

DESCRIPTION

TITLE OF INVENTION

5 **POLISHING DEVICE, POLISHING METHOD, AND MACHINE
 COMPONENT**

TECHNICAL FIELD

[0001]

10 An embodiment of the present disclosure relates to a polishing
 device, a polishing method, and a machine component.

BACKGROUND ART

[0002]

15 In a manufacturing process of various electronic components such
 as a semiconductor device and a display panel for a display device, the
 process is performed in a vacuum. In such a vacuum process, a vacuum
 vessel is used, and a groove is provided on one or both of the contacting
 parts where the parts of the vacuum vessel come into contact with each
20 other, and a sealing member such as an O-ring is installed in the grooves
 in order to ensure the inside of the vessel is sealed. Patent Literature 1
 discloses a cutting method for cutting a workpiece using a spring-necked
 cutting tool.

25 **CITATION LIST**

PATENT LITERATURE

[0003]

 Patent Literature 1: Japanese laid-open patent publication No. H06-

126520.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

5 [0004]

A groove arranged in the sealing part is usually formed by cutting a sealing surface using a rotary cutting tool such as an end mill. After a desired shape of the groove has been cut, slight unevenness or cutting debris may remain on the sealing surface, and polishing is necessary to
10 remove them. Although the polishing of the sealing surface is often performed manually by a worker, it takes a long time to complete the polishing process, and there is a problem that the quality of the sealing surface is not stabilized due to a difference in a surface roughness of the polishing surface depending on the experience and skill of the worker.

15 [0005]

In view of the above problem, an object of an embodiment of the present disclosure is to provide a polishing device and a polishing method capable of reducing the time required for polishing and stabilizing the quality of the sealing surface.

20 [0006]

In addition, an object of an embodiment of the present disclosure is to provide a machine component having a sealing surface with stabilized quality.

25 **SOLUTION TO PROBLEM**

[0007]

A polishing device according to an embodiment of the present disclosure includes a supporting unit supporting a polishing tool, a stage

holding an object to be polished, a first drive unit moving the supporting unit and the stage relative to each other along a shape of a polished surface, and a second drive unit synchronized with the first drive unit and rotating the supporting unit so that one end of a polishing member attached to the polishing tool faces in a movement direction.

[0008]

A polishing method according to an embodiment of the present disclosure is a polishing method for a polishing surface on a hard anodized aluminum, the polishing method including a first step of polishing the polishing surface with a first polishing member at a first pressing strength, and a second step of polishing the polishing surface with a second polishing member at a second pressing strength after the first step, wherein the first pressing strength is lower than the second pressing strength.

[0009]

A machine component according to an embodiment of the present disclosure includes a hard anodized aluminum surface, and a polishing surface on a part of the hard anodized aluminum surface, wherein a waviness of the polishing surface is 0.2 μ m or less and a surface roughness of the polishing surface is 0.4 μ m or less.

ADVANTAGEOUS EFFECTS OF INVENTION

[0010]

According to an embodiment of the present disclosure, by automating a polishing process with a machine, the time required for polishing can be reduced and the quality of a sealing surface can be stabilized.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

FIG. 1 is a diagram for explaining an example of a configuration of a polishing device according to an embodiment of the present disclosure.

FIG. 2 is a functional block diagram of a polishing device according to an embodiment.

FIG. 3 is a schematic view showing an example of a polishing tool used in a polishing device according to an embodiment.

FIG. 4 is a schematic view showing an example of a polishing tool used in a polishing device according to an embodiment.

FIG. 5 is a schematic view showing an example of a polishing tool used in a polishing device according to an embodiment.

FIG. 6 is a schematic exploded view of a jig of a polishing tool used in a polishing device according to an embodiment.

FIG. 7 is a plan view of an example of an object to be polished viewed from above.

FIG. 8 is a schematic view for explaining a moving route of a second polishing member when polishing a non-circular polishing surface of an object to be polished.

