(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 681 878 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
21.01.2026 Bulletin 2026/04

(21) Application number: **25187797.3**

(22) Date of filing: **07.07.2025**

(51) International Patent Classification (IPC):
B24C 5/04 *(2006.01)* ***B05B 1/26*** *(2006.01)*
B05B 7/00 *(2006.01)* ***B05B 7/30*** *(2006.01)*
B24C 1/10 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B24C 5/04; B05B 1/26; B05B 7/0012; B05B 7/30; B24C 1/10

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH LA MA MD TN

(30) Priority: **19.07.2024 JP 2024115573**

(71) Applicant: **Sugino Machine Limited**
Namerikawa City, Toyama 936-8577 (JP)

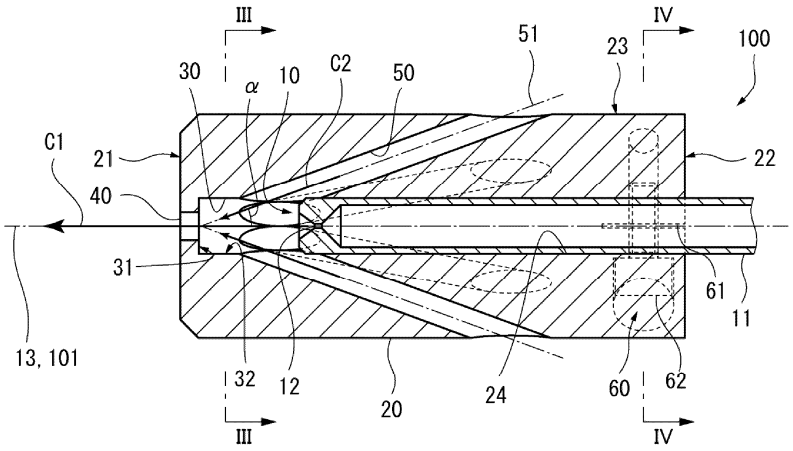
(72) Inventor: **Taiki, MATSUI**
Namerikawa City, Toyama, 9368577 (JP)

(74) Representative: **Global IP Europe**
Patentanwaltskanzlei
Pfarrstraße 14
80538 München (DE)

(54) **CAVITATION PROCESSING NOZZLE**

(57) A cavitation processing nozzle (100) to be immersed in processing liquid (203) containing suspended abrasives (204), to eject a jet (C1) of the processing liquid (203) causing cavitation to a workpiece (300) to apply a compressive residual stress on the surface of the workpiece (300), includes: an ejection unit (10) including an ejection port (12) to eject the jet (C1) along an ejection axis (13); and a liquid guide body (20) disposed on the ejection unit (10) to cover the ejection port (12), and including a liquid chamber (30), a jet outlet (40) extending along the ejection axis (13) and penetrating from the liquid chamber (30) to an outside of the liquid guide body (20), and a liquid guide channel (50) extending in a different direction from the ejection axis (13) and penetrating from the liquid chamber (30) to the outside of the liquid guide body (20).

FIG. 2



EP 4 681 878 A1

Description

BACKGROUND

1. Technical Field

[0001] The present invention relates to a cavitation processing nozzle.

2. Description of the Background

[0002] A cavitation surface processing method called cavitation abrasive surface finishing (CASF) is known in which a cavitation jet containing abrasives is used to smooth and peen the surface of a workpiece (US 2024/0001509 A1).

BRIEF SUMMARY

[0003] In CASF, a feed amount of abrasive material to the workpiece affects the effectiveness of the cavitation processing.

[0004] An object of the present is to improve the effectiveness of cavitation processing by CASF.

[0005] A first aspect of the present invention provides a cavitation processing nozzle configured to be immersed in processing liquid containing suspended abrasives, to eject a jet of the processing liquid causing cavitation to a workpiece to smooth a surface of the workpiece, and to apply a compressive residual stress on the surface of the workpiece, the cavitation processing nozzle including:

an ejection unit including an ejection port configured to eject the jet along an ejection axis; and
a liquid guide body disposed on the ejection unit to cover the ejection port, the liquid guide body including

a liquid chamber to which the ejection port faces,
a jet outlet extending along the ejection axis, the jet outlet penetrating from the liquid chamber to an outside of the liquid guide body, and
a liquid guide channel extending in a different direction from the ejection axis, the liquid guide channel penetrating from the liquid chamber to the outside of the liquid guide body.

