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(54) **PARTIAL SURFACE TREATMENT APPARATUS**

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(57) **ABSTRACT**

A partial surface treatment apparatus includes a first electrode member electrically connected to a treatment object including an outer circumferential surface and a circumferential groove, a second electrode member including an inner circumferential surface, a pair of annular-shaped elastic sealing members configured to seal a clearance between the outer circumferential surface and the inner circumferential surface, an accommodation portion accommodating each of the annular-shaped elastic sealing members, the annular-shaped elastic sealing members are movable in a diameter reduction direction, a pressure applying mechanism supplying a pressurized fluid to the annular-shaped elastic sealing members, the annular-shaped elastic sealing members are in pressure contact with the outer circumferential surface in a case where the annular-shaped elastic sealing members are moved in the diameter reduction direction, and a cutout formed at each of the annular-shaped elastic sealing members to be extended from an outer circumferential side edge portion towards the inner circumferential side.

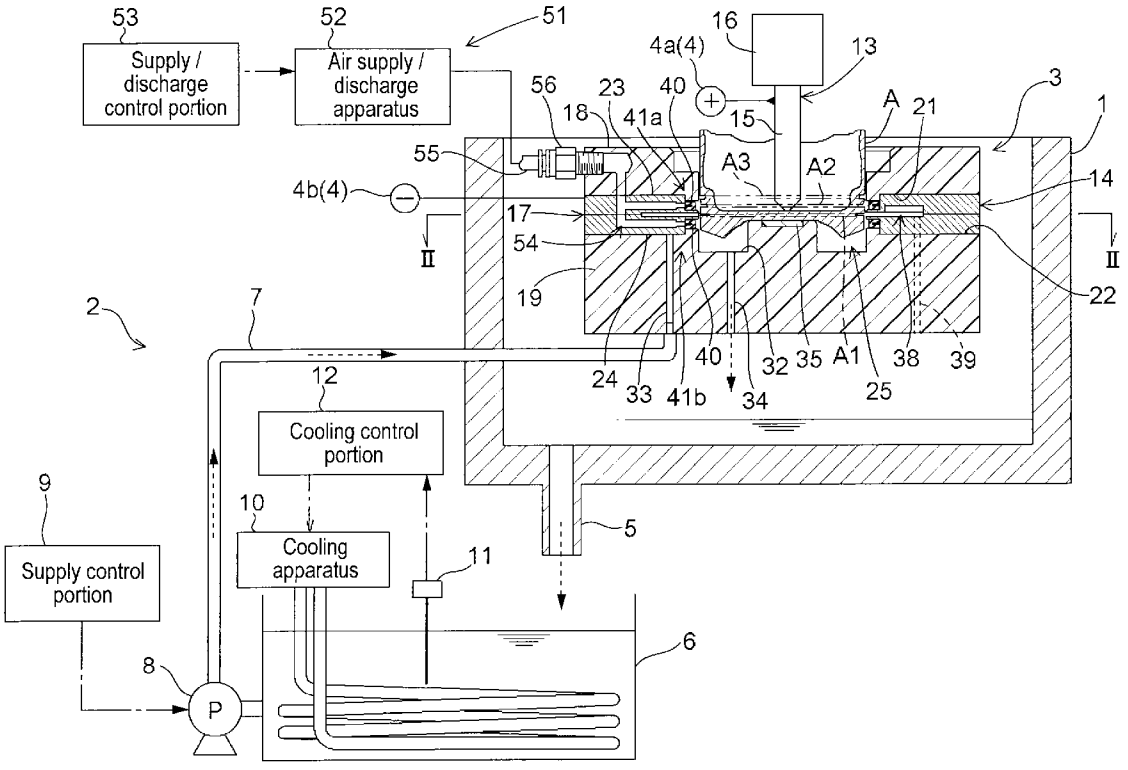


FIG. 1

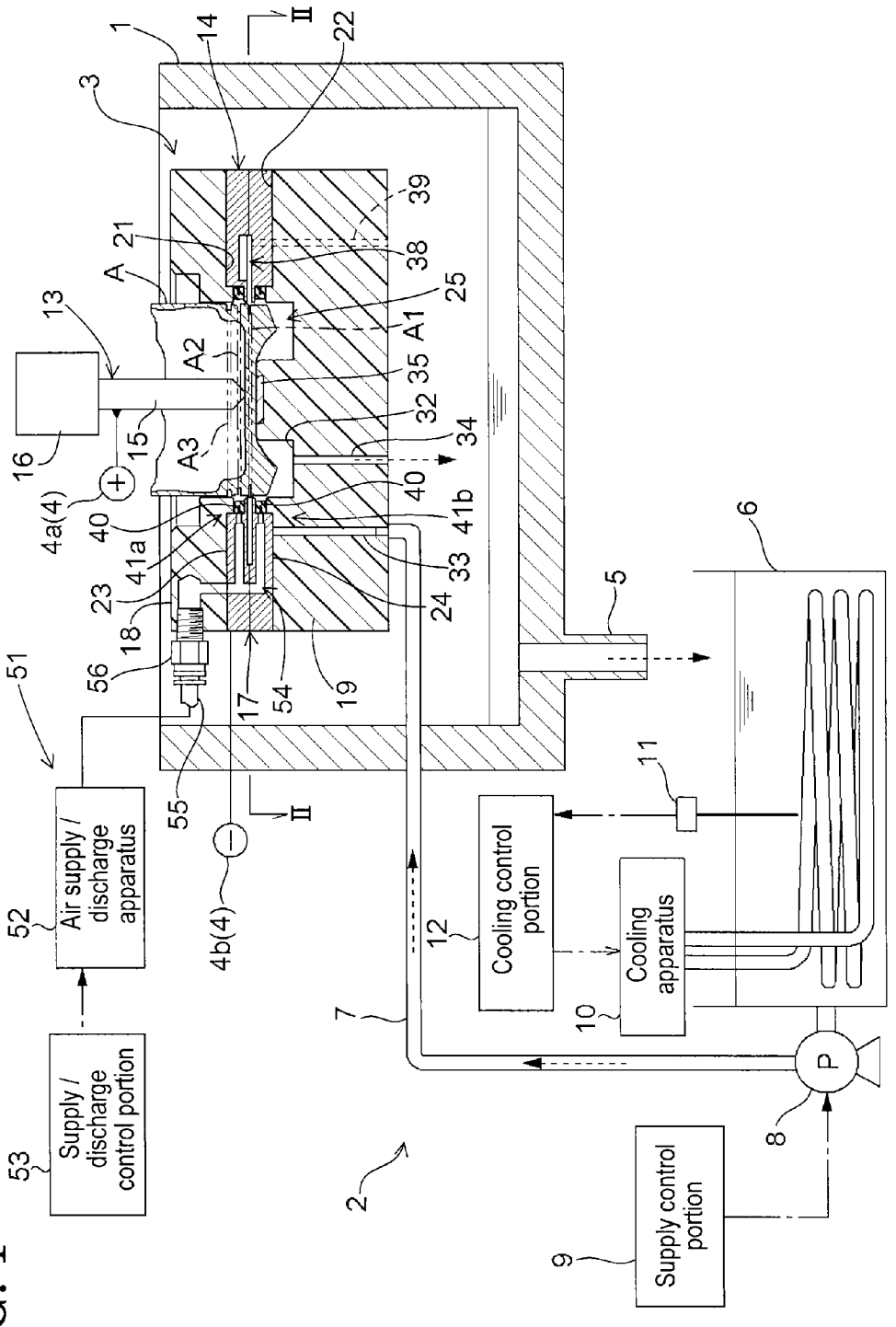

1
14
II
22
3
39
21
38
A
25
13
A2
A1
35
32
16
15
A3
34
4a(4)
40
40
41b
41a
33
23
24
18
56
17
54
19
5
6
51
55
II
11
4b(4)
52
Air supply / discharge apparatus
Cooling control portion
12
Cooling apparatus
7
10
P
8
53
Supply / discharge control portion
2
9
Supply control portion