DESCRIPTION OF EMBODIMENTS

[0012]

Hereinafter, embodiments of the present disclosure will be described with reference to the drawings and the like. However, the present invention can be implemented in many different aspects, and should not be construed as being limited to the description of the embodiments exemplified below. In order to make the description clearer, the drawings may be schematically represented with respect to the width, thickness, shape, and the like of each part as compared with the actual embodiment,

but the drawings are merely examples, and do not limit the interpretation of the present disclosure.

[0013]

In the drawings, the widths, thicknesses, shapes, and the like of the
5 respective portions may be schematically represented in comparison with
the actual embodiments for clarity of explanation, but the drawings are
merely examples, and do not limit the interpretation of the present invention.
Furthermore, in the present specification and the drawings, elements
having the same functions as those described with respect to the above-
10 described drawings are denoted by the same reference signs, and
redundant descriptions thereof may be omitted. Furthermore, in the
present specification and the drawings, the same or similar parts are
denoted by the same reference signs or similar reference signs (reference
signs denoted by A, B, and the like after numerals) and repeated description
15 thereof may be omitted.

[0014]

In the present specification, in the case where a member or region
is “above (or below)” another member or region, it includes the case where
it is directly above (or below) the other member or region, but also the case
20 where it is above (or below) the other member or region, that is, the case
where another component is included between above (or below) the other
member or region.

[0015]

Furthermore, in the present specification, the expressions “ α
25 includes A, B or C,” “ α includes any of A, B and C,” and “ α includes one
selected from a group consisting of A, B, and C” do not exclude the case
where α includes a plurality of combinations of A to C unless otherwise
specified. Furthermore, these expressions do not exclude the case where

α includes other elements.

[0016]

Hereinafter, a polishing device 10 according to an embodiment of the present disclosure will be described with reference to the drawings.

5 [0017]

FIG. 1 is a diagram for explaining an example of a configuration of the polishing device 10 according to an embodiment of the present disclosure. As shown in FIG. 1, the polishing device 10 includes a supporting unit 101, a stage 103, a first drive unit 105, and a second drive unit 107.

[0018]

The supporting unit 101 supports a polishing tool 201. The polishing tool 201 will be described later. The supporting unit 101 is attached to the first drive unit 105.

15 [0019]

The stage 103 holds an object to be polished 203. The object to be polished 203 is part of a machine component. The object to be polished 203 is not particularly limited, but may be, for example, a part constituting vacuum equipment used in a vacuum device. In this case, the object to be polished 203 includes a sealing surface of a vacuum vessel. For example, the sealing surface may be subjected to hard anodizing. The polishing tool 201 can polish a hard anodized coating of the object to be polished 203. In the present embodiment, a coating formed on the object to be polished 203 is not limited to hard anodized aluminum. For example, the hardness of a surface of the object to be polished 203 is about Hv 350 to 450.

[0020]

The first drive unit 105 relatively moves the supporting unit 101 and the stage 103 along a shape of a polishing surface of the object to be

polished 203. In other words, the first drive unit 105 includes a mechanism for moving the position of one or both of the supporting unit 101 and the stage 103 such that the polishing tool 201 is movable along the shape of the polishing surface. The first drive unit 105 includes a first moving unit 109, a first guide 111, a second guide 113, a second moving unit 115, and a third guide 117.

[0021]

The first moving unit 109 moves the supporting unit 101 along a direction z. The first guide 111 is arranged on a body 119 of the polishing device 10 so as to extend in the direction z. The first guide 111 guides a movement of the first moving unit 109 in the direction z. For example, the first guide 111 may be a rail extending in the direction z, and the first moving unit 109 may slide along the first guide 111 in the direction z. The first moving unit 109 and the first guide 111 constitute a first moving mechanism 112 that moves the supporting unit 101.

[0022]

The second guide 113 guides a movement of the stage 103 in the direction x. The second guide 113 may be a rectangular plate having a pair of sides along the direction x and a pair of sides along a direction y. The stage 103 is slidably supported in the direction x by the second guide 113. For example, the stage 103 may be arranged so as to sandwich an edge of the pair of sides along the direction x of the second guide 113, and may slide along the edge of the pair of sides along the direction x of the second guide 113.