[0006] The ejection of the jet generates a low pressure in the liquid chamber. The processing liquid thus flows into the liquid chamber from the outside of the liquid guide body through the liquid guide channel, and flows out from the jet outlet together with the jet. The abrasives flow into the liquid chamber from the outside of the liquid guide body through the liquid guide channel, and flows out from the jet outlet together with the jet.

[0007] The ejection port may be cylindrical about an ejection axis. The ejection port ejects the processing liquid in a linear rod shape. The jet outlet may be cylindrical about the ejection axis. The ejection port diameter of the ejection unit is, for example, 0.5 mm to 3 mm. The ejection pressure of the jet is, for example, 10 MPa to 200 MPa.

[0008] The liquid guide body has, for example, a cylindrical shape or a prismatic shape. At this time, the ejection axis may coincide with a central axis of the liquid guide body. The liquid chamber may be a cylindrical space centered on the central axis. The jet outlet may be formed at a center of a bottom surface of the liquid guide body. The liquid guide channel may open to a side surface of the liquid guide body. A plurality of liquid guide channels may be equally located about the ejection axis. The angle formed by the ejection axis and the liquid guide axis is, for example, 15 degrees to 25 degrees. The cross-section of the liquid guide channel may be circular.

[0009] The liquid guide body may be detachable from the ejection unit. A plurality of types of liquid guide bodies having different shapes may be prepared, and the liquid guide bodies may be appropriately replaced in accordance with various conditions such as a material and a shape of the workpiece.

[0010] The abrasives are abrasive particles. Examples of the abrasives include ceramics, alumina, garnet, and zirconia.

[0011] The workpiece is made of metal. The metal constituting the workpiece is, for example, a heat-resistant alloy, an aluminum alloy, a magnesium alloy, titanium, a titanium alloy, steel, or corrosion-resistant steel. The workpiece is, for example, a mechanical part, a medical device part, or a medical device. Mechanical parts are, for example, pipes, valves, pipe fittings, aerospace components. The medical device includes a surgical implant. Aerospace components include aircraft engine components and other aircraft components, rocket engine components, spacecraft components, satellite components, and rocket piping.

[0012] Both the workpiece and the cavitation processing nozzle are immersed in the processing liquid stored in the tank. In the processing liquid, a jet of the processing liquid is ejected from the cavitation processing nozzle toward the workpiece. The processing liquid is, for example, water. The processing liquid may include a rust inhibitor.

[0013] A cavitation processing is performed on a part or the entire surface of the workpiece.

[0014] According to the present invention, it is possible to improve the effectiveness of the cavitation processing by CASF.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

FIG. 1 is a side view of a cavitation processing nozzle according to a present embodiment.
FIG. 2 is a longitudinal sectional view of the cavitation processing nozzle according to the present embodi-

ment.

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

FIG. 4 is a cross-sectional view taken along line IV-IV in FIG. 2.

FIG. 5 shows a cavitation processing apparatus to which the cavitation processing nozzle of the present embodiment is attached.

DETAILED DESCRIPTION

[0016] As shown in FIGs. 1 to 4, a cavitation processing nozzle 100 according to the embodiment includes an ejection unit 10, a liquid guide body 20, a liquid chamber 30, a jet outlet 40, a liquid guide channel 50, and a fixing portion 60. FIG. 2 is a cross-sectional view taken along line II-II in FIG. 3. The cavitation processing nozzle 100 ejects a jet C1 toward the left in FIGs. 1 and 2. In the cavitation processing nozzle 100, the downstream side of the jet C1 (the left side in FIGs. 1 and 2) is defined as a distal end side, and the upstream side (the right side in FIGs. 1 and 2) is defined as a basal end side.