FIG. 2

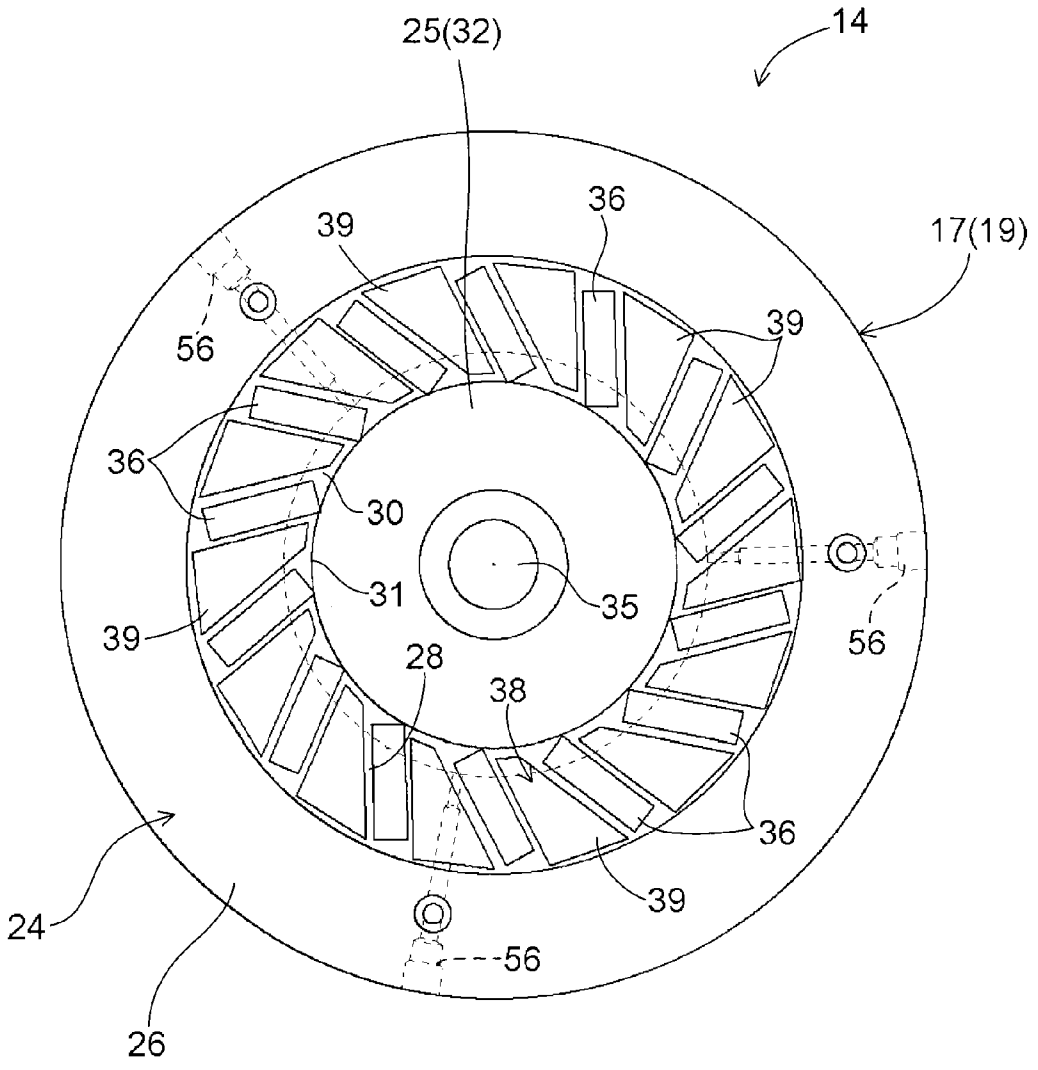


FIG. 3

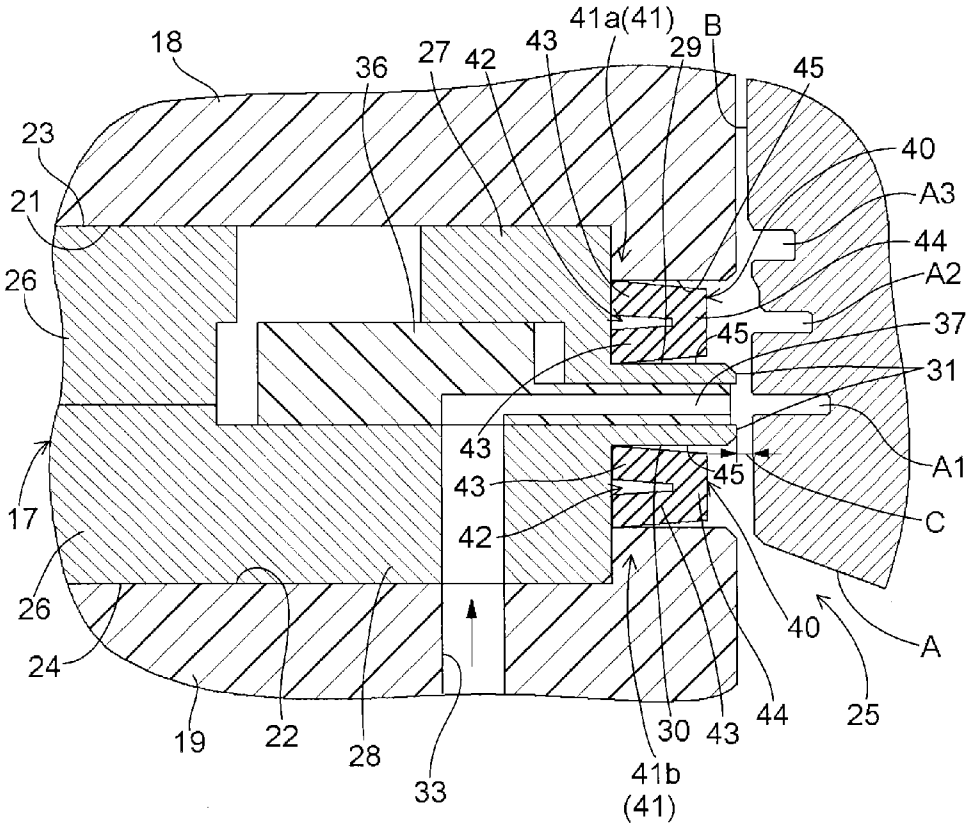
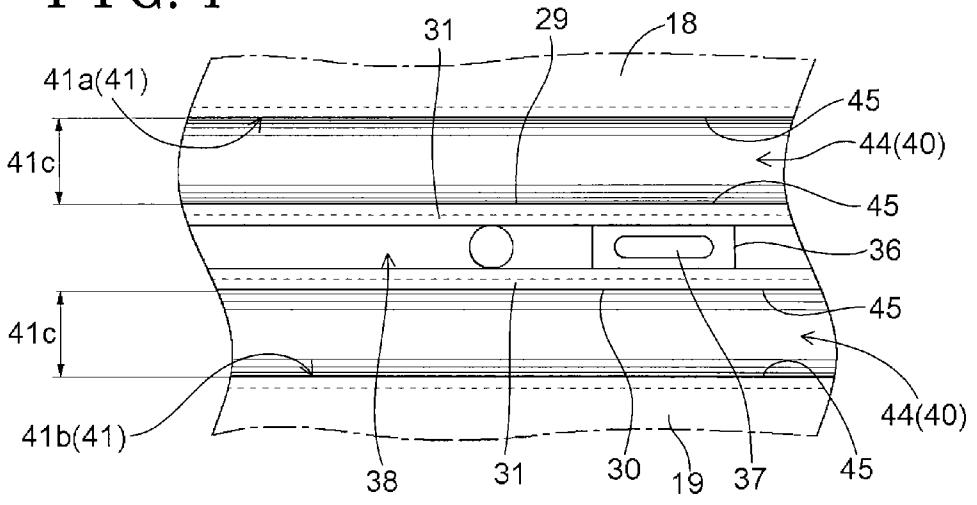

18
36
27
42
43
41a(41)
29
B
45
23
40
21
A3
44
26
A2
45
37
31
43
43
45
A1
17
42
C
26
40
24
A
19
22
28
33
30
43
44
25
41b
(41)

FIG. 4


31
29
18
41a(41)
45
41c
44(40)
45
36
41c
45
44(40)
41b(41)
38
31
30
19
37
45

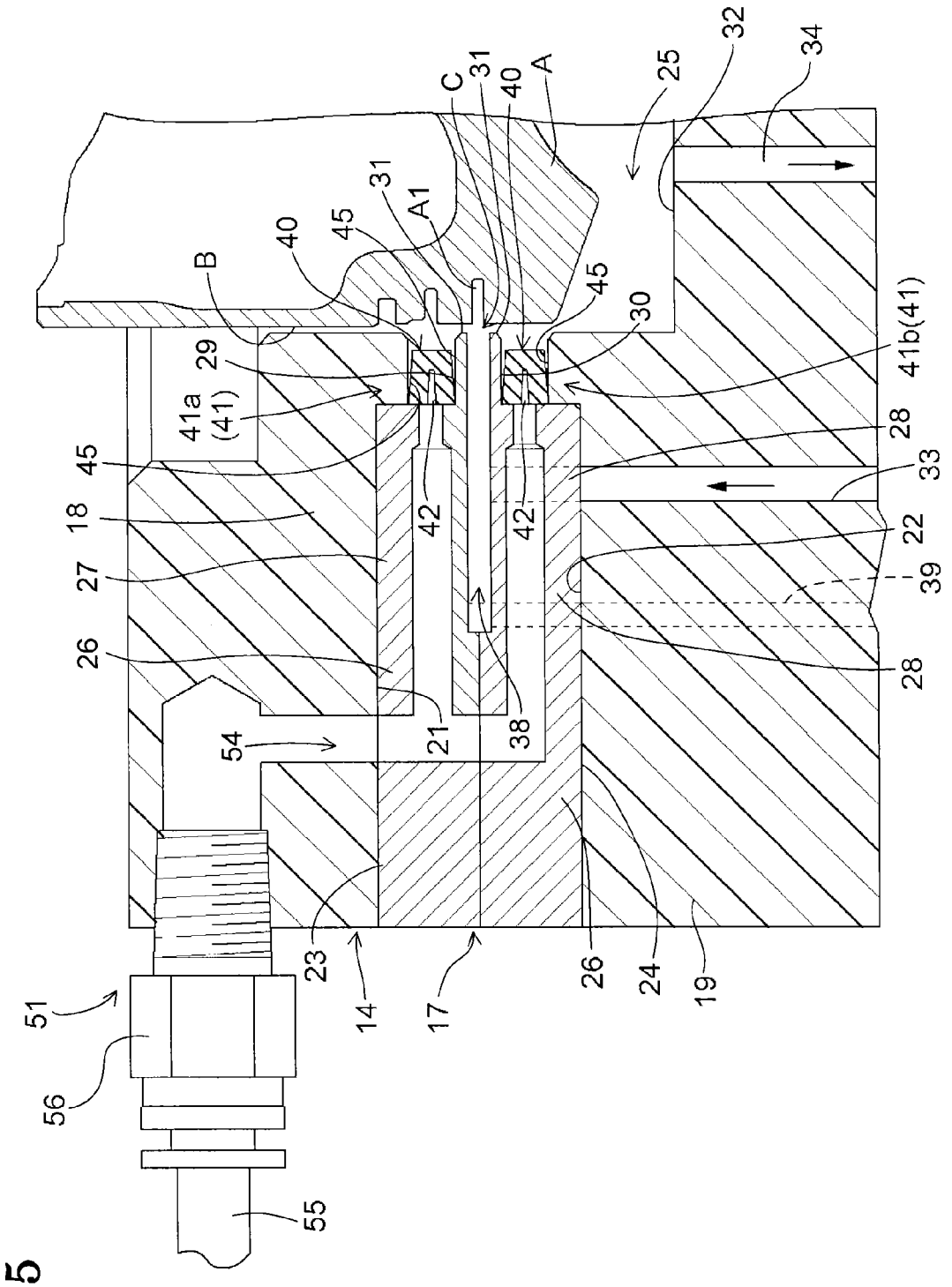

32
34
C
31
40
A
25
31
A1
40
45
B
45
30
41b(41)
29
41a
(41)
28
45
33
18
42
42
22
27
39
26
28
54
21
38
23
14
17
26
24
19
51
56
55

FIG. 5

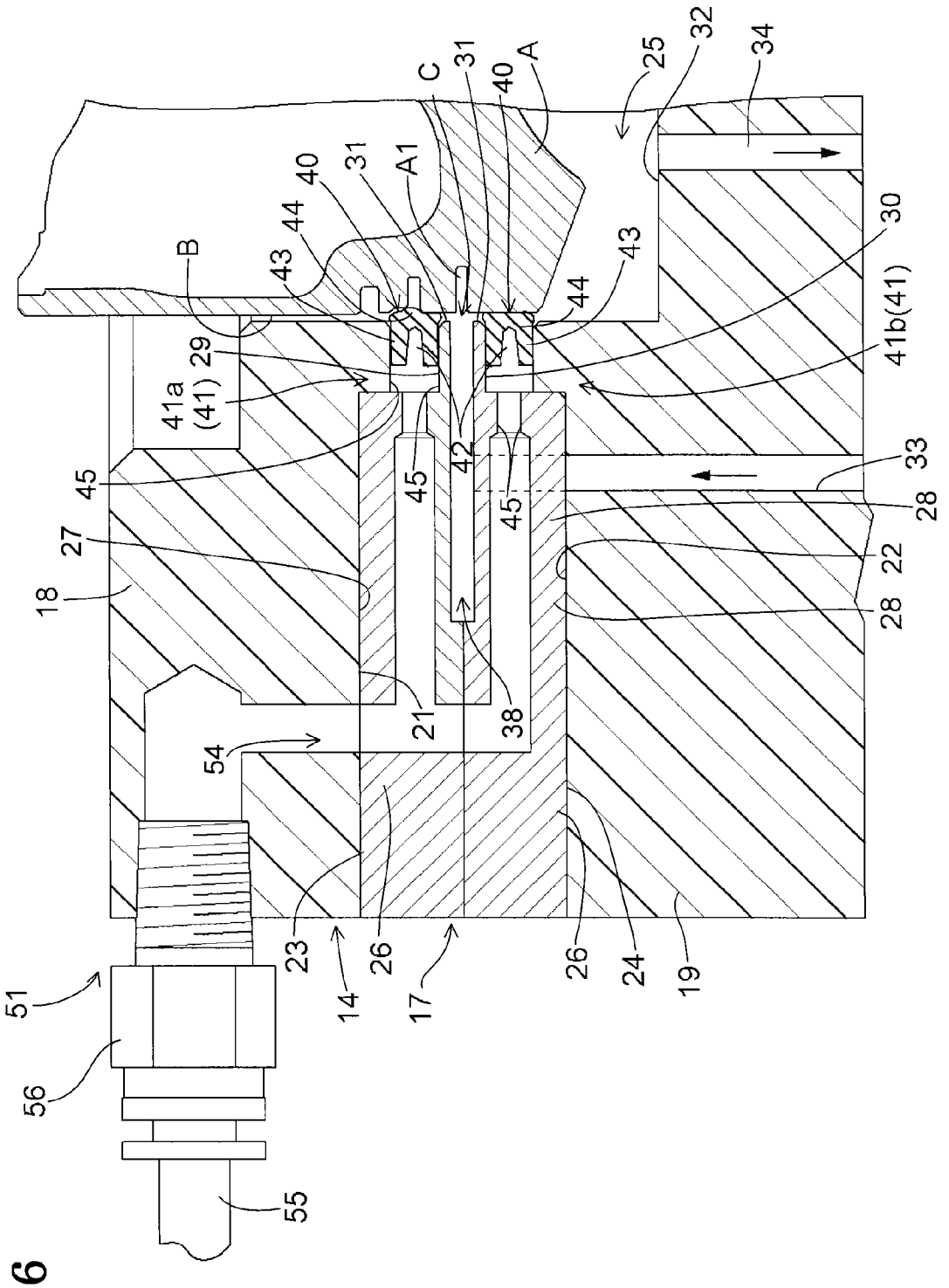

C
31
40
A
25
32
34
40
31
A1
44
43
B
43
44
30
41b(41)
29
41a
(41)
45
42
45
45
33
28
27
22
18
28
21
38
54
23
14
26
17
26
24
19
51
56
55