[0023]

The second moving unit 115 moves the second guide 113 that supports the stage 103 along the direction y. The third guide 117 is arranged on the body 119 of the polishing device 10 so as to extend in the

direction y. The third guide 117 guides a movement of the second guide 113 in the direction y. For example, the third guide 117 may be a rail extending in the direction y, and the second guide 113 may slide in the direction y along the third guide 117.

5 [0024]

The second guide 113, the second moving unit 115, and the third guide 117 may constitute a second moving mechanism 118 that moves the stage 103.

[0025]

10 Although an example of the configuration of the first drive unit 105 has been described, in the present embodiment, the configuration of the first drive unit 105 is not limited to the above. For example, the first drive unit 105 may further include a moving mechanism for moving the supporting unit 101 in the direction x and/or the direction y. In addition, the first drive
15 unit 105 may further include a moving mechanism for moving the stage 103 in the direction z.

[0026]

The second drive unit 107 rotates the supporting unit 101 that supports the polishing tool 201. In addition, the second drive unit 107 may
20 rotate the supporting unit 101 in synchronization with the first drive unit 105 such that one end of the polishing member attached to the polishing tool 201 constantly faces in the movement direction of the polishing tool 201 along the polishing surface of the object to be polished 203.

[0027]

25 Although not shown, the polishing device 10 includes a plurality of motors. These motors cause the first drive unit 105 and the second drive unit 107 to move and rotate the supporting unit 101 and the stage 103.

[0028]

FIG. 2 is an example of a functional block diagram of the polishing device 10. As shown in FIG. 2, the polishing device 10 includes an input operation unit 121 and a controller 122.

[0029]

5 The input operation unit 121 is a device such as an operation panel, an operation button, and a touch panel, and outputs a signal corresponding to the input operation to the controller 122. A worker engaged in the polishing operation may control an operation of the first drive unit 105 and the second drive unit 107 of the polishing device 10 via the input operation
10 unit 121. For example, the worker can set or change the start and stop of the polishing process performed by the polishing device 10, the rotating speed of the supporting unit 101, the moving speed and the movement direction to the supporting unit 101 and the stage 103 via the input operation unit 121.

15 [0030]

 The controller 122 includes a calculation processing circuit, such as a CPU, and a storage. The controller 122 executes a control program stored in the storage by the CPU to control the operations of the first drive unit 105 and the second drive unit 107, and realizes a polishing function by
20 the polishing device 10.

[0031]

 FIG. 3, FIG. 4, and FIG. 5 are schematic views showing an example of the polishing tool 201 supported by the supporting unit 101 of the polishing device 10 according to the present embodiment.

25 [0032]

 The polishing process of the object to be polished 203 performed by the polishing device 10 according to the present embodiment includes a first step of polishing the polishing surface with a first polishing member at

a first pressing strength, and a second step of polishing the polishing surface with a second polishing member at a second pressing strength after the first step. The first polishing member and the second polishing member are made of different materials. In addition, the first pressing strength and the second pressing strength are different from each other. In this case, the pressing strength means a load applied to a polishing jig when the polishing member contacts a surface to be polished of the object to be polished 203 in the polishing process.

[0033]

FIG. 3 is a schematic view showing an example of a polishing tool 201A used in the first step in the polishing process. The polishing tool 201A includes a jig 303 and a first polishing member 305A attached to the jig 303 via a polishing member holding unit 307. For example, the first polishing member 305A may be a brush made of ceramic fiber, nylon, or the like. In other words, the first step in the polishing process is a polishing process using a brush.

[0034]

FIG. 6 is an example of a schematic exploded view of the jig 303. As shown in FIG. 3 and FIG. 6, the jig 303 includes the polishing member holding unit 307, a fixture 309, a holder 311, and a cover 313.

