B branches off from the main pipe 20A in a middle of the main pipe 20A.

[0033] The injection unit 30 mixes the supplied high-pressure water WH with the abrasive grains AB inside the injection unit 30 to inject the high-pressure mixed water MH.

[0034] The detection unit 40 measures a pressure PM inside the abrasive grain pipe 20 at a measurement lo-

cation, detects that the pressure PM is lower than a lower threshold value, and further detects that the pressure PM is higher than the upper threshold value.

(Injection Unit)

[0035] As illustrated in Fig. 2, the injection unit 30 includes a high-pressure water introduction portion 31, an abrasive grain introduction portion 32, an orifice 34, a chamber 35 (mixing portion), and a nozzle 36.

[0036] The chamber 35 is a pressure vessel having a substantially hollow cylindrical shape extending in an axis AX direction with an axis AX as a cylindrical axis. The chamber 35 is sealed except for various openings, and a pressure inside the chamber 35 can be a low pressure by closing the various openings.

[0037] In the chamber 35, the high-pressure water WH introduced from the high-pressure water introduction portion 31 and the abrasive grains AB introduced from the abrasive grain introduction portion 32 are mixed with each other in a space between the orifice 34 and a lower surface of the chamber 35, and thus, become the high-pressure mixed water MH.

[0038] The high-pressure water introduction portion 31 includes an opening which is provided on an upper surface of the chamber 35 and has the axis AX as a center. By connecting the high-pressure water pipe 10 to the high-pressure water introduction portion 31, the high-pressure water WH is introduced from the high-pressure water introduction portion 31 into the injection unit 30.

[0039] The introduced high-pressure water WH is supplied to the orifice 34 via the high-pressure water introduction portion 31.

[0040] The abrasive grain introduction portion 32 is provided in an opening on an upper portion of an outer periphery of the chamber 35. By connecting the abrasive grain pipe 20 to the abrasive grain introduction portion 32, the abrasive grains AB are introduced from the abrasive grain introduction portion 32 into the injection unit 30.

[0041] The orifice 34 has a through hole 34H which extends from the high-pressure water introduction portion 31 toward the nozzle 36 about the axis AX. A base end of the orifice 34 is connected to the high-pressure water introduction portion 31. A tip of the orifice 34 is directed toward the nozzle 36. The through hole 34H on a tip side of the orifice 34 faces the nozzle 36. The tip of the orifice 34 and the nozzle 36 are separated from each other across a space.

[0042] The through hole 34H is a hole which opens from a base end side of the orifice 34 toward a tip side of the orifice 34.

[0043] As an example, the through hole 34H may be a hole of an inner diameter decreases from the base end side of the orifice 34 toward the tip side of the orifice 34.

[0044] As another example, the through hole 34H may be a small-diameter hole which opens to have a simply fixed hole diameter from the base end side of the orifice 34 toward the tip side of the orifice 34.

[0045] In any case, the orifice 34 is made of a hard material such as diamond or ruby to suppress wear. As a result, the orifice 34 injects the high-pressure water introduced into the high-pressure water introduction portion 31 toward the nozzle 36 from the tip side of the orifice 34.

[0046] The nozzle 36 protrudes downward from an opening on the lower surface of the chamber 35.

[0047] The nozzle 36 extends toward a tip which protrudes from a base end on a lower surface side of the chamber 35. An upper end of the nozzle 36 is connected to the opening on the lower surface of the chamber 35. The nozzle 36 has a nozzle hole 36H which penetrates from an upper end toward a lower end about the axis AX.

[0048] The nozzle 36 has a tubular shape in which the nozzle hole 36H generally has a constant diameter from a base end to a tip without changing an inner diameter of the nozzle hole 36H. The nozzle hole 36H has a certain length, and thus, has a function of rectifying the high-pressure mixed water MH to make the high-pressure mixed water to a narrowed flow which is not diffused. Thereby, the nozzle 36 injects the narrowed high-pressure mixed water MH toward the object to be machined OBJ from the tip of the nozzle 36.

[0049] Here, the high-pressure water WH is injected from the orifice 34 at a high pressure. Therefore, the high-pressure mixed water MH is also injected from the nozzle 36 at a high pressure without a change in pressure.

(Detection Unit)

[0050] Returning to Fig. 1, the detection unit 40 includes a measurement unit 41 and a determination unit 42.

[0051] The measurement unit 41 measures the pressure PM inside the abrasive grain pipe 20. In the present embodiment, the measurement unit 41 is connected to a branch end of the branch pipe 20B. For this reason, the measurement unit 41 measures the pressure PM inside the branch pipe 20B at the branch end of the branch pipe 20B which is a measurement location.

[0052] The measurement unit 41 provides the measured pressure PM to the determination unit 42.

[0053] The determination unit 42 detects that the obtained pressure PM is small. Specifically, the determination unit 42 compares the obtained pressure PM with a preset lower threshold value PL. Then, in a case where the pressure PM is lower than the lower threshold value PL, the determination unit 42 detects the intention.

[0054] The determination unit 42 detects that the obtained pressure PM is large. Specifically, the determination unit 42 further compares the pressure PM with a preset upper threshold value PH. Then, in a case where the obtained pressure PM is higher than the upper threshold value PH, the determination unit 42 detects the intention.

[0055] As the lower threshold value PL and the upper threshold value PH, a lower limit and an upper limit of

the pressure PM when a desired machining ability is obtained are set, respectively. The lower limit value and the upper limit value of the pressure PM at which a desired machining ability can be obtained are determined in advance by experience, results, experiments, or the like.

[0056] For example, the measurement unit 41 is a Bourdon tube pressure gauge, and as illustrated in Fig. 3, sets a pressure at the time of the atmospheric pressure to 0 kPa and measures a pressure difference from the atmospheric pressure as the pressure. In the present embodiment, in the determination unit 42, -50 kPa is set as the upper threshold value PH, and -70 kPa is set as the lower threshold value PL.

[0057] In a case where the detection unit 40 detects that the obtained pressure PM is lower than the lower threshold value PL or in a case where the detection unit 40 detects that the obtained pressure PM is higher than the upper threshold value PH, the detection unit 40 may immediately output a command to stop a supply of the high-pressure water to the high-pressure pump 50.

[0058] Moreover, in a case where the detection unit 40 detects that the pressure PM is lower than the lower threshold value PL or in a case where the detection unit 40 detects that the obtained pressure PM is higher than the upper threshold value PH, the detection unit 40 may output a command to a high-pressure valve 37 which is provided immediately before the high-pressure water introduction portion 31 in the middle of the high-pressure water pipe 10 and may control the high-pressure valve so that the high-pressure valve is blocked immediately after the detection.