FIG. 6

FIG. 7

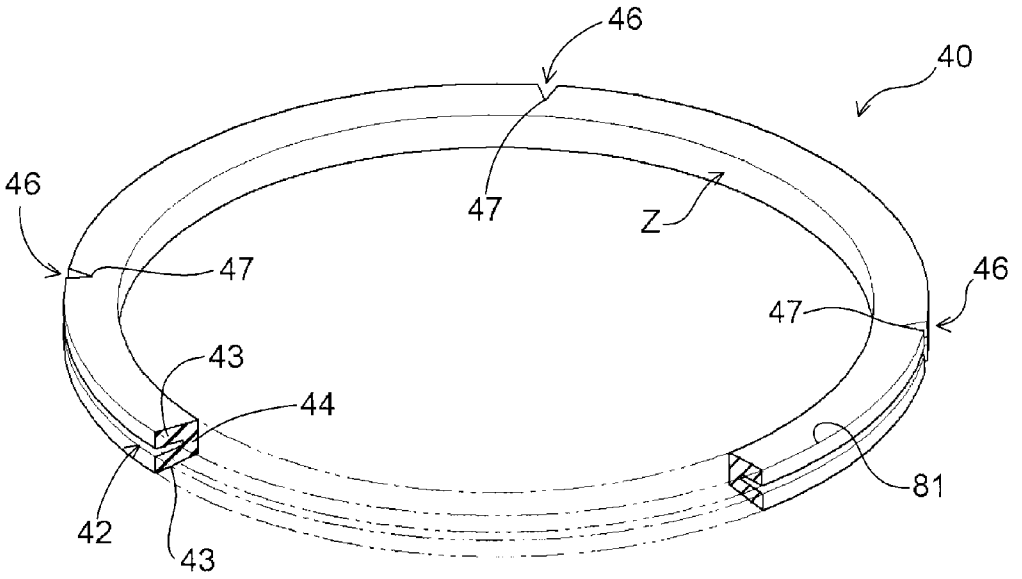

46
40
46
47
Z
47
46
47
43
44
42
43
81

FIG. 8

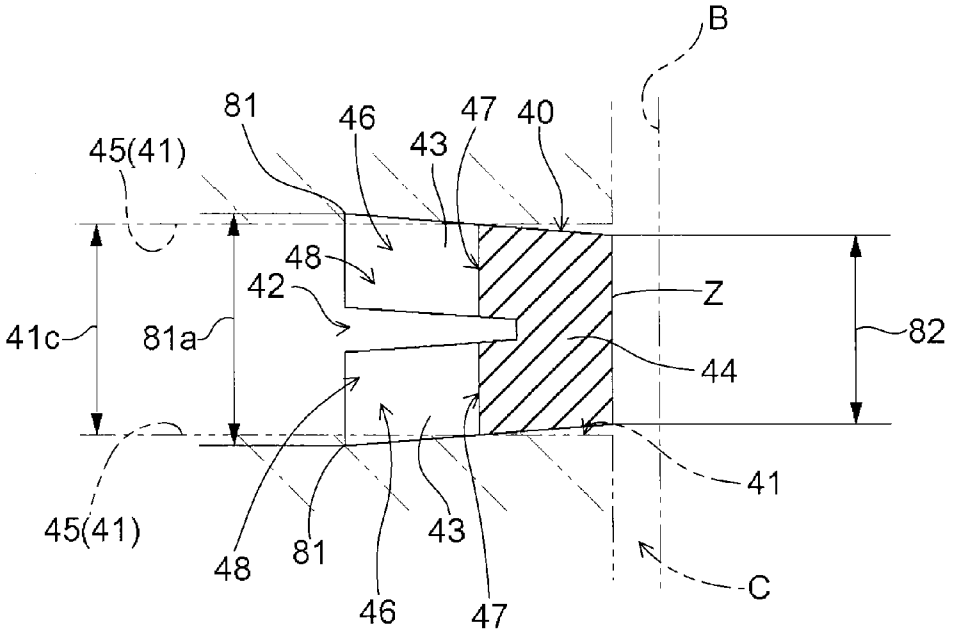

B
81
46
47
40
45(41)
43
48
42
Z
41c
81a
82
44
41
45(41)
48
81
43
46
47
C

FIG. 9

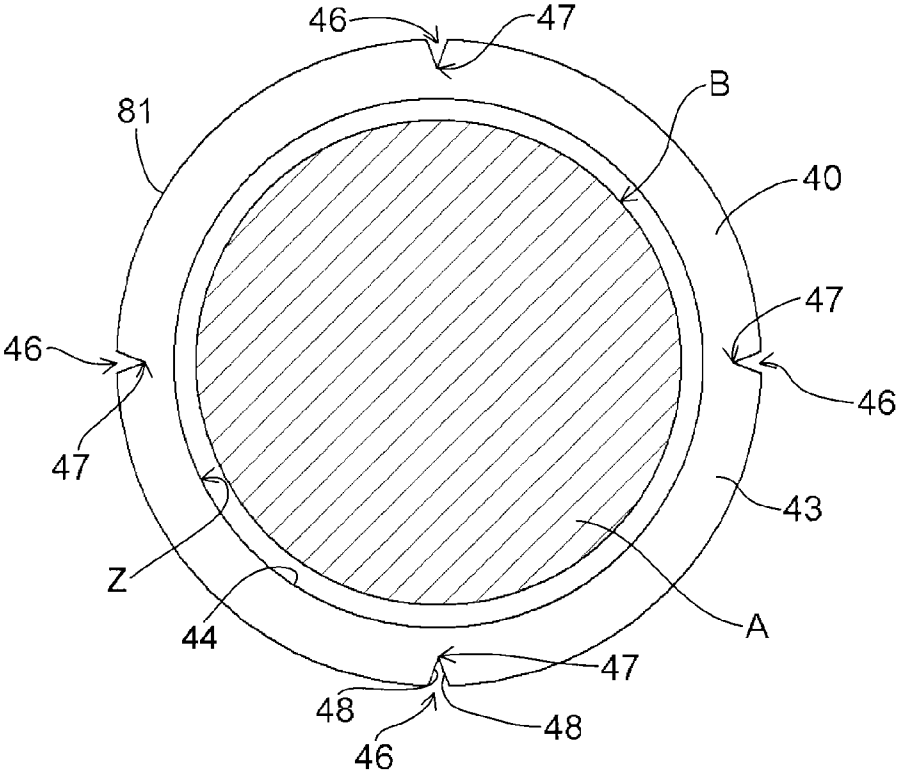

46
47
B
81
40
47
46
46
47
43
Z
A
44
47
48
48
46

FIG. 10

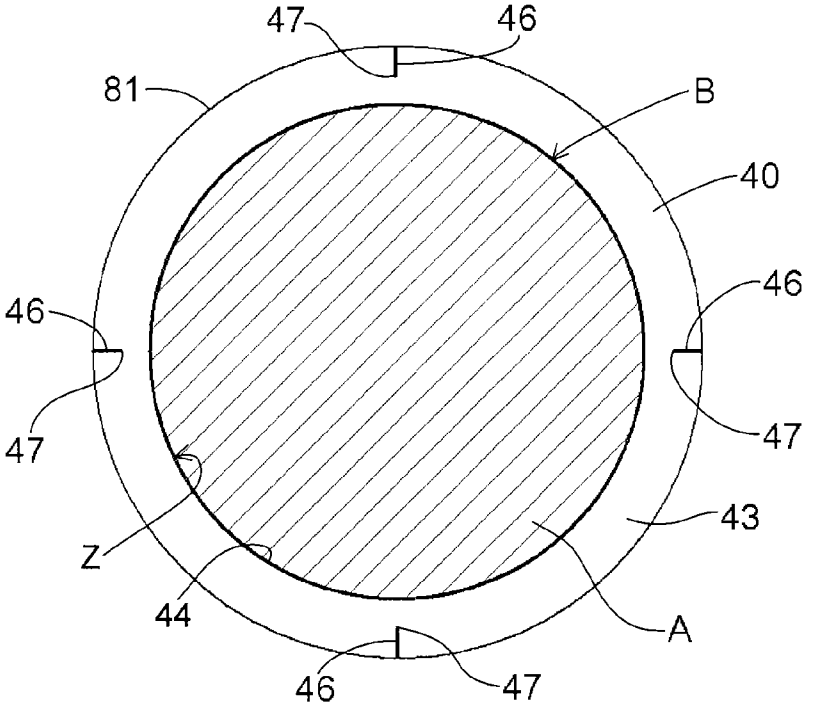

47
46
81
B
40
46
46
47
47
43
Z
A
44
46
47

FIG. 11

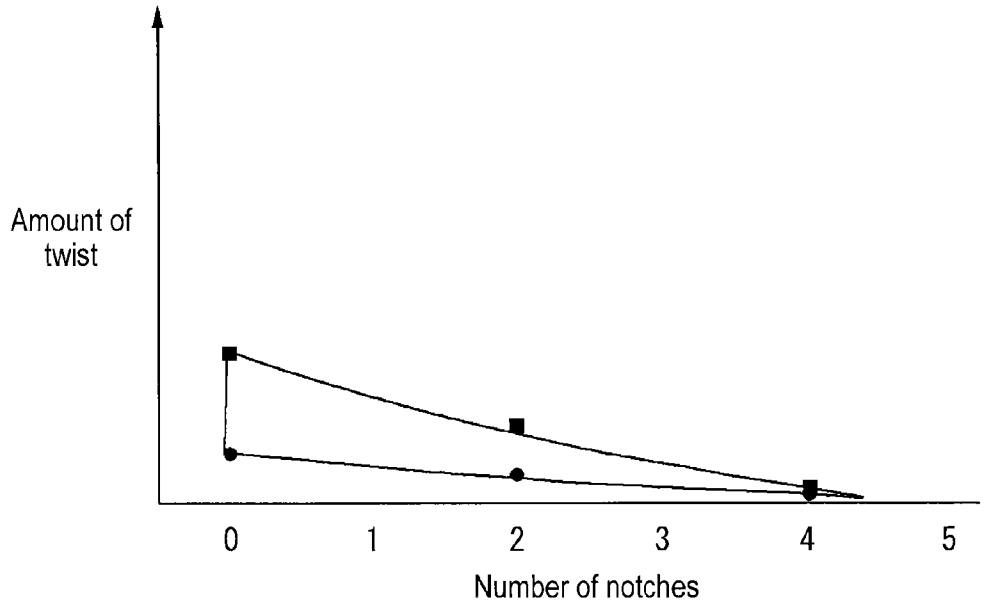

Amount of twist
0
1
2
3
4
5
Number of notches

FIG. 12

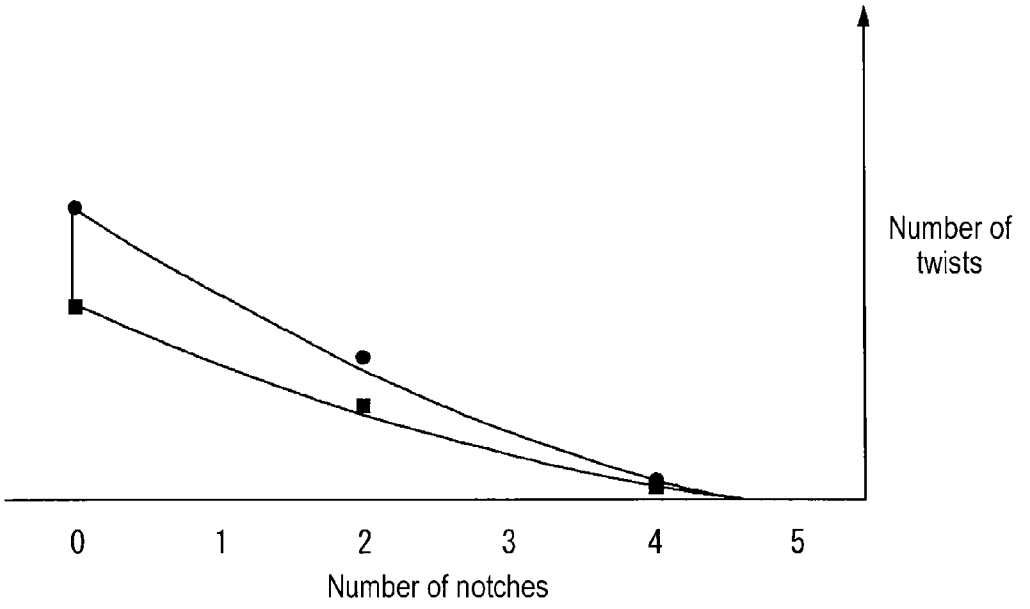

Number of twists
0
1
2
3
4
5
Number of notches

FIG. 13

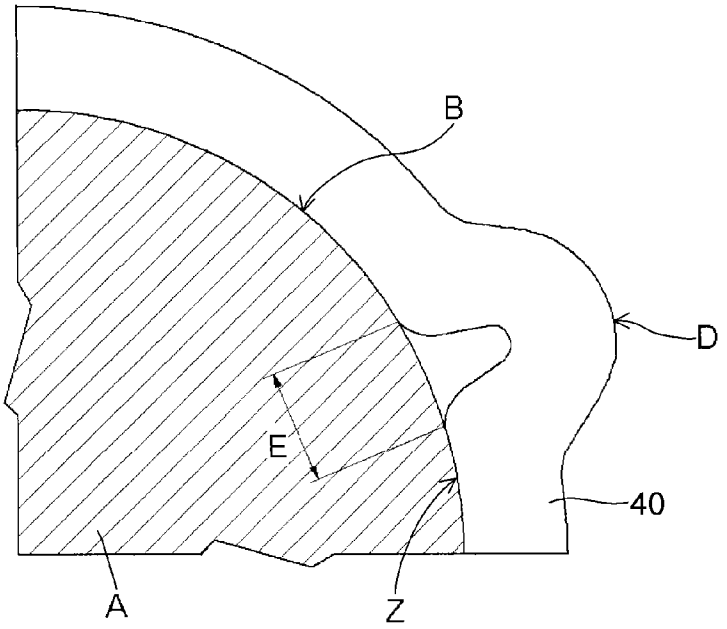
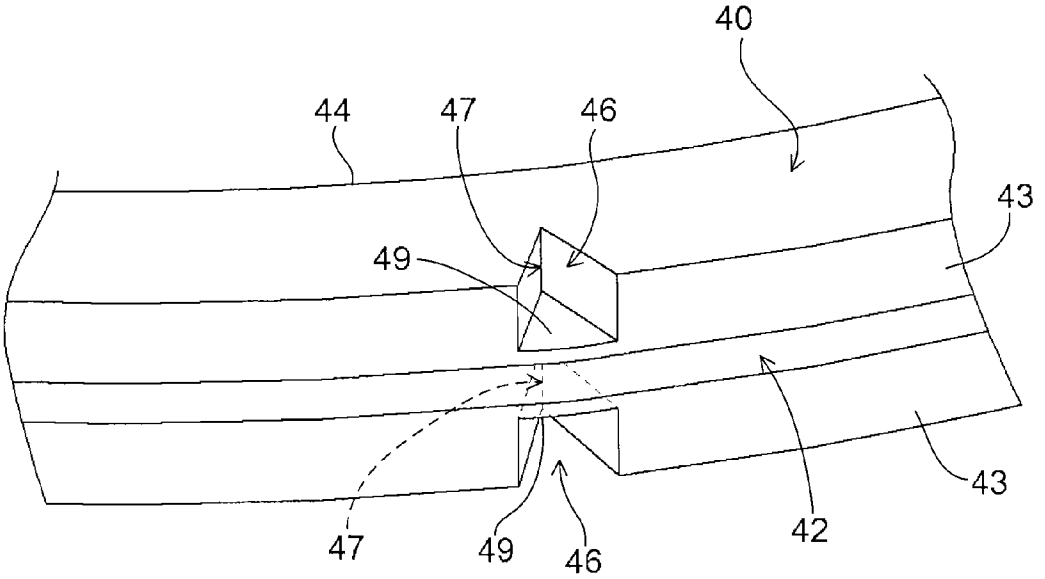


FIG. 14



PARTIAL SURFACE TREATMENT APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims priority under 35 U.S.C. §119 to Japanese Patent Application 2013-195805, filed on Sep. 20, 2013, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] This disclosure generally relates to a partial surface treatment apparatus.

BACKGROUND DISCUSSION

[0003] A known partial surface treatment apparatus is disclosed in JP2011-219858A (which will be hereinafter referred to as Patent reference 1). The known partial surface treatment apparatus includes a first electrode member electrically connected to a treatment object which is made of metal and which includes an outer circumferential surface and a circumferential groove formed at the outer circumferential surface. The known partial surface treatment apparatus includes a second electrode member including an inner circumferential surface facing the outer circumferential surface and the circumferential groove, the inner circumferential surface being spaced apart from the outer circumferential surface and the circumferential groove along an entire circumference of the inner circumferential surface. The known partial surface treatment apparatus includes a pair of annular-shaped elastic sealing members each of which is nonconductive, the annular-shaped elastic sealing members being configured to seal, at both sides relative to the circumferential groove, a clearance formed between the outer circumferential surface and the inner circumferential surface. The known partial surface treatment apparatus includes a circumferential groove portion accommodating each of the annular-shaped elastic sealing members in such a manner that the annular-shaped elastic sealing member is spaced apart from the outer circumferential surface and that the annular-shaped elastic sealing member is movable in a diameter reduction direction. The known partial surface treatment apparatus includes a pressure applying mechanism configured to supply a pressurized fluid to an outer circumferential side of the annular-shaped elastic sealing members fitted into the circumferential groove portions in order to move the annular-shaped elastic sealing members in the diameter reduction direction, an inner circumferential side of each of the annular-shaped elastic sealing members being in pressure contact with the outer circumferential surface in a case where the annular-shaped elastic sealing members are moved in the diameter reduction direction, the pressure applying mechanism configured to release the pressure contact. The known partial surface treatment apparatus includes a supply flow passage through which electrolyte solution is supplied to a space formed between the outer circumferential surface and the inner circumferential surface, the space being sealed with the pair of annular-shaped elastic sealing members. The annular-shaped elastic sealing member of the known partial surface treatment apparatus is formed in a shape including a pair of annular-shaped side wall portions and an annular-shaped end portion. The pair of annular-shaped side wall portions are configured to be in slidably contact with groove side surfaces, which face each other, of the circumferential groove portion while the pair of annular-shaped side wall portions are apart from each other in a groove width direction. The annular-shaped end portion connects inner circumferential portions of the respective annular-shaped side wall portions to each other serially. The annular-shaped elastic sealing member of the known partial surface treatment apparatus is formed in an annular shape where the same cross-sectional shape continues along the entire circumference thereof. An inner circumferential side of the annular-shaped end portion is in pressure contact with the outer circumferential surface of the treatment object.

[0004] According to the known partial surface treatment apparatus disclosed in Patent reference 1, at the both sides relative to the circumferential groove, the annular-shaped elastic sealing members seal the clearance between the outer circumferential surface of the treatment object and the inner circumferential surface of the second electrode member. Then, the electrolyte solution is supplied to a space which is formed between the outer circumferential surface and the inner circumferential surface and is sealed with the annular-shaped elastic sealing members, and thus a surface treatment is conducted relative to the circumferential groove.

[0005] In order to seal the clearance between the outer circumferential surface and the inner circumferential surface, the pressure applying mechanism supplies pressurized fluid such as compressed air to a portion between the pair of annular-shaped side wall portions of the annular-shaped elastic sealing member fitted into the circumferential groove portion, and accordingly the annular-shaped elastic sealing member is moved in the diameter reduction direction in which the inner circumferential side of the annular-shaped end portion is in pressure contact with the outer circumferential surface. Accordingly, a circumferential length, at the inner circumferential side, of the annular-shaped end portion before sealing the clearance is longer compared to a circumferential length, at an outer circumferential side, of the treatment object with which the inner circumferential side of the annular-shaped end portion is to be in pressure contact.