[0035]

The fixture 309 is fixed to the supporting unit 101 of the polishing device 10. The holder 311 is joined to the fixture 309. A hollow storage area 312 is arranged inside the holder 311, and a coil spring 315 is inserted into the storage area 312. A spring constant of the coil spring 315 of the polishing tool 201A used in the first step is 1N/mm or more and 5N/mm or less. A float mechanism is formed by a coil spring 305 inserted into the jig 303.

[0036]

The polishing member holding unit 307 is inserted into and fixed to the storage area 312 of the fixture 309. The polishing member holding unit 307 is inserted into the storage area 312 so as to compress the coil spring 315 via a washer 316. At this time, the polishing member holding unit 307 compresses the coil spring 315 so that it is not completely adhered. The polishing holding member holding unit 307 is provided with a hollow 308. The first polishing member 305A is removably attached to the hollow 308.

[0037]

A pair of openings 317 is arranged in the holder 311. A steel ball 319 is inserted into each opening 317. The cover 313 is arranged on the opening 317 so as to close the opening 317 in which the steel ball 319 is inserted, and is fixed by two snap rings 321 so that the cover 313 is not displaced.

[0038]

FIG. 4 is a schematic view showing an example of a polishing tool 201B used in the second step of the polishing process. The polishing tool 201B has substantially the same configuration as the polishing tool 201A shown in FIG. 3 and FIG. 6, except that the material of a second polishing member 305B attached to the jig 303 is different from the material of the first polishing member 305A, and the coil spring 315 inside the jig 303 has a different spring constant than the coil spring 315 inserted inside the jig 303 of the polishing tool 201A shown in FIG. 3 and FIG. 6.

[0039]

In the polishing tool 201B shown in FIG. 4, for example, the second polishing member 305B is a sponge polishing agent coated with abrasive grains such as aluminum oxide, titanium oxide, or zircon. In other words, the second step in the polishing process is a polishing process using a

sponge. For example, the polishing member 305 may be cylindrical.

[0040]

A spring constant of the coil spring 315 inserted into the jig 303 of the polishing tool 201B is different from the spring constant of the coil spring 315 inserted into the jig 303 of the polishing tool 201A used in the first step. The spring constant of the coil spring 315 inserted into the jig 303 of the polishing tool 201B is greater than 1N/mm and 10N/mm or less. The spring constant of the coil spring 315 inserted into the jig 303 of the polishing tool 201B is greater than the spring constant of the coil spring 315 inserted into the jig 303 of the polishing tool 201A.

[0041]

A worker engaged in the polishing process performed by the polishing device 10 may remove the polishing tool 201A from the supporting unit 101 of the polishing device 10 and attach the polishing tool 201B to the supporting unit 101 after the first step using the polishing tool 201A is completed. In addition, the worker may disassemble the jig 303 of the polishing tool 201A, take out the coil spring 315 with a spring constant of 1N/mm or more and 5N/mm or less from the polishing tool 201A used in the first step, and replace it with the coil spring 315 with a spring constant greater than 1N/mm and 10N/mm or less used in the second step, thereby producing the polishing tool 201B. In this case, the worker may replace the coil spring 315 of the jig 303, remove the first polishing member 305A attached to the polishing tool 201A, and removably attach the second polishing member 305B.

[0042]

FIG. 5 is a schematic view showing another example of a polishing tool 201C used in the second step of the polishing process. A second polishing member 305C attached to the jig 303 of the polishing tool 201C is

another example of a second polishing member that is different from the second polishing member 305B shown in FIG. 4. The polishing tool 201C has substantially the same configuration as the polishing tool 201B shown in FIG. 4, except that a shape of the second polishing member 305C
5 attached to the jig 303 is different from a shape of the second polishing member 305B.

[0043]

A material of the second polishing member 305C of the polishing tool 201C is the same as the material of the second polishing member 305B of
10 the polishing tool 201B. On the other hand, the shape of the second polishing member 305C may be different from that of the second polishing member 305B, for example, hemispherical.