[0017] The ejection unit 10 includes a shaft body 11 and an ejection port 12. The shaft body 11 has a cylindrical shape. The shaft body 11 extends along a central axis 101. The ejection port 12 is located at a distal end of the shaft body 11. The ejection port 12 ejects the jet C1 along an ejection axis 13. The ejection axis 13 coincides with the central axis 101. A high-pressure fluid supply source (not shown), which will be described later, is connected to the basal end side of the shaft body 11.

[0018] The liquid guide body 20 has a cylindrical shape. The liquid guide body 20 extends along the central axis 101. The liquid guide body 20 includes a liquid guide body distal end surface 21, a liquid guide body basal end surface 22, a liquid guide body side surface 23, and an insertion hole 24. The liquid guide body distal end surface 21 and the liquid guide body basal end surface 22 are circular. The liquid guide body 20 is separate from the ejection unit 10. The insertion hole 24 extends from the center of the liquid guide body basal end surface 22 to the inside of the liquid guide body 20 along the central axis 101 toward the distal end. The insertion hole 24 has a circular cross-section. The shaft body 11 is inserted into the insertion hole 24. The liquid guide body 20 is thus disposed on the ejection unit 10 and covers the ejection port 12. The ejection unit 10 is inserted to the near side (the basal end side) than a bottom of the insertion hole 24. That is, a space (liquid chamber 30) is formed between the distal end of the ejection unit 10 and the distal end of the insertion hole 24.

[0019] The liquid chamber 30 is located inside the liquid guide body 20. The liquid chamber 30 is a columnar space centered on the central axis 101. The liquid chamber 30 includes a liquid chamber distal end surface 31 and a liquid chamber side surface 32. The basal end of the liquid chamber 30 is closed by the ejection unit 10. The ejection port 12 thus faces the basal end side of the liquid chamber 30. The liquid chamber 30 is a part of the insertion hole 24 and is a part between the distal end of the ejection unit 10 and the distal end of the insertion hole 24.

[0020] The jet outlet 40 penetrates from the liquid chamber 30 to the outside of the liquid guide body 20. The jet outlet 40 extends along an ejection axis 13. The jet outlet 40 opens at the center of the liquid chamber distal end surface 31 and at the center of the liquid guide body distal end surface 21, respectively. The jet outlet 40 has a circular cross-section. The central line of the jet outlet 40 coincides with the ejection axis 13. The jet outlet 40 has a smaller diameter than the liquid chamber 30.

[0021] The liquid guide channel 50 penetrates from the liquid chamber 30 to the outside of the liquid guide body 20. The liquid guide channel 50 extends in a direction different from the ejection axis 13. The liquid guide channel 50 extends along a liquid guide axis 51. The liquid guide axis 51 is a straight line intersecting the ejection axis 13. As viewed from the direction of the central axis 101, the liquid guide axis 51 extends in the radial direction of the liquid guide body 20. The liquid guide channel 50 opens to the liquid chamber side surface 32 and the liquid guide body side surface 23, respectively. The liquid guide channel 50 is directed toward the distal end side as it comes to the liquid chamber 30. The angle α formed by the ejection axis 13 and the liquid guide axis 51 is, for example, 15 degrees to 25 degrees. For example, the angle α is 20 degrees. The liquid guide channel 50 has a circular cross-section. The central axis of the liquid guide channel 50 coincides with the liquid guide axis 51. The liquid guide channel 50 has a smaller diameter than the liquid chamber 30. As shown in FIG. 3, the cavitation processing nozzle 100 includes a plurality of (six in the present embodiment) liquid guide channels 50. The plurality of liquid guide channels 50 are arranged at equal intervals around the ejection axis 13.

[0022] Note that the liquid guide axis 51 may be a curve.

[0023] As shown in FIG. 4, the fixing portion 60 includes a split groove 61 and a fastening bolt 62. The split groove 61 is formed along the radial direction on the liquid guide body basal end surface 22. The fastening bolt 62 is inserted from the liquid guide body side surface 23 so as to intersect with the split groove 61. The fastening bolt 62 is fastened with the ejection unit 10 inserted into the insertion hole 24. This narrows the distance between the split grooves 61 to fix the liquid guide body 20 to the ejection unit 10.