(Operation)

[0059] The machining apparatus 100 supplies the high-pressure water WH from the high-pressure water pipe 10 and the abrasive grains AB from the abrasive grain pipe 20 to the injection unit 30, respectively. The high-pressure water WH and the abrasive grains AB introduced into the injection unit 30 are mixed with each other inside the chamber 35 and become the high-pressure mixed water MH. The machining apparatus 100 injects the mixed high-pressure mixed water MH toward the object to be machined OBJ from the tip of the nozzle 36.

[0060] At this time, in a case where the detection unit 40 measures the pressure PM inside the abrasive grain pipe 20 and detects that the pressure PM is lower than the lower threshold value PL, the detection unit 40 detects the intention. Meanwhile, in a case where the pressure PM is higher than the upper threshold value PH, the detection unit 40 detects the intention.

(Action and Effect)

[0061] In the present embodiment, the detection unit 40 measures the pressure PM inside the abrasive grain pipe 20.

[0062] In this case, the hopper 60 supplies the extruded abrasive grains AB to the injection unit 30 via the abrasive grain pipe 20. Therefore, The pressure in the abrasive grain pipe 20 at least at the upstream end of the abrasive grain pipe 20 is higher than the downstream end connected to the injection part 30 due to pressure loss in the pipe, but is lower than the atmospheric pressure.

[0063] Meanwhile, the high-pressure water WH introduced from the high-pressure water introduction portion 31 is injected from the orifice 34. Accordingly, a negative pressure is formed immediately below the orifice 34 by a Venturi effect, and the abrasive grains AB introduced from the abrasive grain introduction portion 32 are sucked. For this reason, a pressure inside the abrasive grain pipe 20 in at least a downstream end of the abrasive grain pipe 20 is at least lower than the atmospheric pressure.

[0064] For example, if the abrasive grain AB is clogged in the abrasive grain pipe 20 on the upstream side of the connecting portion of the branch pipe 20B, the pressure PM is lower than that when the abrasive grains AB are not clogged. The same applies to clogging in the hopper 60.

[0065] Therefore, when the detection unit 40 detects that the measured pressure is lower than the lower threshold value PL, it is possible to detect that the abrasive grains AB are clogged on the upstream side (including the hopper 60) of the branch pipe 20B.

[0066] For example, if the abrasive grains AB are clogged in the abrasive grain pipe 20 on a downstream side of the branch pipe 20B and the abrasive grain pipe 20 is blocked on the downstream side of the branch pipe 20B, the pressure PM is higher than that when the abrasive grains AB are not clogged. The same applies to clogging in the nozzle 36, clogging in the abrasive grain introduction portion 32, or the like.

[0067] Therefore, if the detection unit 40 detects that the measured pressure is higher than the upper threshold value PH, it is possible to detect that the abrasive grains AB are clogged on the downstream side (including the nozzle 36) of the branch pipe 20B.

[0068] Therefore, the machining apparatus 100 can detect the clogging of the abrasive grains AB.

[0069] The machining apparatus 100 using the abrasive water jet as in the present embodiment can vigorously inject the high-pressure water mixed with abrasive grains AB from a nozzle to perform trimming (trimming machining). Further, in general, the machining apparatus 100 using the abrasive water jet as in the present embodiment is usually used for cutting a hard-to-cut material, and, for example, can perform trimming (trimming machining) of a wing skin.

[0070] The abrasive grains AB are mixed in order to increase power of the abrasive water jet, and an abrasive such as SiC or Al₂O₃ having a particle size of about several hundred of μm is used in many cases.

[0071] In order to transport the abrasive grains AB,

vacuum transport performed by an aspirator using the Venturi effect of a water jet is often used as in the machining apparatus 100 of the present embodiment. The reason for using the vacuum transport performed by an aspirator is that there is no need to use a new power for transporting the abrasive grains, and the apparatus can be simplified.

[0072] However, if the abrasive grains AB are clogged in the nozzle 36 or the abrasive grains AB are instantaneously clogged in the abrasive grain pipe 20, the pressure of the jet may temporarily decrease. In this state, not only does a "sharpness" of the trim become poor and cutting quality sharply decreases, but also the cutting is impossible if a pressure decrease time of the jet is long.

[0073] The abrasive grains AB have a sharp shape in order to improve cutting performance and quality, and because of this shape, fluidity is poor and the clogging is likely to occur essentially.

[0074] As illustrated in Fig. 3, it is assumed that the abrasive grains AB are clogged and the main pipe 20A is blocked at a position XL on the downstream side of the branch pipe 20B. In this case, the pressure detected by the detection unit 40 is higher than that in a normal state, since the negative pressure of the venturi effect sucked by the injection unit 30 decreases.

[0075] Therefore, when the detection unit 40 detects that the pressure PM is higher than the upper threshold value PH, the detection unit 40 can detect the blockage on the downstream side of the detection unit 4.

[0076] However, in actual, as illustrated in Fig. 3, the blockage by the abrasive grains AB may occur not only on a downstream side than the branch pipe 20B, but also at a position XH on an upstream side of the branch pipe 20B.

[0077] It is assumed that the main pipe 20A is blocked by the abrasive grains AB at the position XH. In this case, due to the negative pressure of the Venturi effect, the pressure detected by the detection unit 40 is lower than that in the normal state. That is, the change is opposite to a case where the abrasive grains AB is clogged on the downstream side of the branch pipe 20B.

[0078] Therefore, the detection unit 40 not only detects that the pressure PM is higher than the upper threshold value PH, but also detects that the pressure PM is lower than the lower threshold value PL.

[0079] That is, as illustrated in Fig. 4, the detection unit 40 determines that the pressure PM is not in a range (normal range) in which the pressure PM is the lower threshold value PL or more and the upper threshold value PH or less, and the detection unit 40 determines that the pressure PM is in a range lower than the lower threshold value PL or in a range (abnormal range) more than the upper threshold value PH.

[0080] In general, in the abrasive water jet, the pressure in the abrasive grain pipe 20 fluctuates according to a pressure fluctuation of a high-pressure pump, a water temperature which determines the negative pressure of the Venturi effect, and flow conditions of the abrasive

grains AB. Therefore, it is necessary to determine a range which is not abnormal.

[0081] As in the present embodiment, for example, when the upper threshold value PH is set to -50 kPa and the lower threshold value PL is set to -70 kPa, it is possible to cope with the fluctuation. This value may vary depending on various conditions.