[0044]

The worker engaged in the polishing process performed by the
15 polishing device 10 may remove the polishing tool 201A from the supporting unit 101 of the polishing device 10 and attach the polishing tool 201C to the supporting unit 101 after the first step using the polishing tool 201A is completed. In addition, the worker may disassemble the jig 303 of the polishing tool 201A, take out the coil spring 315 with a spring constant of
20 1N/mm or more and 5N/mm or less from the polishing tool 201A used in the first step, replace the coil spring 315 with a spring constant greater than 1N/mm and 10N/mm or less used in the second step, and removably attach the second polishing member 305C by removing the first polishing member 305A attached to the polishing tool 201A, thereby producing the polishing
25 tool 201C.

[0045]

The polishing tool 201B shown in FIG. 4 and the polishing tool 201C shown in FIG. 5 can be used in the second step of the polishing process

performed by the polishing device 10. The polishing tool 201B shown in FIG. 4 is preferably used in the case where the polishing surface of the object to be polished 203 is circular. On the other hand, the polishing tool 201C is preferably used in the case where the polishing surface of the object to be polished 203 is non-circular.

[0046]

FIG. 7 is a plan view of an example of the object to be polished 203 viewed from above. For example, the object to be polished 203 is a part constituting the vacuum vessel, and is formed of an aluminum alloy, stainless steel, or the like. The object to be polished 203 has a sealing surface 701. The sealing surface 701 is subjected to hard anodizing, and a thickness of the hard anodized coating may be about 30 μ m to about 100 μ m. The sealing surface 701 includes a plurality of polishing surfaces. In this case, the polishing surface means a surface on the sealing surface 701, that is polished by the polishing tool 201. The polishing surface includes circular polishing surfaces 703a to 703j and non-circular polishing surfaces 705a to 705c.

[0047]

When the circular polishing surfaces 703a to 703j are polished, the polishing tool 201B shown in FIG. 4 is preferably used in the second step. In the second step, the second drive unit 107 of the polishing device 10 rotates the supporting unit 101 supporting the polishing tool 201B at a predetermined rotating speed. In other words, the second polishing member 305B of the polishing tool 201B polishes the circular polishing surfaces 703a to 703j while rotating at a predetermined rotating speed.

[0048]

When polishing the non-circular polishing surfaces 705a to 705c, the polishing tool 201C shown in FIG. 5 is preferably used in the second step.

The second drive unit 107 of the polishing device 10 rotates the supporting unit 101 along the shapes of the polishing surfaces 705a to 705c such that a predetermined end of the second polishing member 305C attached to the polishing tool 201C constantly faces in the direction in which the polishing tool 201C moves. For example, the predetermined end of the second polishing member 305C is part of an outer surface (spherical crown) of the hemispherical second polishing member 305C.

[0049]

FIG. 8 is a schematic view for explaining a moving route of the second polishing member 305C attached to the polishing tool 201C when polishing the non-circular polishing surface. In FIG. 8, the non-circular polishing surface 705b shown in FIG. 7 is shown as the non-circular polishing surface. Furthermore, in FIG. 8, the movement direction of the polishing tool 201C is indicated by a dashed arrow. As shown in FIG. 8, in the second step, the second drive unit 107 rotates the supporting unit 101 such that a predetermined end 801a of the second polishing member 305C constantly faces in the movement direction of the polishing tool 201C along a shape of the polishing surface 705b.

[0050]

A surface roughness of the polishing surface of the object to be polished 203, after the polishing process including the first and second steps performed by the polishing device 10, preferably has a waviness of 0.2 μ m or less, a standard deviation of the waviness of 0.2 μ m or less, a surface roughness of 0.4 μ m or less, and a standard deviation of the surface roughness of 0.3 μ m or less. The surface roughness of the polishing surface of the object to be polished 203 is more preferably 0.2 μ m or less. In this case, among the undulations at different intervals arranged on the polishing surface, the larger one is referred to as "waviness". A reference

length (cut-off value) defined in JIS B0633 can be used to separate the “waviness” from the “roughness” that is a smaller undulation.