[0024] The cavitation processing apparatus 200 to which the cavitation processing nozzle 100 is attached will be described. As shown in FIG. 5, the cavitation processing apparatus 200 includes a tank 201, the cavitation processing nozzle 100, a fixing base 202, and a high-pressure fluid supply source (not shown).

[0025] The tank 201 stores a processing liquid 203. The processing liquid 203 is, for example, water. The processing liquid 203 is obtained by suspending abra-

sives 204. The tank 201 may include a device for circulating the stored processing liquid 203.

[0026] The cavitation processing nozzle 100 is connected to the high-pressure fluid supply source. The ejection port 12 is directed vertically downward. The cavitation processing nozzle 100 is movable in three axial directions, that is, in the horizontal direction (the front-rear direction and the left-right direction) and the vertical direction. The ejection velocity (pressure) of the jet C1 and the three-axis movement of the cavitation processing nozzle 100 are controlled by a control device (not shown).

[0027] The fixing base 202 fixes a workpiece 300. The workpiece 300 is fixed to the fixing base 202 by fasteners (not shown) such as bolts and clamps. The fixing base 202 is movable in the vertical direction. The workpiece 300 is moved in and out of the tank 201 by moving the fixing base 202 in the vertical direction. The vertical movement of the fixing base 202 is controlled by the control device (not shown).

[0028] The cavitation processing nozzle 100 and the workpiece 300 fixed to the fixing base 202 are immersed in the processing liquid 203 in which the abrasives 204 are suspended. The high-pressure fluid supply source is activated to eject the jet C1 along the ejection axis 13 from the ejection port 12 of the cavitation processing nozzle 100. The ejection direction of the jet C1 is vertically downward. The jet C1 is a linear rod-shaped jet. The jet C1 contains many cavities. The cavitation processing apparatus 200 can eject the jet C1 at an arbitrary position on the workpiece 300 from an arbitrary distance.

[0029] The high-pressure processing liquid 203 is ejected from the ejection port 12 at high speed as jet C1, so that a low-pressure portion is generated inside the liquid chamber 30. The low-pressure portion has a lower pressure than the processing liquid 203 around the cavitation processing nozzle 100. The processing liquid 203 thus flows into the liquid chamber 30 as an introduced flow C2 from the outside of the liquid guide body 20 through the liquid guide channel 50. The introduced flow C2 then flows out from the jet outlet 40 together with the jet C1.

[0030] The jet C1 entrains the abrasives 204 and impinges on the workpiece 300. An unnecessary portion of the workpiece 300 is removed by the abrasives 204 included in the jet C1. After the unnecessary portion is removed, the abrasives 204 contained in the jet C1 smooth the surface of the workpiece 300. The addition of the introduced flow C2 to the jet C1 causes more abrasives 204 to be entrained. This improves the effectiveness of the cavitation processing by CASF. The surface of the workpiece 300 is peened by the impact force when the cavities included in the jet C1 collapse. This applies compressive residual stress to the surface of the workpiece 300. The cavitation processing nozzle 100 may be moved along the shape of the workpiece 300 while the jet C1 is ejected.

[0031] The liquid guide body 20 is detachably attachable to the ejection unit 10. A multiple types of liquid guide bodies 20 having different shapes may be prepared, and the liquid guide bodies 20 may be appropriately replaced. For example, the plurality of liquid guide bodies 20 may have different diameters, numbers, and angles with respect to the ejection axis 13 of the liquid guide channel 50. For example, the shape and size of the liquid chamber 30 and the diameter of the jet outlet 40 may be different from each other in the plurality of liquid guide bodies 20. If the shapes of the liquid guide bodies 20 are different, the configurations of the introduced flow C2 are also different. Appropriate cavitation processing can be performed by selecting an appropriate liquid guide body 20 in accordance with various conditions such as a material and a shape of the workpiece 300.