[0006] According to the annular-shaped elastic sealing member provided at the known partial surface treatment apparatus, the inner circumferential sides of the pair of annular-shaped side wall portions are connected to each other at the annular-shaped end portion. The annular-shaped elastic sealing member of the known partial surface treatment apparatus is formed in the annular shape which continues in the same cross-sectional configuration along the entire circumference. As a result, in association with an elastic deformation of the annular-shaped elastic sealing member in the diameter reduction direction, wrinkle tends to be formed at the annular-shaped elastic sealing member due to a compressing force generated at the annular-shaped elastic sealing member in a circumferential direction thereof.

[0007] In a case where a large wrinkle is generated at the annular-shaped elastic sealing member sealing the clearance, the electrolyte solution supplied to the space which is formed between the outer circumferential surface and the inner circumferential surface and which is sealed with the pair of annular-shaped elastic sealing members may leak out from the wrinkled portion.

[0008] In order to avoid such a leakage at the wrinkled portion, it can be conceived that a moving speed of the annular-shaped elastic sealing member in the diameter reduction direction is reduced so that small wrinkles are generated in a spread-out manner in the circumferential direction of the

annular-shaped elastic sealing member, for example. However, in a case where the annular-shaped elastic sealing member is elastically deformed over a long period of time, the surface treatment may not be performed efficiently.

[0009] In addition, in a case where the electrolyte solution leaks out towards the outer circumferential side of the annular-shaped elastic sealing member via the wrinkled portion, the leaking electrolyte solution is mixed with the pressurized fluid supplied to the outer circumferential side of the annular-shaped elastic sealing member. As a result, inconvenience tends to occur, for example, the pressure applying mechanism and/or an electrolyte solution distribution mechanism may be damaged.

[0010] A need thus exists for a partial surface treatment apparatus which is not susceptible to the drawback mentioned above.

SUMMARY

[0011] According to an aspect of this disclosure, a partial surface treatment apparatus includes a first electrode member electrically connected to a treatment object made of metal, the treatment object including an outer circumferential surface and a circumferential groove formed at the outer circumferential surface, a second electrode member including an inner circumferential surface facing the outer circumferential surface and the circumferential groove, the inner circumferential surface being spaced apart from the outer circumferential surface and the circumferential groove along an entire circumference of the inner circumferential surface, a pair of annular-shaped elastic sealing members each of which is nonconductive, the annular-shaped elastic sealing members being configured to seal, at both sides relative to the circumferential groove, a clearance formed between the outer circumferential surface and the inner circumferential surface, an accommodation portion accommodating each of the annular-shaped elastic sealing members in such a manner that the annular-shaped elastic sealing member is spaced apart from the outer circumferential surface and that the annular-shaped elastic sealing member is movable in a diameter reduction direction, the accommodation portion including groove side surfaces arranged to face each other, a pressure applying mechanism configured to supply a pressurized fluid to an outer circumferential side of the annular-shaped elastic sealing members fitted into the accommodation portions in order to move the annular-shaped elastic sealing members in the diameter reduction direction, an inner circumferential side of each of the annular-shaped elastic sealing members being in pressure contact with the outer circumferential surface in a case where the annular-shaped elastic sealing members are moved in the diameter reduction direction, the pressure applying mechanism configured to release the pressure contact between the annular-shaped elastic sealing members and the outer circumferential surface, a supply flow passage through which electrolyte solution is supplied to a space formed between the outer circumferential surface and the inner circumferential surface, the space being sealed with the pair of annular-shaped elastic sealing members, each of the annular-shaped elastic sealing members being formed in a shape including a pair of annular-shaped side wall portions and an annular-shaped end portion, the pair of annular-shaped side wall portions being configured to be in slidably contact with the corresponding groove side surfaces of the accommodation portion while the pair of annular-shaped side wall portions being apart from each other in a groove width direction, the annular-shaped end portion connecting inner circumferential portions of the respective annular-shaped side wall portions to each other serially, and a cutout being formed at each of the annular-shaped elastic sealing members to be extended from an outer circumferential side edge portion of the annular-shaped elastic sealing member towards the inner circumferential side of the annular-shaped elastic sealing member, the cutout being provided at at least one position which is along a circumferential direction of the annular-shaped elastic sealing member.