[0082] If there is a blockage on an upstream side of a pressure measurement location (branch pipe 20B) by the detection unit 40, the flows of the abrasive grains AB stop or an amount of the flow decreases. Accordingly, a sharpness of the jet injected from the machining apparatus 100 deteriorates, and a cut surface of the object to be machined OBJ is rough or the object to be machined OBJ cannot be cut.

[0083] Meanwhile, if there is a blockage on a downstream side of the pressure measurement location (branch pipe 20B) by the detection unit 40, at least one of the blockage of the abrasive grain pipe 20 and the blockage of the injection unit 30 occurs. When the abrasive grain pipe 20 is blocked, the flows of the abrasive grains AB are stopped as described above. When the injection unit 30 is blocked, the jet injected from the machining apparatus 100 stops.

[0084] When the flows of the abrasive grains AB are stopped or the jet injected from the machining apparatus 100 is stopped, the sharpness of the jet becomes deteriorates as described above, and the cut surface of the workpiece is rough or the workpiece cannot be cut.

[0085] In this situation, the trimming cannot be restarted immediately after the blockage is eliminated, and the rough cut surface needs to be repaired by any method.

[0086] Meanwhile, the machining apparatus 100 of the present embodiment can detect the clogging of the abrasive grains AB. Further, it is possible to detect whether the clogged location of the abrasive grains AB is the upstream side or the downstream side of the branch pipe 20B which is the pressure detection location of the detection unit 40. For this reason, it is possible to cope before the cut surface is rough or cannot be cut, and thus, an impact is extremely large in terms of cost and a delivery date.

(Modification Example)

[0087] In the present embodiment, the detection unit 40 detects that the pressure PM is in the range lower than the lower threshold value PL or in the range (abnormal range) higher than the upper threshold value PH. As a modification example, as illustrated in Fig. 5, the detection unit 40 may separately detect that the pressure PM is in the range (abnormal range (I)) lower than the lower threshold value PL and the pressure PM is in the range higher than the upper threshold value PH (abnormal range (II).)

[0088] Furthermore, when the pressure PM is in the abnormal range (I), the detection unit 40 may specify that there is an abnormality (blockage) on the upstream side

of the pressure measurement location by the detection unit 40, and when the pressure PM is in the abnormal range (II), the detection unit 40 may specify that there is an abnormality (blockage) on the downstream side of the pressure measurement location by the detection unit 40.

<Second Embodiment>

[0089] Hereinafter, a machining apparatus according to a second embodiment of the present invention will be described with reference to Fig. 6.

[0090] A machining apparatus 200 of the present embodiment is basically the same as that of the first embodiment, but is different from that of the first embodiment in that a vacuum pump is provided. Moreover, constitutions of injection units are different from each other.

(Constitution)

[0091] The machining apparatus 200 includes the high-pressure water pipe 10, the abrasive grain pipe 20, an injection unit 230, the detection unit 40, the high-pressure pump 50, and the hopper 60. As illustrated in Fig. 6, the machining apparatus 200 further includes a vacuum pump 80.

[0092] As illustrated in Fig. 7, the injection unit 230 mixes the supplied high-pressure water WH with the abrasive grains AB inside the injection unit 30 to inject the high-pressure mixed water MH.

[0093] The injection unit 230 includes the high-pressure water introduction portion 31, the abrasive grain introduction portion 32, an exhaust portion 33, the orifice 34, a chamber 235 (mixing portion), the nozzle 36, and a partition pipe 70.

[0094] The partition pipe 70 is provided inside the chamber 235. The partition pipe 70 separates a first space SP1 extending in one direction from the high-pressure water introduction portion 31 to the nozzle 36 and the second space SP2 around the first space SP1.

[0095] The partition pipe 70 has an opening 70H on an introduction straight line Li extending in introduction directions of the abrasive grains AB from the abrasive grain introduction portion 32.

[0096] The exhaust portion 33 is provided at a position facing the abrasive grain introduction portion 32 across the first space SP1. This position is best. However, the second space SP2 may be provided anywhere as long as it is a place where the second space SP2 can be exhausted and does not affect the flow of abrasive grains passing through the opening 70H. A vacuum pump 80 is connected to the exhaust portion 33. The vacuum pump 80 exhausts gas in the second space SP2 from the exhaust portion 33.

(Operation)

[0097] A pressure inside the chamber 235 is reduced by the vacuum pump 80. Therefore, most of the abrasive

grains AB introduced from the abrasive grain introduction portion 32 are accelerated in the direction of the introduction straight line Li so as to be sucked into the chamber 235. Moreover, most of the accelerated abrasive grains AB rush into the opening 70H due to inertial motion, are mixed with the high-pressure water WH to be the high-pressure mixed water MH, and are injected from the nozzle 36.

10 (Action and Effect)

[0098] In general, the negative pressure formed by the Venturi effect has many small fluctuations. Accordingly, when the abrasive grains AB are transported into the injection unit using the Venturi effect as in the first embodiment, a transport amount of the abrasive grains AB may be unstable. When the transport amount of the abrasive grains AB is unstable, it is difficult to keep a transport flow rate of the abrasive grains AB into the injection unit high.

[0099] Further, the negative pressure due to the Venturi effect of the high-pressure jet is small. In this case, when the vacuum pump 80 is separately provided and the abrasive grains AB are transported by decompressed air, it is possible to increase the flow rate.

[0100] Therefore, in the present embodiment, the air inside the second space SP2 is exhausted using an independent dedicated system for introducing the abrasive grains, and in the machining apparatus 200, the separate vacuum pump 80 is provided to transport the abrasive grains AB by decompressed air.

[0101] For this reason, it is possible to keep the flow rate of the abrasive grains AB into the injection unit 230 large.

[0102] In addition, effects of suppressing the negative pressure fluctuation of the high-pressure jet can be expected.

[0103] Therefore, it is possible to suppress the clogging of the abrasive grains AB.

[0104] In addition, in the present embodiment, in the machining apparatus 200, the partition pipe 70 is provided inside the chamber 235. Further, in the machining apparatus 200, the exhaust portion 33 is provided at the position facing the abrasive grain introduction portion 32 across the first space SP1. Accordingly, solid (abrasive grain) - gas (air) separation can be performed inside the injection unit 230.

[0105] If the air inside the chamber 235 is exhausted at a pressure lower than the pressure formed by the Venturi effect without providing the partition pipe 70, the flows of the abrasive grains AB from the abrasive grain introduction portion 32 to the opening 70H on the introduction straight line Li are obstructed.

[0106] Meanwhile, in the present embodiment, since the partition pipe 70 is provided, the flows of the abrasive grains AB on the introduction straight line Li are not easily obstructed. As a result, the abrasive grains AB are introduced from the abrasive grain introduction portion 32 into

the first space SP1 through the opening 70H.