[0032] The present invention is not limited to the above-described embodiments, and various modifications can be made without departing from the gist of the present invention, and all technical matters included in the technical idea described in the claims are the subject of the present invention. While the above embodiments have been shown by way of example, those skilled in the art will recognize that various alternatives, modifications, variations, and improvements can be made from the disclosure herein, which fall within the scope of the appended claims.

Reference Signs List

[0033]

10	Ejection unit
12	Ejection port
13	Ejection axis
20	Liquid guide body
30	Liquid chamber
40	Jet outlet
50	Liquid guide channel
100	Cavitation processing nozzle
203	Processing liquid
204	Abrasives
C1	Jet

Claims

1. A cavitation processing nozzle (100) configured to be immersed in processing liquid (203) containing suspended abrasives (204), to eject a jet (C1) of the processing liquid (203) causing cavitation to a workpiece (300) to smooth a surface of the workpiece (300), and to apply a compressive residual stress on the surface of the workpiece (300), the cavitation processing nozzle (100) comprising:

   an ejection unit (10) including an ejection port (12) configured to eject the jet (C1) along an ejection axis (13); and
   a liquid guide body (20) disposed on the ejection unit (10) to cover the ejection port (12), the liquid

guide body (20) including

a liquid chamber (30) to which the ejection port (12) faces,
a jet outlet (40) extending along the ejection axis (13), the jet outlet (40) penetrating from the liquid chamber (30) to an outside of the liquid guide body (20), and
a liquid guide channel (50) extending in a different direction from the ejection axis (13), the liquid guide channel (50) penetrating from the liquid chamber (30) to the outside of the liquid guide body (20).

2. The cavitation processing nozzle (100) according to claim 1, wherein
the liquid guide channel (50) allows the processing liquid (203) to flow from the outside of the liquid guide body (20) to the liquid chamber (30) as an introduced flow (C2).

3. The cavitation processing nozzle (100) according to claim 2, wherein
the jet outlet (40) flows out the jet (C1) containing the introduced flow (C2) from the liquid chamber (30).

4. The cavitation processing nozzle (100) according to any one of claims 1 to 3, wherein
the liquid guide channel (50) extends along a liquid guide axis (51) that is a straight line intersecting the ejection axis (13).

5. The cavitation processing nozzle (100) according to any one of claims 1 to 4, wherein
the liquid guide channel (50) extends toward a downstream side of the jet (C1) as the liquid guide channel (50) comes closer to the liquid chamber (30).

6. The cavitation processing nozzle (100) according to any one of claims 1 to 5, wherein
the liquid guide body (20) includes a plurality of the liquid guide channels (50).

7. The cavitation processing nozzle (100) according to any one of claims 1 to 6, wherein
the liquid guide body (20) is a separate member from the ejection unit (10).