[0051]

5 In the present embodiment, the polishing process performed by the polishing device 10 includes the first step of polishing the polishing surface with the first pressing strength by the first polishing member 305A, and the second step of polishing the polishing surface with the second pressing strength by the second polishing member 305B or the second polishing member 305C after the first step. Since the spring constant of the coil
10 spring 315 inserted into the jig 303 of the polishing tool 201A to which the first polishing member 305A is attached and the spring constant of the coil spring 315 inserted into the jig 303 of the polishing tools 201B or 201C to which the second polishing members 305B or 305C are attached are different from each other, the pressing strength applied to the polishing tool
15 201A and the polishing tools 201B or 201C can be changed between the first step which is the polishing process by a brush and the second step which is the polishing process by a sponge containing abrasive grains. Specifically, the second pressing strength can be greater than the first pressing strength.

20 [0052]

This makes it possible to automate the polishing process with a machine, reduce the time required for polishing, and stabilize the quality of the sealing surface. In addition, the waviness and the surface roughness of the polishing surface can be made smaller than the waviness and the
25 surface roughness of the polishing surface polished by the manual operation of the worker, and airtightness of the sealing surface can be improved.

[0053]

In addition, by rotating the supporting unit 101 by the second drive unit 107 so that a predetermined end of the second polishing member 305C constantly faces in the movement direction of the polishing tool 201C, the polishing process can be mechanically automated even when the polishing surface is non-circular.

[EXAMPLES]

[0054]

[Example 1]

[Polishing Device and Object to be Polished]

Aluminum alloy A6061 with dimensions: $\phi 360\text{mm} \times t40\text{mm}$ is prepared as the object to be polished, subjected to hard anodizing on the surface, and a hard anodized coating with a thickness of $80\mu\text{m}$ is formed. The aluminum alloy A6061 on which the hard anodized coating was formed on the surface was used as the object to be polished, and the surface on which the hard anodized coating was formed was polished by the polishing device according to the present embodiment. The polishing surface of the object to be polished was the same as the polishing surface of the object to be polished 203 shown in FIG. 7. A Robodrill manufactured by FANUC Corporation was used as the polishing device, and a float holder (FH-ST12-SL10) manufactured by XEBEC CO., LTD. was used as the jig of the polishing tool.

[0055]

[Polishing Tool]

In the first step of the polishing process performed by the polishing device, a polishing tool (hereinafter referred to as a first polishing tool) manufactured by inserting a coil spring (WL10-35, spring constant: 1N/mm) manufactured by MISUMI CO., LTD. into the inside of the jig and attaching a brush (A11-EB06M) manufactured by XBEC CO., LTD. with a brush length

adjusted to 12mm to the jig was used. In addition, when polishing the circular polishing surface in the second step of the polishing process performed by the polishing device, a polishing tool (hereinafter, referred to as second polishing tool A) manufactured by inserting a coil spring (WT10-35, spring constant: 2N/mm) manufactured by MISUMI CO., LTD. into the inside of the jig was used, a sponge polishing agent (Super Fine) manufactured by 3M Company was cut out in a cylindrical shape with the diameter of 21mm and the thickness of 5mm, and attached to the jig. In addition, when polishing the non-circular polishing surface in the second step of the polishing process performed by the polishing device, a polishing tool (hereinafter referred to as a second polishing tool B) manufactured by inserting a coil spring (WT10-35, spring constant: 2N/mm) manufactured by MISUMI CO., LTD. into the inside of the jig was used, the sponge polishing agent (Super Fine) manufactured by 3M Company was cut out with a width of 6mm and a length of 40 mm, the tip was processed to have a hemispherical shape with a diameter of 5mm, and attached to the jig.