[0107] Therefore, it is possible to further suppress the clogging of the abrasive grains AB.

<Machining Method>

[0108] The machining method in each of the embodiments will be described with reference to Fig. 8.

[0109] Hereinafter, a case where the machining apparatus 100 is used will be described. However, the same applies to a case where the machining apparatus 200 is used.

[0110] First, the machining apparatus 100 measures the pressure inside the abrasive grain pipe 20 (ST10: a step of measuring the pressure).

[0111] Subsequent to ST10, the machining apparatus 100 compares the obtained pressure PM with the preset lower threshold value PL (ST20: a step of comparing with the lower threshold value).

[0112] As a result of the comparison, in a case where the machining apparatus 100 determines that the obtained pressure PM is lower than the preset lower threshold value PL (ST20: YES), the process proceeds to ST40.

[0113] As a result of the comparison, when the machining apparatus 100 determines that the obtained pressure PM is not lower than the preset lower threshold value PL (ST20: NO), the process proceeds to ST30.

[0114] In ST30, the machining apparatus 100 compares the pressure PM with the preset upper threshold value PH (ST30: a step of comparing with the upper threshold value).

[0115] As a result of the comparison, in a case where the machining apparatus 100 determines that the obtained pressure PM is not higher than the preset upper threshold value PH (ST30: NO), the process returns to ST10, and the pressure inside the abrasive grain pipe 20 is measured again.

[0116] As a result of the comparison, in a case where the machining apparatus 100 determines that the obtained pressure PM is higher than the preset upper threshold value PH (ST30: YES), the process proceeds to ST40.

[0117] In ST40, the machining apparatus 100 detects that pressure PM is out of the range (the pressure PM is lower than the lower threshold value PL or higher than the upper threshold value PH).

[0118] Subsequent to ST40, when detecting that the obtained pressure PM is lower than the lower threshold value PL or detecting that the pressure PM is higher than the upper threshold value PH, the detection unit 40 immediately supplies high-pressure water to the high-pressure pump 50. A command to stop is output (ST50: output step). Further, in ST50, in a case where the detection unit 40 detects that the pressure PM is lower than the lower threshold value PL, or in a case where the detection unit 40 detects that the pressure PM is higher than the upper threshold value PH, the detection unit 40 may output a command to the high-pressure valve 37 which is

provided immediately before the high-pressure water introduction portion 31 in the middle of the high-pressure water pipe 10 as illustrated in Fig. 2. The high-pressure valve 37 receiving the command stops the injection of the high-pressure water WH, and thus, the machining apparatus 100 stops the injection of the high-pressure mixed water MH.

(Modification Example)

[0119] Each step of the present machining method is performed by the machining apparatus. However, as a modification example, at least one of steps ST10 to ST50 may be performed by an operator.

[0120] Moreover, in steps ST20 and ST30 of the machining method, the machining apparatus compares the obtained pressure PM with the lower threshold value PL and also compares the obtained pressure PM with the upper threshold value PH. However, as a modification example, it is not necessary to compare the obtained pressure PM with the upper threshold value PH only by comparing the obtained pressure PM with the preset lower threshold value PL. In this case, in ST40, the machining apparatus detects only that the pressure PM is lower than the lower threshold value, and does not detect that the pressure PM is higher than the upper threshold value PH.

[0121] Hereinbefore, some embodiments of the present invention are described. However, the embodiments are presented by way of example only, and are not intended to limit a scope of the invention. The embodiments can be implemented in other various forms, and various omissions, replacements, and modifications can be made within a scope which does not depart from the gist of the invention. The embodiments and modifications thereof are included in the scope and gist of the invention, and are also included in the invention described in the claims and equivalents thereof.

[0122] For example, in each of the embodiments, the machining apparatus and the machining method perform cutting of the object to be machined OBJ, but may perform machining of the object to be machined OBJ even without cutting the object to be machined OBJ.

Industrial Applicability

[0123] According to an aspect of the present invention, it is possible to detect clogging of abrasive grains. Reference Signs List

[0124]

- 10: high-pressure water pipe
- 20: abrasive grain pipe
- 20A: main pipe
- 20B: branch pipe
- 30: injection unit
- 31: high-pressure water introduction portion
- 32: abrasive grain introduction portion

33: exhaust portion
 34: orifice
 34H: through hole
 35: chamber
 36: nozzle
 36H: nozzle hole
 37: high-pressure valve
 40: detection unit
 41: measurement unit
 42: determination unit
 50: high-pressure pump
 60: hopper
 70: partition pipe
 70H: opening
 80: vacuum pump
 100: machining apparatus
 200: machining apparatus
 230: injection unit
 235: chamber
 AB: abrasive grain
 AX: axis
 Li: introduction straight line
 MH: high-pressure mixed water
 OBJ: object to be machined
 PH: upper threshold value
 PL: lower threshold value
 PM: pressure
 SP1: first space
 SP2: second space
 WH: high-pressure water

Claims

1. A machining apparatus comprising:
 - a high-pressure water pipe through which high-pressure water is supplied;
 - an abrasive grain pipe through which abrasive grains are supplied;
 - an injection unit which includes a high-pressure water introduction portion into which the high-pressure water is introduced, an abrasive grain introduction portion into which the abrasive grains are introduced, a mixing portion in which the high-pressure water and the abrasive grains are mixed with each other, and a nozzle which injects the high-pressure water having the mixed abrasive grains to an object to be machined; and
 - a detection unit which measures a pressure inside the abrasive grain pipe and detects that the pressure is lower than a lower threshold value.
2. The machining apparatus according to claim 1, wherein the detection unit further detects that the pressure is higher than an upper threshold value.
3. The machining apparatus according to claim 1 or 2, wherein the detection unit specifies that an abnormality is present on an upstream side of a pressure measurement location by the detection unit in a case where the pressure is lower than the lower threshold value.

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4. The machining apparatus according to any one of claims 1 to 3, further comprising:
 - a partition pipe which separates a first space extending in one direction from the high-pressure water introduction portion to the nozzle and a second space around the first space from each other, inside the mixing portion and includes an opening on an introduction straight line extending in an introduction direction of the abrasive grains from the abrasive grain introduction portion; and
 - an exhaust portion which is provided at a position facing the abrasive grain introduction portion across the first space and exhausts air inside the second space.