[0012] According to another aspect of this disclosure, a partial surface treatment apparatus includes a first electrode member electrically connected to a treatment object made of metal, the treatment object including an outer circumferential surface and a circumferential groove formed at the outer circumferential surface, a second electrode member including an inner circumferential surface facing the outer circumferential surface and the circumferential groove, the inner circumferential surface being spaced apart from the outer circumferential surface and the circumferential groove along an entire circumference of the inner circumferential surface, a pair of annular-shaped elastic sealing members each of which is nonconductive, the annular-shaped elastic sealing members being configured to seal, at both sides relative to the circumferential groove, a clearance formed between the outer circumferential surface and the inner circumferential surface, an accommodation portion accommodating each of the annular-shaped elastic sealing members in such a manner that the annular-shaped elastic sealing member is spaced apart from the outer circumferential surface and that the annular-shaped elastic sealing member is movable in a diameter reduction direction, the accommodation portion including groove side surfaces arranged to face each other, a pressure applying mechanism configured to supply a pressurized fluid to an outer circumferential side of the annular-shaped elastic sealing members fitted into the accommodation portions in order to move the annular-shaped elastic sealing members in the diameter reduction direction, an inner circumferential side of each of the annular-shaped elastic sealing members being in pressure contact with the outer circumferential surface in a case where the annular-shaped elastic sealing members are moved in the diameter reduction direction, the pressure applying mechanism configured to release the pressure contact between the annular-shaped elastic sealing members and the outer circumferential surface, a supply flow passage through which electrolyte solution is supplied to a space formed between the outer circumferential surface and the inner circumferential surface, the space being sealed with the pair of annular-shaped elastic sealing members, each of the annular-shaped elastic sealing members including a pair of annular-shaped side wall portions, an annular-shaped end portion and a plurality of cutouts, the pair of annular-shaped side wall portions being configured to be in slidably contact with the corresponding groove side surfaces of the accommodation portion, the pair of annular-shaped side wall portions being apart from each other in a groove width direction, the annular-shaped end portion connecting inner circumferential portions of the respective annular-shaped side wall portions to each other serially, the plurality of cutouts being formed along a circumferential direction of the annular-shaped elastic sealing member while a uniform space is provided therebetween, each of the cutouts being extended from an outer

circumferential edge of the annular-shaped elastic sealing member towards a radially inner side of the annular-shaped elastic sealing member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The foregoing and additional features and characteristics of this disclosure will become more apparent from the following detailed description considered with the reference to the accompanying drawings, wherein:

[0014] FIG. **1** is a schematic view of a partial surface treatment apparatus (an anodizing treatment apparatus) according to first and second embodiments disclosed here;

[0015] FIG. **2** is a plan view of a second electrode portion which is seen from a direction of the arrow of line II-II in FIG. **1**;

[0016] FIG. **3** is a cross-sectional view illustrating an electrolyte solution supply nozzle portion of a second electrode member according to the embodiments;

[0017] FIG. **4** is a side view illustrating an inner circumferential side of the electrolyte solution supply nozzle portion of the second electrode member;

[0018] FIG. **5** is a cross-sectional view illustrating a state where annular-shaped elastic sealing members are apart from a piston outer circumferential surface according to the embodiments;

[0019] FIG. **6** a cross-sectional view illustrating a state where the annular-shaped elastic sealing members are in pressure contact with the piston outer circumferential surface;

[0020] FIG. **7** is a perspective view of the annular-shaped elastic sealing member;

[0021] FIG. **8** is an enlarged cross-sectional view of the annular-shaped elastic sealing member;

[0022] FIG. **9** is a plan view illustrating the annular-shaped elastic sealing member which is separated from the piston outer circumferential surface;

[0023] FIG. **10** a plan view illustrating the annular-shaped elastic sealing member which is in pressure contact with the piston outer circumferential surface;

[0024] FIG. **11** is a graph representing relationship between "the number of notches" and "an amount of twist";

[0025] FIG. **12** a graph representing relationship between "the number of notches" and "the number of twists";

[0026] FIG. **13** is a view explaining "the amount of twist" and "the number of twists"; and

[0027] FIG. **14** is a perspective view illustrating an annular-shaped elastic sealing member of the second embodiment.

DETAILED DESCRIPTION

[0028] A first embodiment disclosed here will be described hereunder with reference to the drawings. In this embodiment, an anodizing treatment apparatus which conducts an anodizing treatment (a surface treatment) to a surface of a piston A made of an aluminum alloy which serves as a treatment object made of metal is described as an example of a partial surface treatment apparatus of this embodiment. Illustrated in each of FIGS. **1** to **10** is the anodizing treatment apparatus, which executes the anodizing treatment to a piston ring groove A1 of the piston A. Additionally, "the piston ring groove A1 of the piston A", "the anodizing treatment" and "the anodizing treatment apparatus" are examples, therefore the partial surface treatment apparatus is adaptable to other surface treatments.

[0029] More specifically, the anodizing treatment is applied to an outer circumferential surface B (which will be hereinafter referred to as a piston outer circumferential surface) including the piston ring groove A1 (i.e. a compression ring groove) positioned closer to a top portion of the piston A out of three piston ring grooves A1, A2 and A3. The piston ring grooves A1, A2 and A3 are formed on the piston A in such a manner that the piston ring groove A1 is positioned closer to the top portion of the piston A, the piston ring groove A3 is positioned at a skirt portion of the piston A and the piston ring groove A2 is positioned between the piston ring grooves A1 and A3. The piston ring groove A1 corresponds to a circumferential groove formed on the piston outer circumferential surface B.

[0030] The anodizing treatment apparatus includes an electrolyte solution tank **1**, an electrolyte solution supplying portion **2**, an oxidation treatment portion **3** and an electrifying portion **4**. As illustrated in FIGS. **1** and **2**, the electrolyte solution tank **1**, which is made of a polyvinyl chloride or SUS316, is formed in a container having an opening portion at an upper end portion thereof. The electrolyte solution tank **1** receives electrolyte solution, which flows through the oxidation treatment portion **3** in order to collect the electrolyte solution. Furthermore, the electrolyte solution tank **1** includes a reflux passage **5** for flowing back the electrolyte solution to the electrolyte solution supplying portion **2**.

[0031] The electrolyte solution supplying portion **2** includes a cooling tank **6** for cooling down the electrolyte solution which is flown back thereto from the electrolyte solution tank **1**, a supply passage **7** through which the electrolyte solution in the cooling tank **6** is supplied to the oxidation treatment portion **3**, a supply pump **8** provided at the supply passage **7**, and a supply control portion **9** which controls an actuation of the supply pump **8** in order to supply the electrolyte solution to the oxidation treatment portion **3** at a predetermined timing.

[0032] The cooling tank **6** includes a cooling apparatus **10** which cools down the collected electrolyte solution, and a cooling control portion **12** which controls an actuation of the cooling apparatus **10** on the basis of a detection information of the electrolyte solution temperature obtained by a temperature sensor **11** so that the electrolyte solution is cooled down to a predetermined temperature.

[0033] The electrifying portion **4** electrifies the oxidation treatment portion **3**. The electrifying portion **4** may be configured so as to include a current control device, so that the electrifying portion **4** can adjust a current density. A known current control device constituted by an ampere meter, a voltage indicator, a rectifier and the like may be used as the current control device.

[0034] The oxidation treatment portion **3** includes a first electrode portion **13** (anode) and a second electrode portion **14** (cathode). The first electrode portion **13** includes a first electrode member **15** which is made of metal having electric conductivity such as copper or SUS316, and a lifting device **16** which is configured so as to lift up and lower the first electrode member **15** relative to the second electrode portion **14**. The first electrode member **15** also serves as a retaining member for supporting and retaining the piston A. Furthermore, the first electrode member **15** is electrically connected to an anode terminal **4***a* of the electrifying portion **4**.

[0035] The retaining member **15** (i.e. the first electrode member **15**) includes an engagement pawl at a lower end portion thereof so that the retaining member **15** is engageable

with and disengageable from an inner circumferential surface of the piston A. The engagement pawl engages with the inner circumferential surface of the piston A, and accordingly the retaining member **15** retains the piston A in a state where an axis of the piston A extends in a vertical direction and the piston A is being electrically connected to the retaining member **15**.

[0036] As illustrated in FIG. **2**, the second electrode portion **14** is formed in such a manner that an outer shape thereof forms a round shape in a plane view. Furthermore, the second electrode portion **14** includes a piston insertion bore **25** which extends in a concentric manner and which is formed in a round shape in a plane view. Accordingly, the piston A is inserted into the piston insertion bore **25** so that the axis the piston A extends in an up/down direction along the piston insertion bore **25**.

[0037] As illustrated in FIG. **1**, the second electrode portion **14** includes a second electrode member **17**, a first fixing plate **18** and a second fixing plate **19**. The second electrode member **17** is made of metal having the electric conductivity such as the copper or SUS316. On the other hand, each of the first and second fixing plates **18** and **19** is made of a nonconductive material (insulator) such as a polyvinyl chloride resin and the like. Furthermore, the first and second fixing plates **18** and **19** are arranged so as to sandwich the second electrode member **17**, more specifically, the first fixing plate **18** is arranged at an upper portion of the second electrode member **17** and the second fixing plate **19** is arranged at a lower portion of the second electrode member **17**. The first fixing plate **18** and the second fixing plate **19** are connected to each other by means of a bolt (bolts).

[0038] The second electrode member **17** is provided between an upwardly-recessed surface portion **21** and a downwardly-recessed surface portion **22** so as to be fitted into a space formed therebetween. Furthermore, the second electrode member **17** is connected to each of the upwardly-recessed surface portion **21** and the downwardly-recessed surface portion **22** by means of a bolt (bolts). The upwardly-recessed surface portion **21** is formed at an outer circumferential lower surface of the first fixing plate **18**, which is arranged at the upper side, so as to recess upwardly in an annular shape. On the other hand, the downwardly-recessed surface portion **22** is formed at an outer circumferential upper surface of the second fixing plate **19**, which is arranged at the lower side, so as to recess downwardly in an annular shape.

[0039] As illustrated in FIG. **1**, the second electrode member **17** is constituted by a first electrode plate **23** and a second electrode plate **24**. The two electrode plates, that is, the first and second electrode plates **23** and **24** are connected to each other by means of a bolt (bolts) in a state where the first electrode plate **23** is arranged upon the second electrode plate **24**. The second electrode member **17** is electrically connected to a cathode terminal **4***b* of the electrifying portion **4**.

[0040] As illustrated in FIGS. **3** to **6**, the first electrode plate **23** includes an outer circumferential portion **26** which is positioned close to the outer circumference of the first electrode plate **23** and a first thin plate portion **27** which is positioned at a side close to the piston insertion bore **25**. The first thin plate portion **27** is formed to be thinner than the outer circumferential portion **26**. Similarly, the second electrode plate **24** includes an outer circumferential portion **26** which is positioned close to the outer circumference of the first electrode plate **23** and a second thin plate portion **28** which is positioned at the side close to the piston insertion bore **25**. The second thin plate portion **28** is formed to be thinner than the outer circumferential portion **26**. Further, the first electrode plate **23** includes a first flange plate portion **29** which is formed in an annular shape so as to extend towards the piston insertion bore **25** along an inner circumferential portion of the first thin plate portions **27**, and the second electrode plate **24** includes a second flange plate portion **30** which is formed in an annular shape so as to extend towards the piston insertion bore **25** along an inner circumferential portion of the second thin plate portions **28**. A space at a radially inner side of an inner circumferential surface (which will be hereinafter referred to as an electrode inner circumferential surface) **31** of each of the first and second flange plate portions **29** and **30** is formed to serve as the piston insertion bore **25**. Therefore, the electrode inner circumferential surface **31** of each of the first and second flange plate portions **29** and **30** is formed as an annular-shaped inner circumferential surface that faces the piston outer circumferential surface B and the piston ring groove A1 while being spaced apart from the piston outer circumferential surface B and the piston ring groove A1 by a constant distance along the entire circumference.

[0041] As illustrated in FIG. **1**, the second fixing plate **19** includes a round-shaped recessed surface portion **32** and a round-shaped protruding surface portion **35**. The round-shaped recessed surface portion **32** is formed in such a manner that a diameter thereof corresponds to the piston insertion bore **25** and that the round-shaped recessed surface portion **32** is concentric with the piston insertion bore **25**. On the other hand, the round-shaped protruding surface portion **35** supports a top surface of the piston A which is placed on the round-shaped protruding surface portion **35** in a state where the axis of the piston A extends in the up/down direction. The second fixing plate **19** includes a connecting fluid passage **33** which is connected to the supply passage **7** of the electrolyte solution, and a discharge hole **34** through which the electrolyte solution accumulated within the round-shaped recessed surface portion **32** is naturally discharged (due to the gravity flow) to the electrolyte solution tank **1**.

[0042] Accordingly, as illustrated in FIG. **1**, the piston A, which is retained by the retaining member **15** (the first electrode member **15**) in the state where the piston A is electrically connected to the first electrode member **15** while the axis of the piston A extends in the vertical direction, is inserted into the piston insertion bore **25** and the top surface of the piston A is placed on the round-shaped protruding surface portion **35**. Accordingly, as illustrated in FIG. **3**, the piston A is arranged at a position in such a manner that the piston outer circumferential surface B is being away from the electrode inner circumferential surfaces **31** so as to form a clearance C, which is a constant clearance, between the piston outer circumferential surface B and the electrode inner circumferential surfaces **31** along the entire circumference thereof in a concentric manner.

[0043] As illustrated in FIGS. **2** to **4**, plural electrolyte solution supply nozzles **36** are arranged between the first thin plate portion **27** and the first flange portion **29** of the first electrode plate **23** on the one hand and the second thin plate portion **28** and the second flange portion **30** of the second electrode plate **24** on the other hand. The plural electrolyte solution supply nozzles **36** are arranged in a circumferential direction while keeping a predetermined distance between the neighboring electrolyte solution supply nozzles **36** in the circumferential direction. Each of the electrolyte solution

supply nozzles **36** is arranged in such a manner that the electrolyte solution is supplied between the piston outer circumferential surface B and the electrode inner circumferential surfaces **31** in a direction that is inclined relative to a tangential line of the electrode inner circumferential surfaces **31**.