[0056]

[Polishing Process of Circular Polishing Surface]

[First Step]

In the first step of the polishing process, for each of the 10 circular polishing surfaces of the object to be polished (see the polishing surfaces 703a to 703j shown in FIG. 7), the first polishing tool is moved from helical Z: 2.0mm to Z -1.0mm at a position in the radial 7.5mm with a rotating speed of 5000rpm and a feed speed of 2000mm/min, and each of the circular polishing surfaces was polished 5 times in a circular arc with the radial 7.5mm, shifted by 1.75mm, and then each of the circular polishing surfaces was polished 5 times in a spiral path. After that, for each of the 10 circular polishing surfaces of the object to be polished, the rotating speed of the

first polishing tool was changed to 8000rpm, moved from the helical Z 2.0 to Z -1.0 at a position in the radial 7.5mm with the feed speed of 2000mm/min, and each of the circular polishing surfaces was polished 5 times in a circular arc with the radial 7.5mm, shifted by 1.75mm, and then
5 each of the circular polishing surfaces was polished 5 times in the spiral path.

[0057]

[Second Step]

In the second step of the polishing process, for each of the 10
10 circular polishing surfaces of the object to be polished, the second polishing tool A is lowered to Helical Z: -3.0mm at the rotating speed of 30rpm of the second polishing tool A, and a stop polishing process was performed for 10 seconds, constituting one set, and two sets of this process was carried out.

[0058]

15 [Polishing Process of Non-Circular Polishing Surface]

[First Step]

In the first step of the polishing process, for each of the three non-circular polishing surfaces of the object to be polished (see the polishing surfaces 705a to 705c shown in FIG. 7), the rotating speed of 5000rpm and
20 the feed speed of 2000mm/min of the first polishing tool were set, the first polishing tool was lowered to the helical Z: -1.0mm, the polishing surface 705a and the polishing surface 705b were polished 10 times, and the polishing surface 705c was polished 5 times, constituting one set, and two sets of this process were carried out for each of the polishing surface 705a,
25 the polishing surface 705b, and the polishing surface 705c. After that, the rotating speed of the first polishing tool was changed to 8000rpm, the first polishing tool was lowered to the helical Z: -0.5mm, the polishing surface 705a and the polishing surface 705b were polished 20 times, respectively,

and the polishing surface 705c was polished 10 times, constituting one set, and two sets of this process were carried out for each of the polishing surface 705a, the polishing surface 705b, and the polishing surface 705c.

[0059]

5 [Second step]

In the second step of the polishing process, for each of the three non-circular polishing surfaces of the object to be polished (see the polishing surfaces 705a to 705c shown in FIG. 7), the feed speed was set to 2000/min of the second polishing tool B at the R portion, and the feed
10 speed was set to 4000/min at the linear portion, the second polishing tool B was lowered to the helical Z: -1.0mm, the polishing surface 705a and the polishing surface 705b were polished 20 times, respectively, and the polishing surface 705c was polished 10 times, constituting one set, and six sets were carried out.

15 [0060]

[Comparative Example 1]

As Comparative Example 1, the circular polishing surfaces 703a to 703j and the non-circular polishing surfaces 705a to 705c in the same object to be polished as the object to be polished used in Example 1 were manually
20 polished by the worker. The manual polishing process is as follows.

[0061]

First, the same object to be polished as in Example 1 was used as the object to be polished. Similar to Example 1, the polishing surface of the object to be polished was the same as the polishing surface of the object
25 to be polished 203 shown in FIG. 7. Next, a masking seal exposing the 10 circular polishing surfaces of the object to be polished (see the polishing surfaces 703a to 703j shown in FIG. 7) and the three non-circular polishing surfaces (see the polishing surfaces 705a to 705c shown in FIG. 7) was

adhered to the sealing surface 701 of the object to be polished. In addition, a reinforcement gabarit was adhered to the masking seal. After that, a Sulclut (manufactured by Kyodo Yushi) was applied to each of the polishing surfaces 703a to 703j and 705a to 705c, and then each of the polishing surfaces 703a to 703j and 705a to 705c was manually polished for 1.5 hours using a sponge polishing agent (Fine) manufactured by 3M Company. Next, each of the polishing surfaces 703a to 703j and 705a to 705c was manually polished for 1.5 hours using the sponge polishing agent (Super Fine) manufactured by 3M Company. After that, each of the polishing surfaces 703a to 703j and 705a to 705c was wiped with a clean wiper with NEI clean 2, and the masking seal was peeled off from the sealing surface 701.