FIG. 1

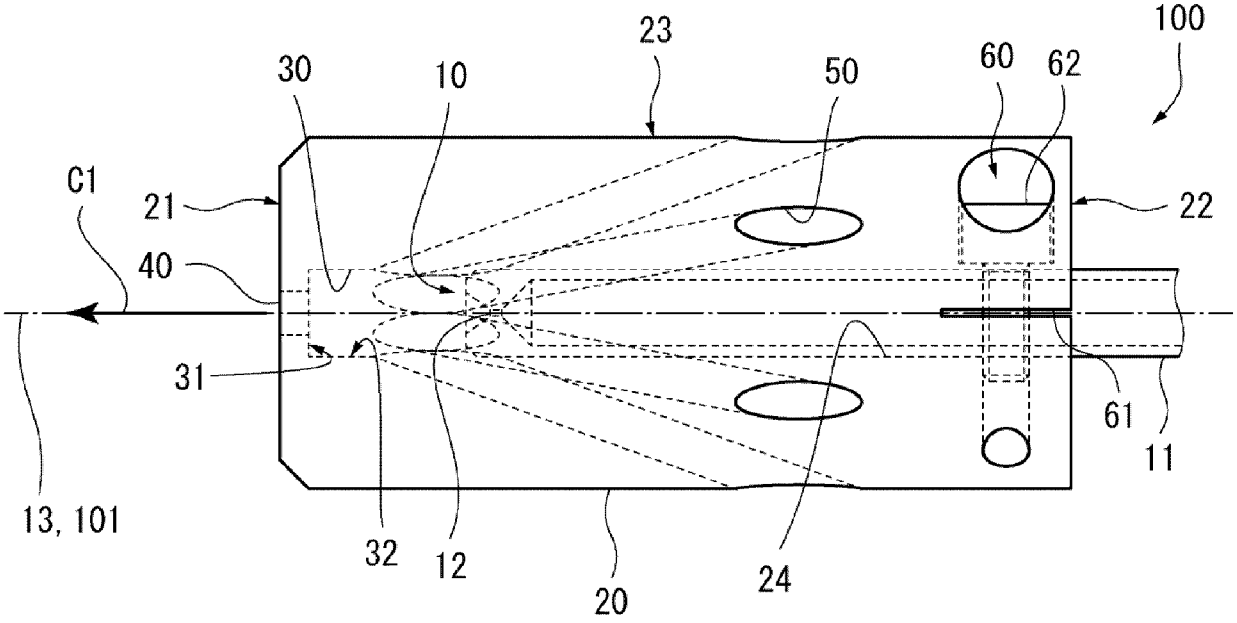


FIG. 2

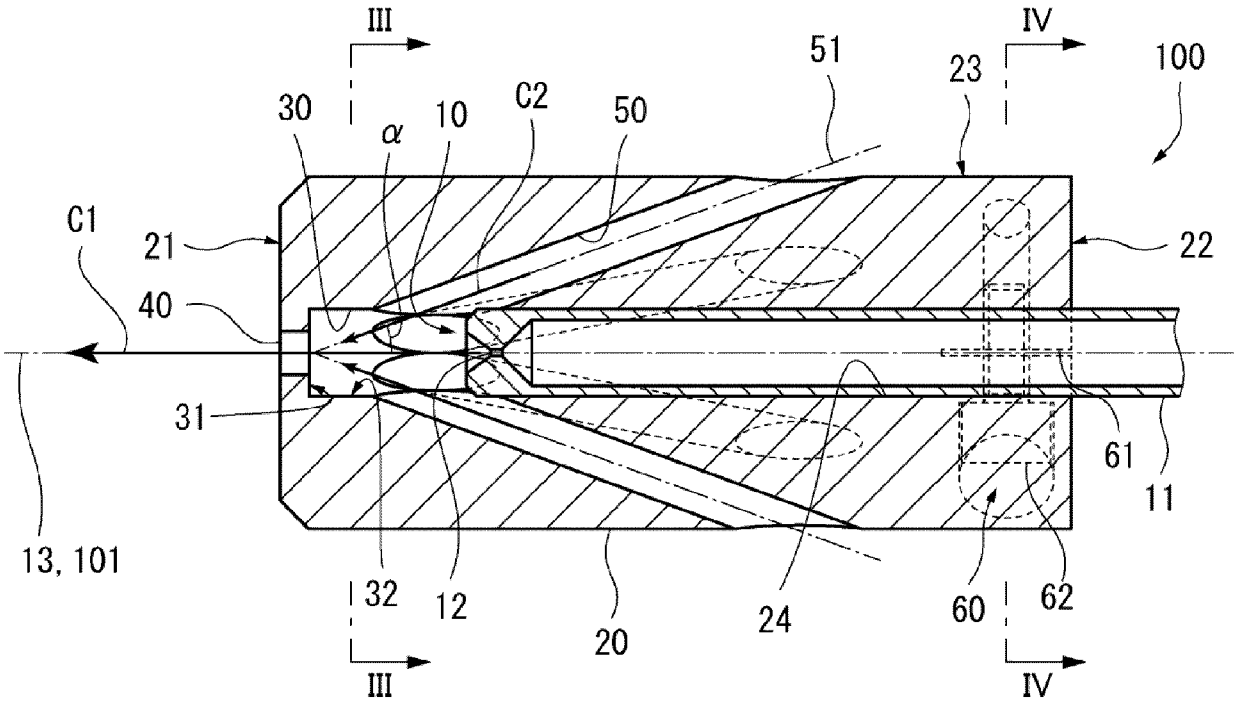

III
IV
51
23
100
30
α
10
C2
50
C1
21
22
40
31
61
11
13, 101
32
12
20
24
60
62
III
IV

FIG. 3

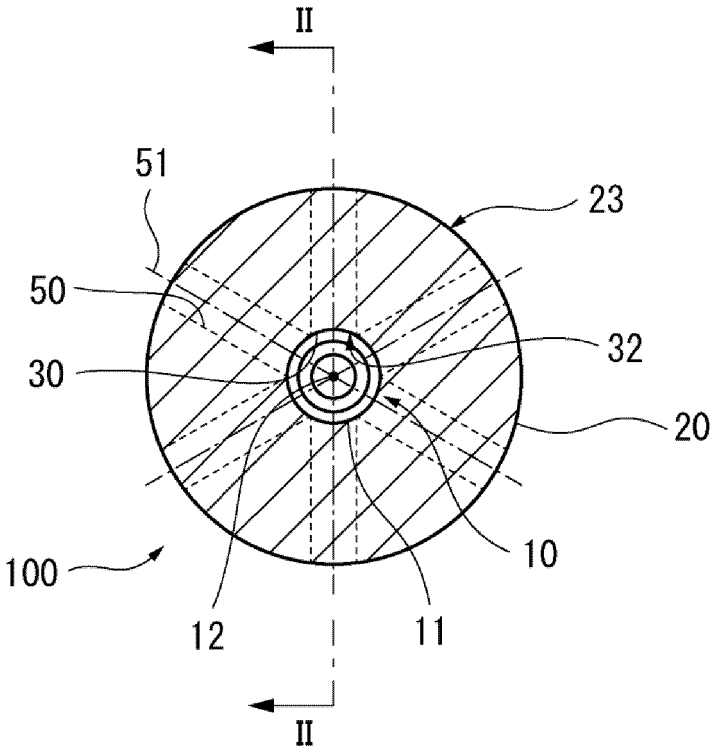


FIG. 4

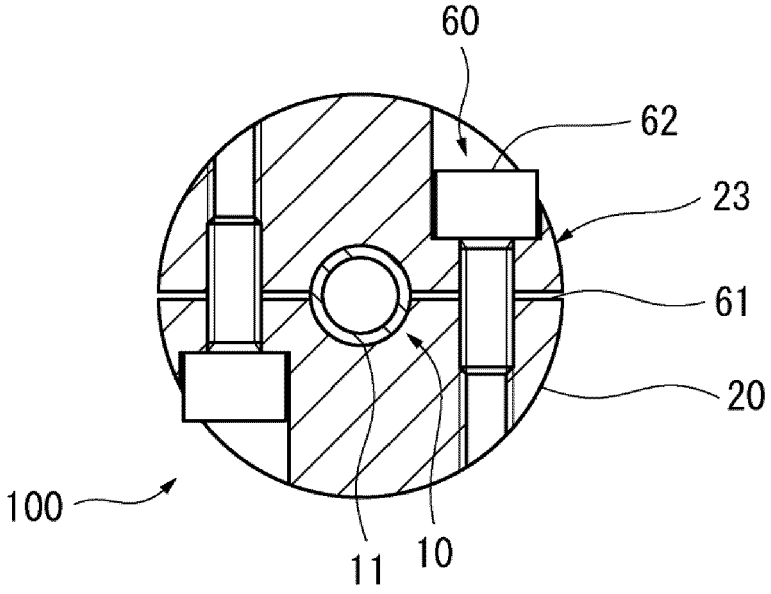
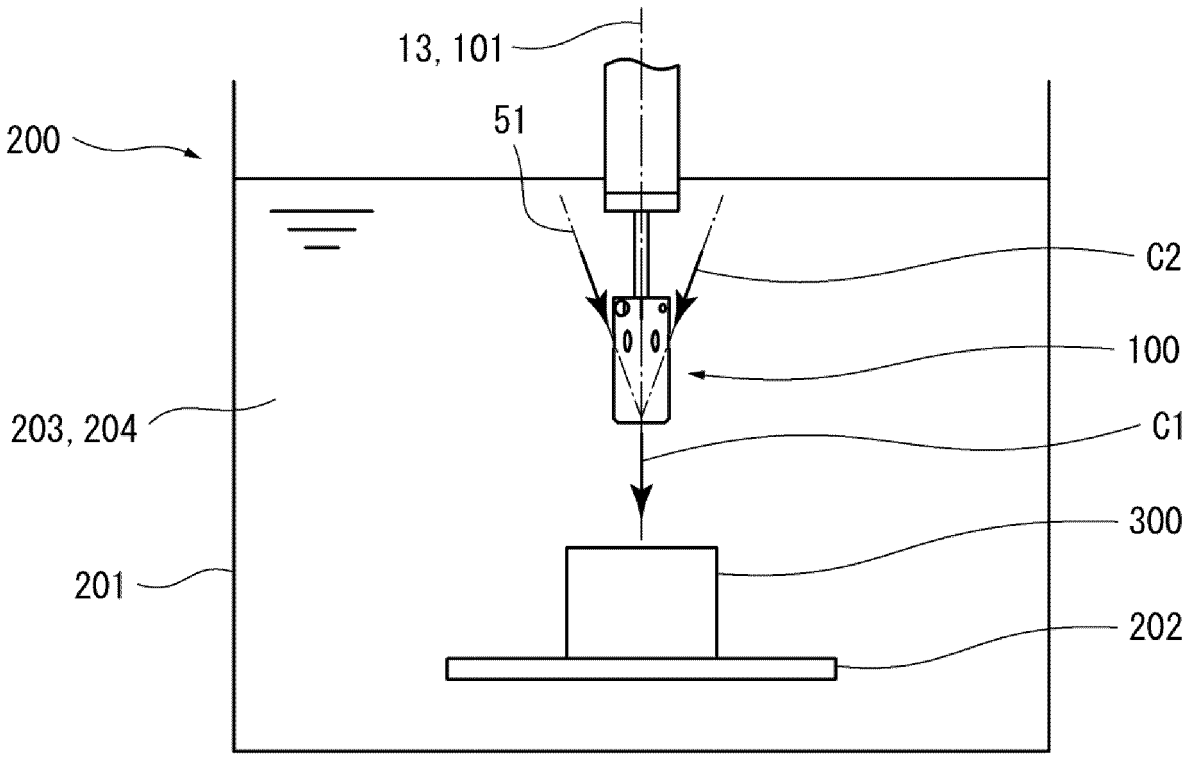


FIG. 5



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 25 18 7797

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP H06 47671 A (BABCOCK HITACHI KK; HITACHI LTD) 22 February 1994 (1994-02-22) * paragraphs [0069] - [0073]; figures 15-17 *	1-6	INV. B24C5/04 B05B1/26 B05B7/00 B05B7/30
X	JP 2000 167545 A (BABCOCK HITACHI KK) 20 June 2000 (2000-06-20) * paragraph [0001]; figure 15 *	1-6	ADD. B24C1/10
X	JP H05 86466 U (UNKNOWN) 22 November 1993 (1993-11-22) * paragraphs [0016], [0017]; figure 1 *	1,4-7	
X	CN 115 213 822 A (UNIV JIANGSU) 21 October 2022 (2022-10-21) * paragraphs [0032], [0033]; figure 2 *	1,4-7	

TECHNICAL FIELDS SEARCHED (IPC)
B05B
B24C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	14 November 2025	Beltzung, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 25 18 7797

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-11-2025

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H0647671 A	22-02-1994	JP 3343371 B2	11-11-2002
		JP H0647671 A	22-02-1994
JP 2000167545 A	20-06-2000	NONE	
JP H0586466 U	22-11-1993	NONE	
CN 115213822 A	21-10-2022	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20240001509 A1 **[0002]**