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5. A machining apparatus comprising:
 - a high-pressure water pipe through which high-pressure water is supplied;
 - an abrasive grain pipe through which abrasive grains are supplied;
 - an injection unit which includes a high-pressure water introduction portion into which the high-pressure water is introduced, an abrasive grain introduction portion into which the abrasive grains are introduced, a mixing portion in which the high-pressure water and the abrasive grains are mixed with each other, and a nozzle which injects the high-pressure water having the mixed abrasive grains to an object to be machined; and
 - a partition pipe which separates a first space extending in one direction from the high-pressure water introduction portion to the nozzle and a second space around the first space from each other, inside the mixing portion and includes an opening on an introduction straight line extending in an introduction direction of the abrasive grains from the abrasive grain introduction portion; and
 - an exhaust portion which is provided at a position facing the abrasive grain introduction portion across the first space and exhausts air inside the second space.

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6. A machining method comprising:
 - a step of measuring a pressure inside an abrasive grain pipe of a machining apparatus including a high-pressure water pipe through which high-pressure water is supplied, an abrasive grain pipe through which abrasive grains are supplied, and a nozzle which is connected to the high-pressure water pipe and the abrasive grain pipe and injects the high-pressure water mixed with the abrasive grains to an object to be machined; and
 - a step of detecting that the pressure is lower than a

lower threshold value.