[0044] As illustrated in FIGS. **3** and **4**, each of the electrolyte solution supply nozzles **36** is connected to the connecting fluid passage **33**. Furthermore, each of the electrolyte solution supply nozzles **36** includes a supply flow passage **37** through which the electrolyte solution is supplied to a space formed between the piston outer circumferential surface B and the electrode inner circumferential surfaces **31**. As will be described later, the space between the piston outer circumferential surface B and the electrode inner circumferential surfaces **31** is sealed with a pair of annular-shaped elastic sealing members **40** each including a circular form. The supply flow passage **37** of each of the electrolyte solution supply nozzles **36** opens at the electrode inner circumferential surfaces **31**.

[0045] As illustrated in FIGS. **1** to **4**, between the neighboring electrolyte solution supply nozzles **36** in the circumferential direction, a space between the first thin plate portion **27** and the second thin plate portion **28**, and a space between the first flange portion **29** and the second flange portion **30** are provided so as to serve as a discharge flow passage **38** of the electrolyte solution.

[0046] As illustrated in FIG. **2**, a through hole **39** extending through the second thin plate portion **28** and the second fixing plate **19** is formed between the neighboring electrolyte solution supply nozzles **36** in the circumferential direction. The electrolyte solution within the discharge flow passage **38** is naturally discharged towards the electrolyte solution tank **1** through the through holes **39** by gravity.

[0047] As illustrated in FIGS. **1** and **3** to **6**, the pair of annular-shaped elastic sealing members **40** and a pair of accommodation portions **41** are provided at the second electrode member **17**, at a side where the electrode inner circumferential surface **31** is positioned. The pair of annular-shaped elastic sealing members **40**, each of which is a nonconductive sealing member, are arranged at an upper side and a lower side, respectively. Each of the accommodation portions **41** accommodates the corresponding annular-shaped elastic sealing member **40** in such a manner that the annular-shaped elastic sealing member **40** is spaced apart from the piston outer circumferential surface B by a distance along the entire circumference thereof, and that the corresponding annular-shaped elastic sealing member **40** is movable in a diameter reduction direction, that is, in a direction in which a diameter of the annular-shaped elastic sealing member **40** decreases.

[0048] The accommodation portions **41** include a first accommodation portion **41***a* into which the annular-shaped elastic sealing member **40** arranged at the upper side is fitted and a second accommodation portion **41***b* into which the annular-shaped elastic sealing member **40** arranged at the lower side is fitted. The first accommodation portion **41***a* is formed between a groove side surface **45** constituted by an upper surface of the first flange plate portion **29** of the first electrode plate **23** and a groove side surface **45** constituted by a bottom surface of the first fixing plate **18**, and the groove side surfaces **45** which constitute the first accommodation portion **41***a* face each other to be parallel to each other. The second accommodation portion **41***b* is formed between a groove side surface **45** constituted by a lower surface of the second flange plate portion **30** of the second electrode plate **24** and a groove side surface **45** constituted by an upper surface of the second fixing plate **19**, and the groove side surfaces **45** which constitute the second accommodation portion **41***b* face each other to be parallel to each other.

[0049] Illustrated in each of FIGS. **7** and **8** is the annular-shaped elastic sealing member **40** before being fitted into the accommodation portion **41**. As illustrated in FIG. **7**, each of the annular-shaped elastic sealing members **40** is made of a nonconductive material (an insulator) such as rubber and the like and is formed in the annular shape or a ring shape. Each of the annular-shaped elastic sealing members **40** includes a recessed portion **42** which opens toward an outer circumferential side of the annular-shaped elastic sealing member **40** and is formed serially or continuously along the entire circumference thereof. The annular-shaped elastic sealing members **40** are configured to seal the clearance C formed between the piston outer circumferential surface B and the electrode inner circumferential surfaces **31**, at both sides relative to the piston ring groove A1, that is, at the upper side and the lower side relative to the piston ring groove A1, respectively.

[0050] Each of the annular-shaped elastic sealing members **40** integrally includes a pair of annular-shaped side wall portions **43**, **43** and an annular-shaped end portion **44**. The pair of annular-shaped side wall portions **43** are configured to be in slidably contact with the corresponding groove side surfaces **45** of the accommodation portions **41***a*, **41***b* while the pair of annular-shaped side wall portions **43** are apart from each other by a distance in a groove width direction. The annular-shaped end portion **44** connects inner circumferential portions of the pair of annular-shaped side wall portions **43** to each other serially or continuously. Accordingly, each of the annular-shaped elastic sealing members **40** includes a transverse cross section which is formed substantially in a shape of a letter U that is in a horizontal position. A space defined between the pair of annular-shaped side wall portions **43** defines the recessed portion **42**.

[0051] The annular-shaped elastic sealing members **40** are fitted into the respective first and second accommodation portions **41***a* and **41***b* in a manner that each of the annular-shaped end portions **44** does not protrude towards the piston outer circumferential surface B relative to the electrode inner circumferential surface **31**. By bringing the annular-shaped end portions **44** into pressure contact with the piston outer circumferential surface B, the clearance C between the piston outer circumferential surface B and the electrode inner circumferential surfaces **31** is sealed.

[0052] As illustrated in FIG. **8**, a pressure contact surface Z of each of the annular-shaped end portions **44**, which is configured to be in pressure contact with the piston outer circumferential surface B, is formed by a surface that is parallel to an axial direction of the annular-shaped elastic sealing members **40**. Thus, the pressure contact surface Z is a surface formed in a cylindrical shape that faces the piston outer circumferential surface B to be parallel thereto. The axial direction of the annular-shaped elastic sealing members **40** is a direction which extends through the annular shape at the center thereof.

[0053] As illustrated in FIG. **8**, in a state where each of the annular-shaped elastic sealing members **40** is not fitted in the corresponding accommodation portion **41**, a thickness of an outer circumferential portion of the annular-shaped elastic sealing member **40**, that is, an axial length **81***a* at outer circumferential side edge portions **81** of the respective annular-shaped side wall portions **43**, is set to be longer than an opening width **41***c* of the accommodation portion **41**. In addi-

tion, in the state where each of the annular-shaped elastic sealing members **40** is not fitted in the corresponding accommodation portion **41**, a thickness of an inner circumferential portion of the annular-shaped elastic sealing member **40**, that is, an axial length **82** of the pressure contact surface Z, is set to be shorter than the opening width **41***c* of the accommodation portion **41**.

[0054] Accordingly, each of the annular-shaped elastic sealing members **40** is fitted into the corresponding accommodation portion **41** in a state where the pair of annular-shaped side wall portions **43** are elastically deformed in directions in which the pair of annular-shaped side wall portions **43** come closer to each other. The annular-shaped side wall portions **43** are pressed against the respective groove side surfaces **45** by an elastic restoring force of the pair of annular-shaped side wall portions **43** that tend to deform in directions in which the annular-shaped side wall portions **43** are away from each other to return to their original shapes.

[0055] A cutout **46** is provided at at least one position of each of the annular-shaped elastic sealing members **40** in a circumferential direction. The cutout **46** is formed to be extended from the outer circumferential side edge portion **81** towards the inner circumferential side of the annular-shaped elastic sealing member **40**, that is, towards a radially inner side of the annular-shaped elastic sealing member **40**. For example, as illustrated in FIG. **9**, the cutout **46** includes a start portion and an end portion **47**. The cutout **46** is formed in a manner that the start portion thereof corresponds to the outer circumferential side edge portions **81** and that the end portion **47** thereof is provided within a region of the annular-shaped side wall portion **43**, that is, the region in which the annular-shaped side wall portion **43** is formed. For example, the cutout **46** is provided at four positions of each of the pair of annular-shaped side wall portions **43** so as to be arranged in the circumferential direction with a uniform space provided between each of the neighboring cutouts **46** in the circumferential direction. At each of the annular-shaped side wall portions **43**, each of the cutouts **46** includes an identical shape to one another. Furthermore, the positions of the cutouts **46** in the circumferential direction at one of the annular-shaped side wall portions **43** are identical to the positions of the cutouts **46** in the circumferential direction at the other of the annular-shaped side wall portions **43**.

[0056] Each of the cutouts **46** includes a pair of end surfaces **48** which intersect each other at an acute angle at the end portion **47** so as to be continuous with each other smoothly in a manner that a distance between the pair of end surfaces **48** increases towards the outer circumferential side edge portion **81** serving as the start portion. Accordingly, in a plane view, each of the cutouts **46** is formed by a notch that is formed in a V-shape or a substantially V-shape where the distance between the end surfaces **48** increases towards the outer circumferential side, that is, the V-shape opens towards the outer circumferential side.

[0057] As illustrated in FIGS. **1**, **5** and **6**, the partial surface treatment apparatus includes a pressure applying mechanism **51**. The pressure applying mechanism **51** is configured to simultaneously supply compressed air, which serves as pressurized fluid, to the outer circumferential side of the annular-shaped elastic sealing members **40** which are fitted into the first accommodation portion **41***a* and the second accommodation portion **41***b*, respectively. Thus, the pressure applying mechanism **51** is configured to move the annular-shaped elastic sealing members **40** in the diameter reduction direction. In a case where the annular-shaped elastic sealing members **40** are moved in the diameter reduction direction, the inner circumferential side (the pressure contact surface Z of the annular-shaped end portion **44**) of each of the annular-shaped elastic sealing members **40** is brought into pressure contact with the piston outer circumferential surface B along the entire circumference of the annular-shaped elastic sealing member **40**. Furthermore, the pressure applying mechanism **51** is configured to release the pressure-contact of the annular-shaped elastic sealing members **40** against the piston outer circumferential surface B.

[0058] The pressure supplying mechanism **51** includes an air supply/discharge apparatus **52**, a supply/discharge control portion **53**, an air supply/discharge passage **54** and a pipe (tube) connector **56**. The air supply/discharge apparatus **52** is configured to perform supply and discharge of the compressed air. The supply/discharge control portion **53** controls an operation of supplying/discharging the air which is conducted by the air supply/discharge apparatus **52**. The air supply/discharge passage **54** is in communication with the outer circumferential sides of the respective first accommodation portion **41***a* and second accommodation portion **41***b*. The pipe connector **56** connects an air supply/discharge pipe (tube) **55** of the air supply/discharge apparatus **52** with the air supply/discharge passage **54**.

[0059] The air supply/discharge passage **54** is provided at the second electrode portion **14** at three positions in a circumferential direction of the second electrode portion **14**. Furthermore, each of the air supply/discharge passages **54** is connected to the air supply/discharge pipe **55** at the pipe connector **56** so that, from the three positions in the circumferential direction, the compressed air is supplied to and discharged from the first accommodation portion **41***a* and the second accommodation portion **41***b*.

[0060] Next, an operation for conducting the anodizing treatment will be given below. After the piston A is inserted into the piston insertion bore **25** and is placed on the round-shaped protruding surface portion **35**, the supply/discharge control portion **53** actuates the air supply/discharge apparatus **52** to supply the compressed air to each of the first accommodation portion **41***a* and the second accommodation portion **41***b* through the corresponding air supply/discharge passages **54**.

[0061] FIG. **5** illustrates a state (i.e., a fitted state) in which the annular-shaped elastic sealing members **40** are fitted into the respective first accommodation portion **41***a* and second accommodation portion **41***b* when the compressed air is not supplied by the air supply/discharge apparatus **52**. FIG. **9** illustrates a shape of the annular-shaped elastic sealing member **40** in a plane view in a state where the compressed air is not supplied by the air supply/discharge apparatus **52**. As illustrated in FIG. **9**, each of the cutouts **46** opens towards the outer circumferential side to form the shape of a letter V. In the fitted state, the annular-shaped side wall portions **43** of each of the annular-shaped elastic sealing members **40** are closely in contact with the corresponding groove side surfaces **45**.

[0062] FIG. **6** illustrates a state in which the compressed air is supplied by the air supply/discharge apparatus **52** to the first accommodation portion **41***a* and the second accommodation portion **41***b*, and as a result thereof, the annular-shaped elastic sealing members **40** are moved in the diameter reduction direction towards the piston outer circumferential surface B and the pressure contact surfaces Z of the annular-shaped end portions **44** are in pressure contact with the piston outer

circumferential surface B. FIG. **10** illustrates a shape of the annular-shaped elastic sealing member **40** in a plane view when the pressure contact surface Z of the annular-shaped end portion **44** is in pressure contact with the piston outer circumferential surface B as a result of the supply of the compressed air by the air supply/discharge apparatus **52**.

[0063] In the state where the pressure contact surface Z is in pressure contact with the piston outer circumferential surface B (i.e., a pressure contact state), the pair of end surfaces **48** forming each of the cutouts **46** are closely in contact with each other across the entire surface thereof, and the annular-shaped side wall portions **43**, which are arranged at upper and lower sides, respectively, are pressed against the corresponding groove side surfaces **45** by the compressed air. As a result, a posture of each of the annular-shaped elastic sealing members **40** is stabilized and the compressed air is prevented from leaking towards the piston outer circumferential surface B.

[0064] Accordingly, because the pressure contact surfaces Z of the annular-shaped end portions **44** of the respective annular-shaped elastic sealing members **40** are in pressure contact with the piston outer circumferential surface B, the clearance C defined by the piston outer circumferential surface B and the electrode inner circumferential surfaces **31** is sealed at both sides relative to the piston ring groove A1. Then, the electrolyte solution is circulated so as to be flowed from the supply flow passage **37** into the space which is formed between the piston outer circumferential surface B and the electrode inner circumferential surfaces **31** and is sealed with each of the annular-shaped elastic sealing members **40**, and so as to be discharged from the discharge flow passage **38** while the anodizing treatment is applied to the piston ring groove A1.

[0065] After the anodizing treatment to the piston ring groove A1 is completed, the supply/discharge control portion **53** actuates the air supply/discharge apparatus **52** so that the compressed air is forcibly discharged from the first accommodation portion **41***a* and the second accommodation portion **41***b* through the air supply/discharge passages **54** and the air supply/discharge pipe **55**, in other words, so that the pressure contact of the annular-shaped elastic sealing members **40** with the piston outer circumferential surface B is released.

[0066] As an air pressure decreases in association with the discharge of the compressed air from the first accommodation portion **41***a* and the second accommodation portion **41***b*, each of the annular-shaped elastic sealing members **40** is deformed in a diameter expansion direction, that is, in a direction in which the diameter of the annular-shaped elastic sealing member **40** increases, to return to the original shape. Accordingly, as illustrated in FIG. **5**, each of the annular-shaped elastic sealing members **40** retracts towards a back side of the corresponding accommodation portion **41**, that is, deep within the corresponding accommodation portion **41**, so that the annular-shaped end portions **44** do not protrude from the electrode inner circumferential surfaces **31**.

[0067] FIG. **11** shows a graph representing relationship between "the number of notches" and a size of a wrinkle portion D. The number of notches is the number of the cutouts **46** formed at each of the pair of annular-shaped side wall portions **43** of the annular-shaped elastic sealing member **40** so as to be arranged in the circumferential direction with the uniform interval provided between the neighboring cutouts **46**. Each of the cutouts **46** is formed to include the notch configuration. The wrinkle portion D is formed in a case where the pressure contact surface Z of the annular-shaped elastic sealing member **40** is brought in pressure contact with the piston outer circumferential surface B as illustrated in FIG. **13**. The size of the wrinkle portion D is defined as "an amount of twist" which corresponds to a length E of a part of the wrinkle portion D, the part which is spaced apart from the piston outer circumferential surface B (that is, a wavy part formed at the annular-shaped elastic sealing member **40**) as illustrated in FIG. **13**.

[0068] FIG. **12** illustrates a graph representing relationship between "the number of notches" and the number of the wrinkle portions D. The number of notches is the number of the cutouts **46** formed at each of the pair of annular-shaped side wall portions **43** of the annular-shaped elastic sealing member **40** so as to be arranged in the circumferential direction with the uniform interval provided between the neighboring cutouts **46**. Each of the cutouts **46** is formed to include the notch configuration. The wrinkle portion D is formed in the case where the pressure contact surface Z of the annular-shaped elastic sealing member **40** is brought in pressure contact with the piston outer circumferential surface B as illustrated in FIG. **13**. The number of the wrinkle portions D is defined as "the number of twists" which corresponds to the number of the parts of the wrinkle portions D, the part which is spaced apart from the piston outer circumferential surface B as illustrated in FIG. **13**.

[0069] In FIGS. **11** and **12**, dots appearing on each of the graphs represent relationship among a case where the cutouts **46** are not formed at the annular-shaped elastic sealing member **40**, a case where the cutouts **46** are formed at two positions of the annular-shaped elastic sealing member **40** in total, and a case where the cutouts **46** are formed at four positions of the annular-shaped elastic sealing member **40** in total.

[0070] In FIGS. **11** and **12**, squares appearing on each of the graphs represent relationship among a case where the cutouts **46** are not formed at another annular-shaped elastic sealing member **40** (that is, a different annular-shaped elastic sealing member **40** from the annular-shaped elastic sealing member **40** whose results are represented by the above-described dots) a case where the cutouts **46** are formed at two positions of the annular-shaped elastic sealing member **40** in total, and a case where the cutouts **46** are formed at four positions of the annular-shaped elastic sealing member **40** in total.

[0071] It may be considered that the larger a curvature of the annular-shaped elastic sealing member **40** is, the greater the number of notches may be provided. In this embodiment, each of the annular-shaped elastic sealing members **40** includes an inner diameter of approximately 77 millimeter (mm) and an outer diameter of approximately 88 millimeter (mm).

[0072] A second embodiment disclosed here will be described hereunder with reference to the drawing. FIG. **14** illustrates another embodiment of the cutout **46** formed at each of the annular-shaped side wall portions **43** of the annular-shaped elastic sealing members **40**. In this embodiment, the pair of end surfaces **48**, which constitute each of the cutouts **46** formed in the notch configuration, are integrally connected to each other at a thin portion **49**. The thin portion **49** includes a fan shape formed along the circumferential direction of the annular-shaped elastic sealing member **40** and is provided at a side at which the pair of annular-shaped side wall portions **43** face each other across the recessed portion **42**.

[0073] According to this embodiment, the number and/or the size of the wrinkle portions, which are generated at the

annular-shaped elastic sealing members **40**, are restricted from increasing while the compressed air is reliably prevented from leaking from the recessed portions **42** to the cutouts **46** and the electrolyte solution is reliably prevented from leaking from the cutouts **46** to the recessed portions **42**. Other structures and configurations in the second embodiment are similar to those of the first embodiment.

[0074] Other embodiments will be described hereunder. 1. According to the partial surface treatment apparatus disclosed here, only one of the pair of annular-shaped side wall portions may be provided with "the cutout". 2. According to the partial surface treatment apparatus disclosed here, the number and/or the shape of "the cutout" formed at one of the pair of annular-shaped side wall portions may differ from the number and/or the shape of "the cutout" formed at the other of the pair of annular-shaped side wall portions. 3. According to the partial surface treatment apparatus disclosed here, "the cutout" formed at one of the pair of annular-shaped side wall portions and "the cutout" formed at the other of the pair of annular-shaped side wall portions may be arranged to be dislocated or offset from each other in the circumferential direction. 4. The partial surface treatment apparatus disclosed here may include "the cutout" which is formed in such a manner that the end surfaces formed by the cutout are closely in contact with each other. 5. According to the partial surface treatment apparatus disclosed here, the end portion of "the cutout", whose start portion corresponds to the outer circumferential side edge portion of the annular-shaped side wall portion, may be provided within a region of the annular-shaped end portion. In this case, the end portion of "the cutout" formed at one of the pair of annular-shaped side wall portions and the end portion of "the cutout" formed at the other of the pair of annular-shaped side wall portions may be connected to each other serially or continuously in the axial direction. 6. The partial surface treatment apparatus disclosed here may include a pressure applying mechanism configured to supply pressurized liquid such as operating fluid which serves as the pressurized fluid. 7. The partial surface treatment apparatus disclosed here is applicable to various types of partial surface treatment apparatuses, for example, treatment equipment for conducting a surface treatment such as an electroplating treatment.

[0075] According to the aforementioned embodiment, the partial surface treatment apparatus includes the first electrode member **15** electrically connected to the piston A made of metal, the piston A including the piston outer circumferential surface B and the piston ring groove A1 formed at the piston outer circumferential surface B, the second electrode member **17** including the electrode inner circumferential surface **31** facing the piston outer circumferential surface B and the piston ring groove A1, the electrode inner circumferential surface **31** being spaced apart from the piston outer circumferential surface B and the piston ring groove A1 along the entire circumference of the electrode inner circumferential surface **31**, the pair of annular-shaped elastic sealing members **40** each of which is nonconductive, the annular-shaped elastic sealing members **40** being configured to seal, at both sides relative to the piston ring groove A1, the clearance C formed between the piston outer circumferential surface B and the electrode inner circumferential surface **31**, the accommodation portion **41** accommodating each of the annular-shaped elastic sealing members **40** in such a manner that the annular-shaped elastic sealing member **40** is spaced apart from the piston outer circumferential surface B and that the annular-shaped elastic sealing member **40** is movable in the diameter reduction direction, the accommodation portion **41** including the groove side surfaces **45** arranged to face each other, the pressure applying mechanism **51** configured to supply the compressed air to the outer circumferential side of the annular-shaped elastic sealing members **40** fitted into the accommodation portions **41** in order to move the annular-shaped elastic sealing members **40** in the diameter reduction direction, the inner circumferential side of each of the annular-shaped elastic sealing members **40** being in pressure contact with the piston outer circumferential surface B in a case where the annular-shaped elastic sealing members **40** are moved in the diameter reduction direction, the pressure applying mechanism **51** configured to release the pressure contact between the annular-shaped elastic sealing members **40** and the piston outer circumferential surface B, the supply flow passage **37** through which the electrolyte solution is supplied to the space formed between the piston outer circumferential surface B and the electrode inner circumferential surface **31**, the space being sealed with the pair of annular-shaped elastic sealing members **40**, each of the annular-shaped elastic sealing members **40** being formed in the shape including the pair of annular-shaped side wall portions **43** and the annular-shaped end portion **44**, the pair of annular-shaped side wall portions **43** being configured to be in slidably contact with the corresponding groove side surfaces **45** of the accommodation portion **41** while the pair of annular-shaped side wall portions **43** being apart from each other in the groove width direction, the annular-shaped end portion **44** connecting the inner circumferential portions of the respective annular-shaped side wall portions **43** to each other serially, and the cutout **46** being formed at each of the annular-shaped elastic sealing members **40** to be extended from the outer circumferential side edge portion **81** of the annular-shaped elastic sealing member **40** towards the inner circumferential side of the annular-shaped elastic sealing member **40**, the cutout **46** being provided at at least one position which is along the circumferential direction of the annular-shaped elastic sealing member **40**.

[0076] According to the above described configuration, the cutout **46** is formed at at least one position which is along the circumferential direction of the annular-shaped elastic sealing member **40** to be extended from the outer circumferential side edge portion **81** of the annular-shaped elastic sealing member **40** towards the inner circumferential side of the annular-shaped elastic sealing member **40**. Accordingly, when the compressed air is supplied to the outer circumferential side of the annular-shaped elastic sealing member **40** in order to move the annular-shaped elastic sealing member **40** in the diameter reduction direction in which the inner circumferential side of the annular-shaped elastic sealing member **40** is brought into pressure contact with the piston outer circumferential surface B, the portions of the annular-shaped elastic sealing member **40** which face each other across the cutout **46** are deformed relative to each other so that the wrinkle is restricted from being formed at the annular-shaped elastic sealing member **40**. Accordingly, the wrinkle is not likely to be formed to the annular-shaped elastic sealing member **40** in a case where the clearance C formed between the piston outer circumferential surface B of the piston A and the electrode inner circumferential surface **31** of the second electrode member **17** is sealed.

[0077] Consequently, according to the partial surface treatment apparatus of the aforementioned embodiments, the

electrolyte solution does not tend to leak out even in a case where the moving speed of the annular-shaped elastic sealing member **40** in the diameter reduction direction is increased. Thus, efficiency in performing the surface treatment to the piston ring groove A1 is easily enhanced and the electrolyte solution is prevented from being mixed with the compressed air. As a result, inconvenience including damage to the pressure applying mechanism **51** is not likely to occur.

[0078] According to the aforementioned embodiment, the cutout **46** includes the start portion and the end portion **47**, and the start portion corresponds to the outer circumferential side edge portion **81** of the annular-shaped elastic sealing member **40** and the end portion **47** is provided within the region of the annular-shaped side wall portions **43**.