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FIG. 1

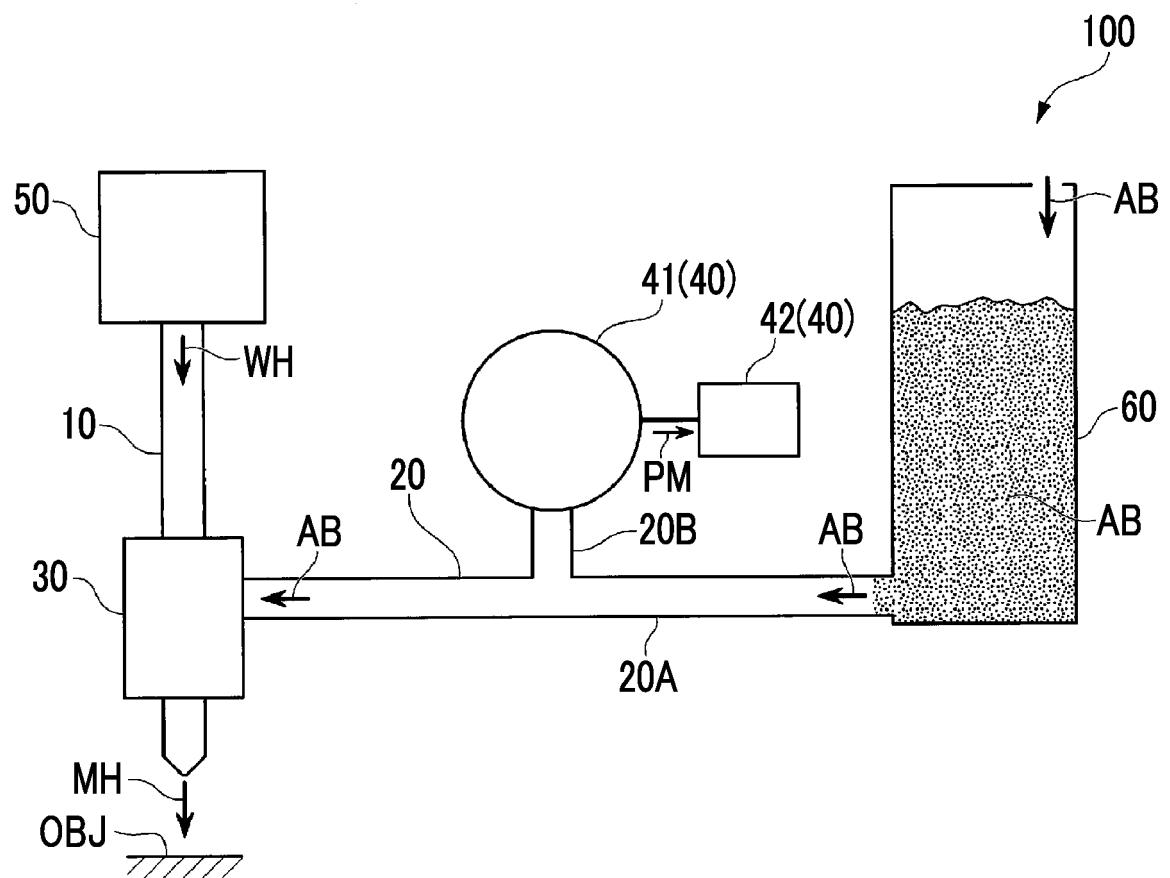


FIG. 2

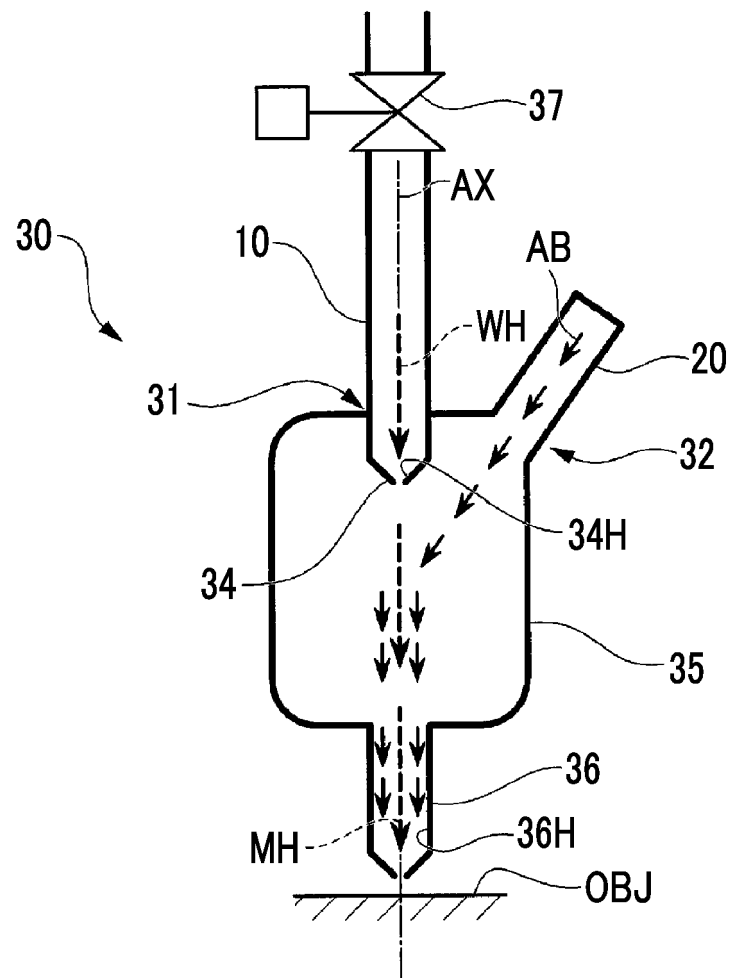


FIG. 3

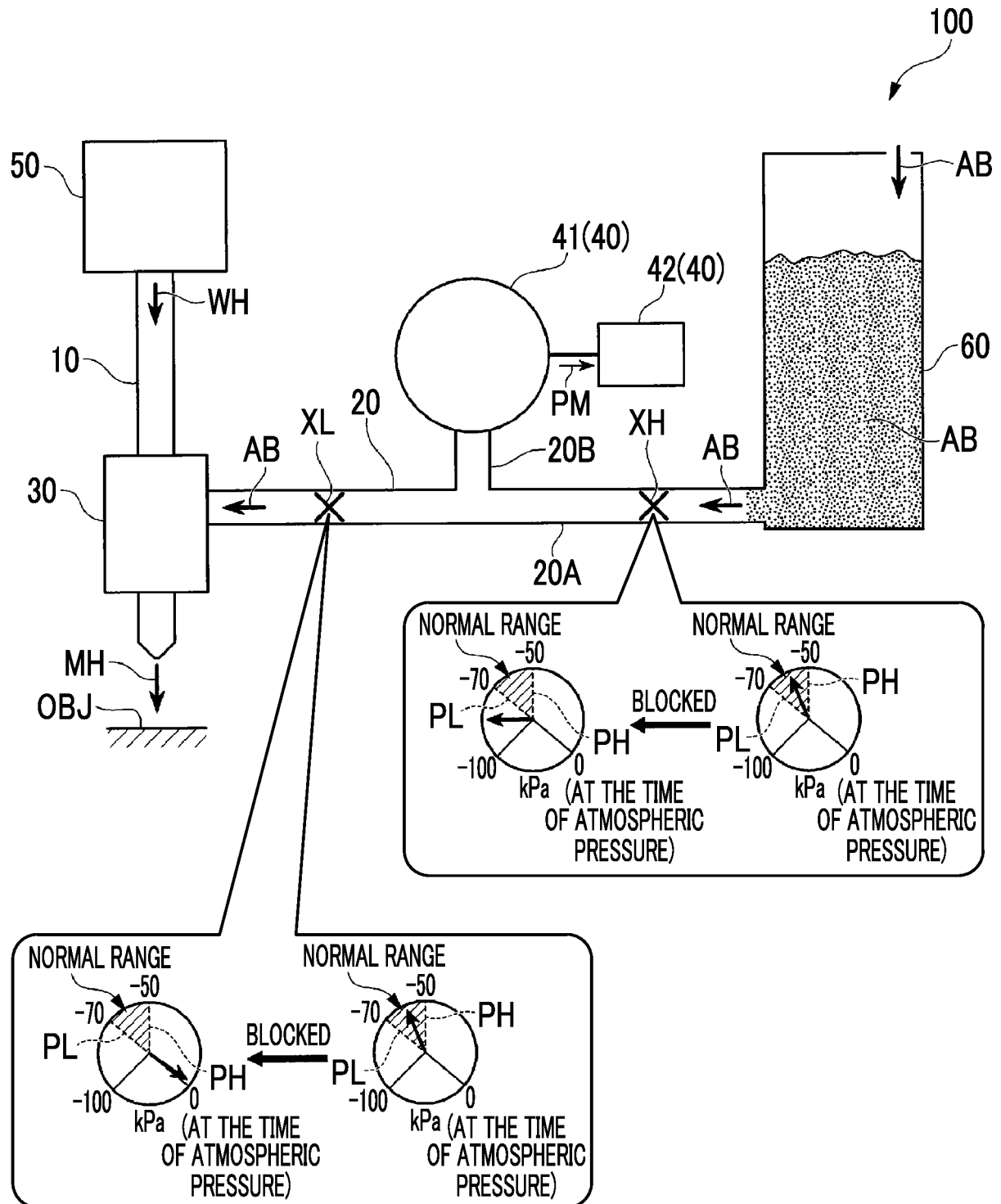


FIG. 4

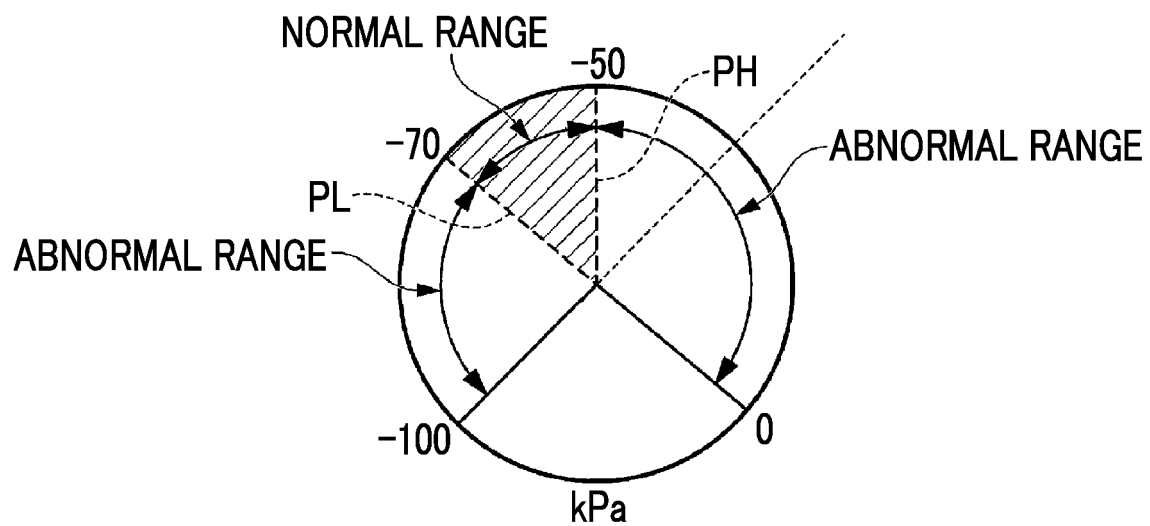


FIG. 5

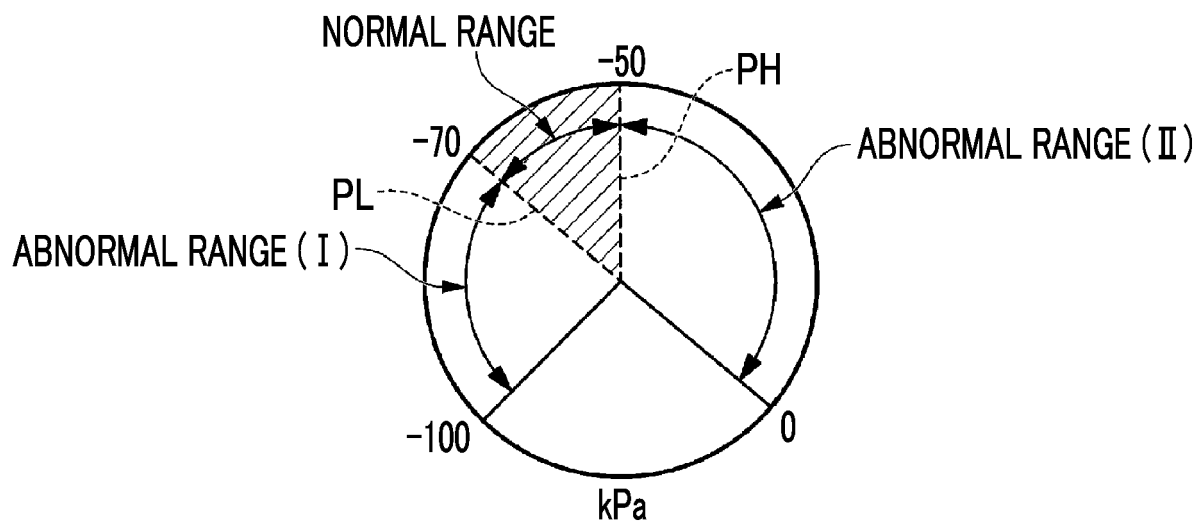


FIG. 6

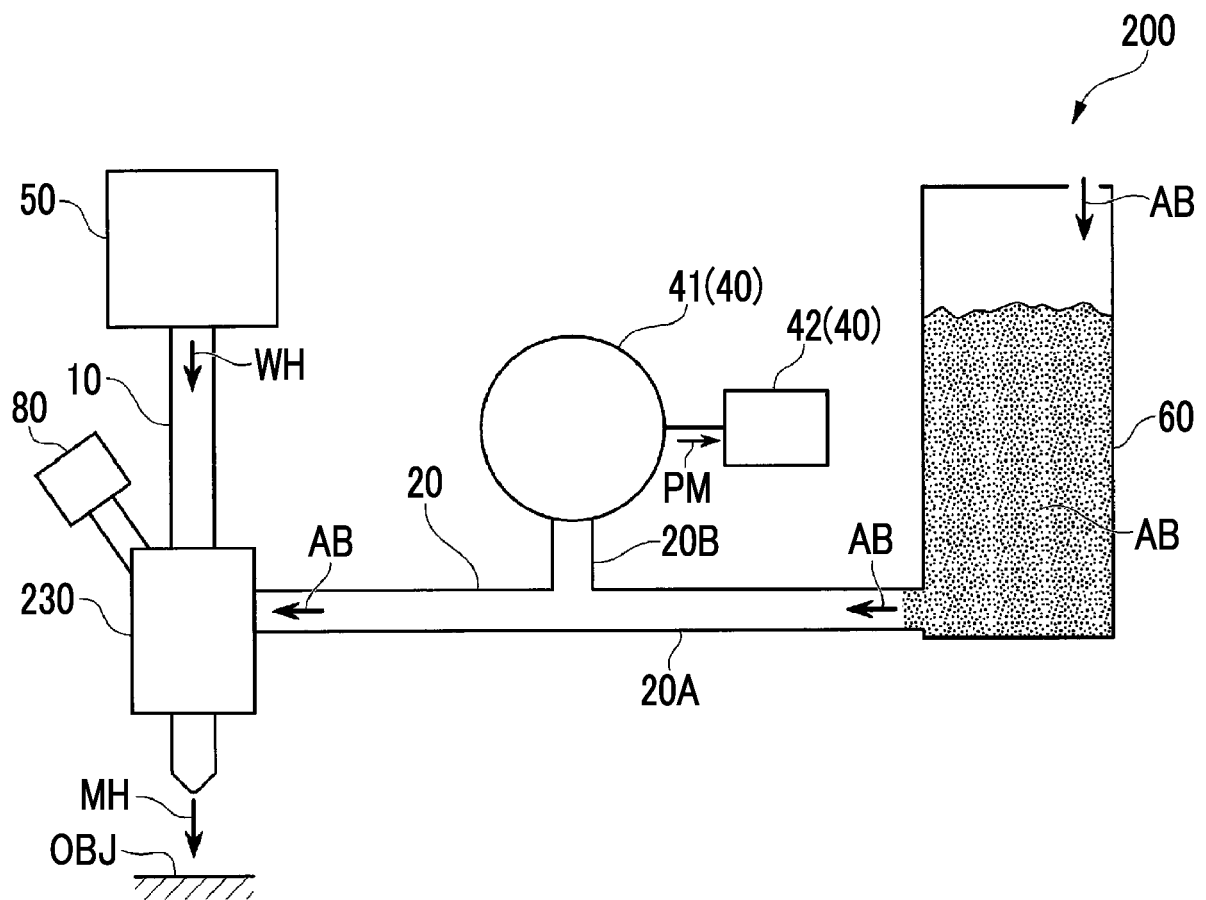


FIG. 7

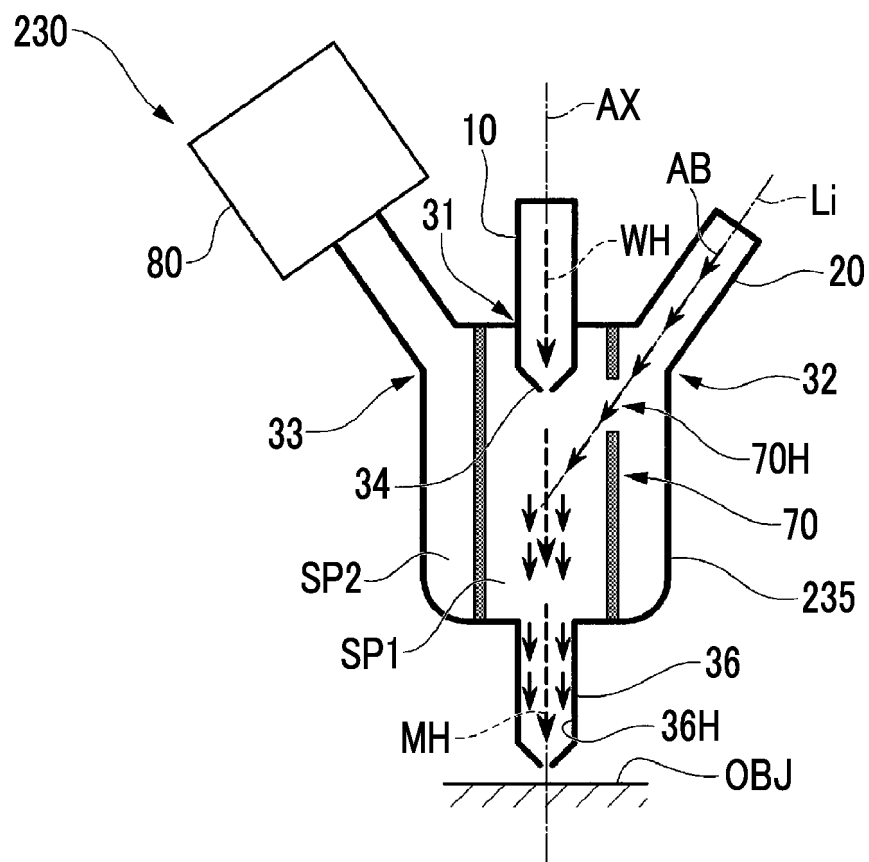
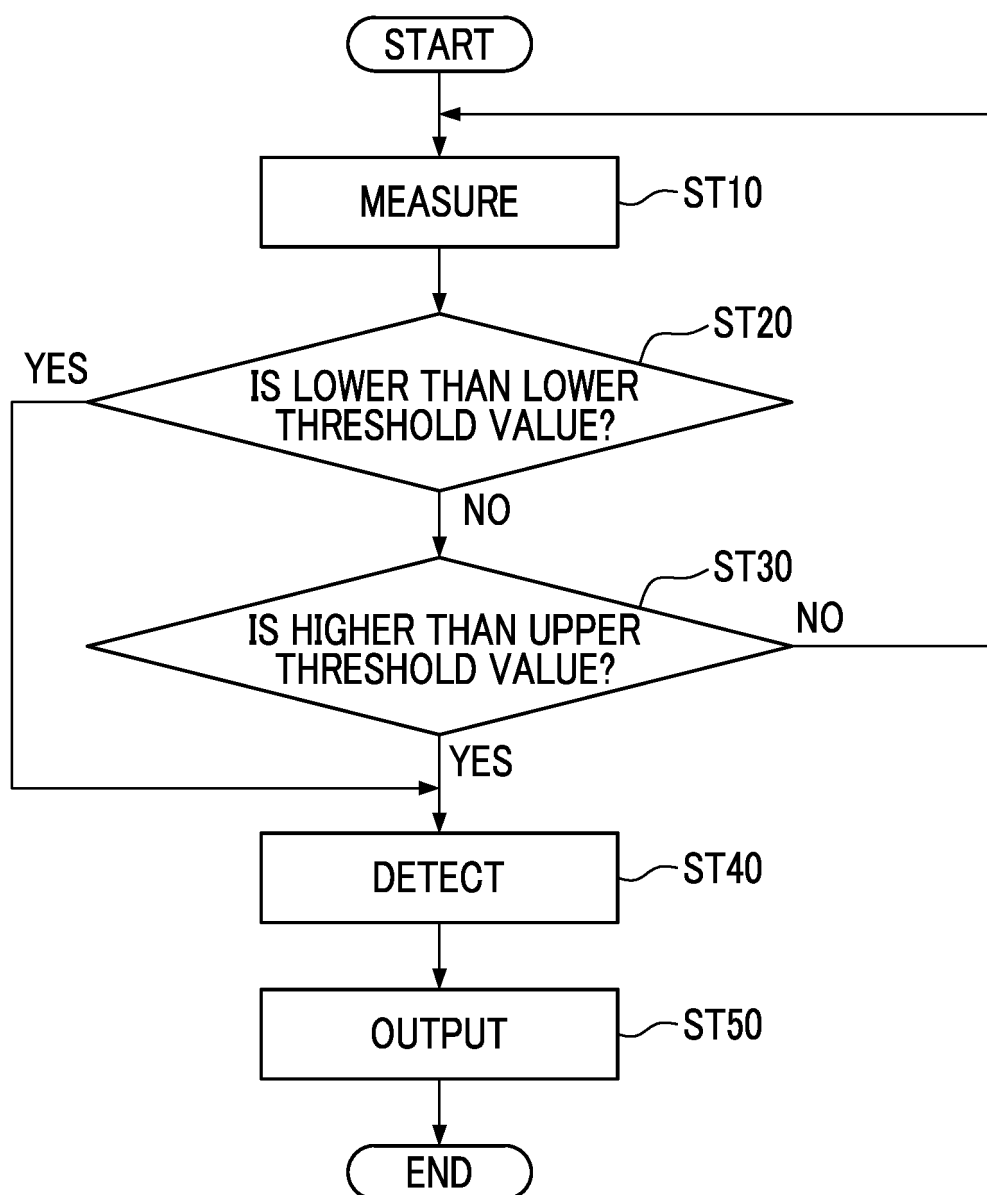


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/000331

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B24C9/00 (2006.01) i, B24C5/02 (2006.01) i, B24C7/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. B24C1/00-9/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI (Derwent Innovation)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4478368 A (FLUIDYNE CORPORATION) 23 October 1984, column 13, line 12 to column 14, line 62, fig. 13, 14 & US 4555872 A	1-6
A	JP 2015-512793 A (FINEPART SWEDEN AB) 30 April 2015 & US 2015/0031270 A1 & WO 2013/135538 A1 & EP 2825351 A1 & CN 104271316 A	1-6
A	JP 7-80773 A (NIPPON STEEL CORPORATION) 28 March 1995 (Family: none)	1-6



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12.02.2019

Date of mailing of the international search report

05.03.2019

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Japan Patent Office

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Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2-59268 A (OKUMURA CORPORATION) 28 February 1990 (Family: none)	1-6
A	JP 3-505553 A (CLEANING TECHNOLOGY LIMITED) 05 December 1991 & US 5065551 A & GB 8804970 A & WO 1989/008007 A1 & EP 335503 A2	1-6
A	JP 10-156723 A (EBARA CORPORATION) 16 June 1998 (Family: none)	1-6
A	JP 2013-215854 A (SUGINO MACH LTD.) 24 October 2013 & US 2013/0267152 A1 & EP 2650083 A1	1-6
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REFERENCES CITED IN THE DESCRIPTION

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- JP 2019466 A [0005]