[0079] According to the above described configuration, the cutout **46** is formed in a manner that the cutout **46** does not come into or does not enter the annular-shaped end portion **44**. Consequently, the annular-shaped end portion **44** is prevented from being excessively deformed in association with the decrease of the diameter of the annular-shaped elastic sealing member **40**. As a result, a sealing performance of the annular-shaped elastic sealing member **40** is maintained easily for a long period of time. Furthermore, when compared to a case where the end portion **47** of the cutout **46** is provided at the annular-shaped end portion **44**, strength of the annular-shaped end portion **44** is maintained more easily for a longer period of time.

[0080] According to the aforementioned embodiment, the cutout **46** includes the start portion corresponding to the outer circumferential side edge portion **81** of the annular-shaped elastic sealing member **40** and the end portion **47**, and the cutout **46** includes the pair of end surfaces **48** which intersect each other at the acute angle at the end portion **47** and are continuous with each other smoothly in a manner that the distance between the pair of end surfaces **48** increases towards the start portion.

[0081] According to the above described configuration, the end surfaces **48**, which face or oppose each other with the cutout **46** interposed therebetween, are prevented from coming into a close contact with each other when the annular-shaped elastic sealing member **40** moves in the diameter reduction direction, and thus the occurrence of the wrinkle is avoided. Furthermore, because the opposing end surfaces **48** are brought into close contact with each other gradually from a side of the end portion **47**, the electrolyte solution is prevented from leaking out from the cutout **46**.

[0082] According to the aforementioned embodiment, the cutout **46** is formed at each of the pair of annular-shaped side wall portions **43**.

[0083] According to the above described configuration, in association with the movement of the annular-shaped elastic sealing member **40** in the diameter reduction direction, a posture of the annular-shaped end portion **44** in a seal width direction is maintained constant more easily compared to a case where the cutout **46** is formed at only one of the pair of annular-shaped side wall portions **43**. Accordingly, a press-contact force relative to the outer circumferential surface of the annular-shaped end portions **44** is distributed in the seal width direction, and thus the clearance C is easily sealed in a stabled manner.

[0084] According to the aforementioned embodiment, the partial surface treatment apparatus includes the first electrode member **15** electrically connected to the piston A made of metal, the piston A including the piston outer circumferential surface B and the piston ring groove A1 formed at the piston outer circumferential surface B, the second electrode member **17** including the electrode inner circumferential surface **31** facing the piston outer circumferential surface B and the piston ring groove A1, the electrode inner circumferential surface **31** being spaced apart from the piston outer circumferential surface B and the piston ring groove A1 along the entire circumference of the electrode inner circumferential surface **31**, the pair of annular-shaped elastic sealing members **40** each of which is nonconductive, the annular-shaped elastic sealing members **40** being configured to seal, at both sides relative to the piston ring groove A1, the clearance C formed between the piston outer circumferential surface B and the electrode inner circumferential surface **31**, the accommodation portion **41** accommodating each of the annular-shaped elastic sealing members **40** in such a manner that the annular-shaped elastic sealing member **40** is spaced apart from the piston outer circumferential surface B and that the annular-shaped elastic sealing member **40** is movable in the diameter reduction direction, the accommodation portion **41** including the groove side surfaces **45** arranged to face each other, the pressure applying mechanism **51** configured to supply the compressed air to the outer circumferential side of the annular-shaped elastic sealing members **40** fitted into the accommodation portions **41** in order to move the annular-shaped elastic sealing members **40** in the diameter reduction direction, the inner circumferential side of each of the annular-shaped elastic sealing members **40** being in pressure contact with the piston outer circumferential surface B in a case where the annular-shaped elastic sealing members **40** are moved in the diameter reduction direction, the pressure applying mechanism **51** configured to release the pressure contact between the annular-shaped elastic sealing members **40** and the piston outer circumferential surface B, the supply flow passage **37** through which the electrolyte solution is supplied to the space formed between the piston outer circumferential surface B and the electrode inner circumferential surface **31**, the space being sealed with the pair of annular-shaped elastic sealing members **40**, each of the annular-shaped elastic sealing members **40** including the pair of annular-shaped side wall portions **43**, the annular-shaped end portion **44** and the plural cutouts **46**, the pair of annular-shaped side wall portions **43** being configured to be in slidably contact with the corresponding groove side surfaces of the accommodation portion **41**, the pair of annular-shaped side wall portions **43** being apart from each other in the groove width direction, the annular-shaped end portion **44** connecting the inner circumferential portions of the respective annular-shaped side wall portions **43** to each other serially, the plurality of cutouts **46** being formed along the circumferential direction of the annular-shaped elastic sealing member **40** while the uniform space is provided therebetween, each of the cutouts **46** being extended from the outer circumferential edge of the annular-shaped elastic sealing member **40** towards the radially inner side of the annular-shaped elastic sealing member **40**.

[0085] According to the above described configuration, the plural cutouts **46** are formed along the circumferential direction of the annular-shaped elastic sealing member **40** in a manner that the uniform space is provided between the neighboring cutouts **46** in the circumferential direction. Accordingly, when the compressed air is supplied to the outer circumferential side of the annular-shaped elastic sealing member **40** in order to move the annular-shaped elastic seal-

ing member **40** in the diameter reduction direction in which the inner circumferential side of the annular-shaped elastic sealing member **40** is brought into pressure contact with the piston outer circumferential surface B, the portions of the annular-shaped elastic sealing member **40** which face each other across the cutout **46** are deformed relative to each other so that the wrinkle is restricted from being formed at the annular-shaped elastic sealing member **40**. Accordingly, the wrinkle is not likely to be formed to the annular-shaped elastic sealing member **40** in a case where the clearance C formed between the piston outer circumferential surface B of the piston A and the electrode inner circumferential surface **31** of the second electrode member **17** is sealed.

[0086] Consequently, according to the partial surface treatment apparatus of the embodiments, the electrolyte solution does not tend to leak out even in a case where the moving speed of the annular-shaped elastic sealing member **40** in the diameter reduction direction is increased. Thus, the efficiency in performing the surface treatment to the piston ring groove A1 is easily enhanced and the electrolyte solution is prevented from being mixed with the compressed air. As a result, the inconvenience including the damage to the pressure applying mechanism **51** is not likely to occur.

[0087] The principles, preferred embodiments and mode of operation of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the particular embodiments disclosed. Further, the embodiments described herein are to be regarded as illustrative rather than restrictive. Variations and changes may be made by others, and equivalents employed, without departing from the spirit of the present invention. Accordingly, it is expressly intended that all such variations, changes and equivalents which fall within the spirit and scope of the present invention as defined in the claims, be embraced thereby.

1. A partial surface treatment apparatus, comprising:

a first electrode member electrically connected to a treatment object made of metal, the treatment object including an outer circumferential surface and a circumferential groove formed at the outer circumferential surface;

a second electrode member including an inner circumferential surface facing the outer circumferential surface and the circumferential groove, the inner circumferential surface being spaced apart from the outer circumferential surface and the circumferential groove along an entire circumference of the inner circumferential surface;

a pair of annular-shaped elastic sealing members each of which is nonconductive, the annular-shaped elastic sealing members being configured to seal, at both sides relative to the circumferential groove, a clearance formed between the outer circumferential surface and the inner circumferential surface;

an accommodation portion accommodating each of the annular-shaped elastic sealing members in such a manner that the annular-shaped elastic sealing member is spaced apart from the outer circumferential surface and that the annular-shaped elastic sealing member is movable in a diameter reduction direction, the accommodation portion including groove side surfaces arranged to face each other;

a pressure applying mechanism configured to supply a pressurized fluid to an outer circumferential side of the annular-shaped elastic sealing members fitted into the accommodation portions in order to move the annular-shaped elastic sealing members in the diameter reduction direction, an inner circumferential side of each of the annular-shaped elastic sealing members being in pressure contact with the outer circumferential surface in a case where the annular-shaped elastic sealing members are moved in the diameter reduction direction, the pressure applying mechanism configured to release the pressure contact between the annular-shaped elastic sealing members and the outer circumferential surface;

a supply flow passage through which electrolyte solution is supplied to a space formed between the outer circumferential surface and the inner circumferential surface, the space being sealed with the pair of annular-shaped elastic sealing members;

each of the annular-shaped elastic sealing members being formed in a shape including a pair of annular-shaped side wall portions and an annular-shaped end portion, the pair of annular-shaped side wall portions being configured to be in slidably contact with the corresponding groove side surfaces of the accommodation portion while the pair of annular-shaped side wall portions being apart from each other in a groove width direction, the annular-shaped end portion connecting inner circumferential portions of the respective annular-shaped side wall portions to each other serially; and

a cutout being formed at each of the annular-shaped elastic sealing members to be extended from an outer circumferential side edge portion of the annular-shaped elastic sealing member towards the inner circumferential side of the annular-shaped elastic sealing member, the cutout being provided at at least one position which is along a circumferential direction of the annular-shaped elastic sealing member.

2. The partial surface treatment apparatus according to claim **1**, wherein

the cutout includes a start portion and an end portion, and

the start portion corresponds to the outer circumferential side edge portion of the annular-shaped elastic sealing member and the end portion is provided within a region of the annular-shaped side wall portions.

3. The partial surface treatment apparatus according to claim **1**, wherein

the cutout includes a start portion corresponding to the outer circumferential side edge portion of the annular-shaped elastic sealing member and an end portion, and

the cutout includes a pair of end surfaces which intersect each other at an acute angle at the end portion and are continuous with each other smoothly in a manner that a distance between the pair of end surfaces increases towards the start portion.

4. The partial surface treatment apparatus according to claim **1**, wherein the cutout is formed at each of the pair of annular-shaped side wall portions.

5. A partial surface treatment apparatus, comprising:

a first electrode member electrically connected to a treatment object made of metal, the treatment object including an outer circumferential surface and a circumferential groove formed at the outer circumferential surface;

a second electrode member including an inner circumferential surface facing the outer circumferential surface and the circumferential groove, the inner circumferential surface being spaced apart from the outer circumfer-

ential surface and the circumferential groove along an entire circumference of the inner circumferential surface;

a pair of annular-shaped elastic sealing members each of which is nonconductive, the annular-shaped elastic sealing members being configured to seal, at both sides relative to the circumferential groove, a clearance formed between the outer circumferential surface and the inner circumferential surface;

an accommodation portion accommodating each of the annular-shaped elastic sealing members in such a manner that the annular-shaped elastic sealing member is spaced apart from the outer circumferential surface and that the annular-shaped elastic sealing member is movable in a diameter reduction direction, the accommodation portion including groove side surfaces arranged to face each other;

a pressure applying mechanism configured to supply a pressurized fluid to an outer circumferential side of the annular-shaped elastic sealing members fitted into the accommodation portions in order to move the annular-shaped elastic sealing members in the diameter reduction direction, an inner circumferential side of each of the annular-shaped elastic sealing members being in pressure contact with the outer circumferential surface in a case where the annular-shaped elastic sealing members are moved in the diameter reduction direction, the pressure applying mechanism configured to release the pressure contact between the annular-shaped elastic sealing members and the outer circumferential surface;

a supply flow passage through which electrolyte solution is supplied to a space formed between the outer circumferential surface and the inner circumferential surface, the space being sealed with the pair of annular-shaped elastic sealing members; and

each of the annular-shaped elastic sealing members including a pair of annular-shaped side wall portions, an annular-shaped end portion and a plurality of cutouts, the pair of annular-shaped side wall portions being configured to be in slidably contact with the corresponding groove side surfaces of the accommodation portion, the pair of annular-shaped side wall portions being apart from each other in a groove width direction, the annular-shaped end portion connecting inner circumferential portions of the respective annular-shaped side wall portions to each other serially, the plurality of cutouts being formed along a circumferential direction of the annular-shaped elastic sealing member while a uniform space is provided therebetween, each of the cutouts being extended from an outer circumferential edge of the annular-shaped elastic sealing member towards a radially inner side of the annular-shaped elastic sealing member.

6. The partial surface treatment apparatus according to claim **5**, wherein

each of the cutouts includes a start portion and an end portion, and

the start portion corresponds to the outer circumferential side edge portion of the annular-shaped elastic sealing member and the end portion is provided within a region of the annular-shaped side wall portions.

7. The partial surface treatment apparatus according to claim **5**, wherein

each of the cutouts includes a start portion corresponding to the outer circumferential side edge portion of the annular-shaped elastic sealing member and an end portion, and

each of the cutouts includes a pair of end surfaces which intersect each other at an acute angle at the end portion and are continuous with each other smoothly in a manner that a distance between the pair of end surfaces increases towards the start portion.

8. The partial surface treatment apparatus according to claim **5**, wherein the cutouts are formed at each of the pair of annular-shaped side wall portions.

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