[0062]

A surface roughness (Ra) of the polishing surface after carrying out the polishing process and working hours described in Example 1 are shown in the following Table 1. In addition, the surface roughness (Ra) of the polishing surface after carrying out the polishing process of Comparative Example 1 and working hours are shown in the following Table 2.

[Table 1]

	Polishing surface	
Surface roughness (Ra)	703a	0.250 μ m
	703b	0.215 μ m
	703c	0.219 μ m
	703d	0.230 μ m
	703e	0.222 μ m
	703f	0.220 μ m

	703g	0.199 μ m
	703h	0.184 μ m
	703i	0.211 μ m
	703j	0.180 μ m
	705a	0.131 μ m
	705b	0.209 μ m
	705c	0.233 μ m
Surface roughness (Ra) average	-	0.208 μ m
Surface roughness (Ra) standard deviation	-	0.030 μ m
Working hours	-	40minutes

[Table 2]

	Polishing surface	
Surface roughness (Ra)	703a	0.221 μ m
	703b	0.241 μ m
	703c	0.283 μ m
	703d	0.211 μ m
	703e	0.264 μ m
	703f	0.168 μ m
	703g	0.200 μ m
	703h	0.341 μ m
	703i	0.252 μ m

	703j	0.228 μ m
	705a	0.347 μ m
	705b	0.384 μ m
	705c	0.357 μ m
Surface roughness (Ra) average	-	0.269 μ m
Standard deviation of surface roughness (Ra)	-	0.068 μ m
Working hours	-	180 minutes

[0063]

Comparing Example 1 and Comparative Example 1, it can be seen that polishing by the polishing device according to the present embodiment can obtain a better result than or substantially the same result as polishing by a manual operation, while significantly reducing the time required for the polishing process than polishing by the manual operation. Furthermore, in Example 1, it can be seen that the difference in surface roughness depending on the polishing position is smaller than that in Comparative Example 1, and the quality of the sealing surface can be stabilized.

10 [0064]

[Example 2]

In the same object to be polished as the object to be polished used in Example 1, the circular polishing surfaces 703a, 703e, and 703j and the non-circular polishing surfaces 705a to 705c were polished by a polishing process substantially the same as in Example 1. However, unlike Example 1, defining the second step described in Example 1 above as one cycle using the second polishing tool A or the second polishing tool B, the sponge

was replaced after one cycle was complete, and the process was carried out for three cycles, respectively.

[0065]

Table 3 below shows the waviness and surface roughness of the circular polishing surfaces 703a, 703e, and 703j after the polishing process according to Example 2, and Table 4 shows the waviness and surface roughness of the non-circular polishing surfaces 705a to 705c after the polishing process according to Example 2. The cut-off value for separating the waviness and the surface roughness was set to 200 μ m.

10 [Table 3]

Polishing surface	Waviness (Wa[μ m])	Standard deviation of waviness (Wq[μ m])	Surface roughness (Arithmetic mean roughness) (Sa[μ m])	Standard deviation of surface roughness (Sq[μ m])
703a	0.062	0.079	0.193	0.262
703e	0.061	0.074	0.155	0.208
703j	0.071	0.083	0.115	0.150
Average	0.066	0.079	0.155	0.207

[Table 4]

Polishing surface	Waviness (Wa[μ m])	Standard deviation of waviness (Wq[μ m])	Surface roughness (Arithmetic mean roughness) (Sa[μ m])	Standard deviation of surface roughness (Sq[μ m])
705a	0.068	0.084	0.135	0.170

705b	0.149	0.182	0.112	0.156
705c	0.107	0.130	0.153	0.195
Average	0.108	0.132	0.133	0.173

[0066]

As shown in Table 3 and Table 4, by performing the polishing process by the polishing device according to the present embodiment, the waviness of the polishing surface in both the circular polishing surface and the non-circular polishing surface was 0.2 μ m or less, and the standard deviation of the waviness was 0.2 μ m or less. In addition, the surface roughness of the polishing surface was 0.2 μ m or less and the standard deviation of the surface roughness was 0.3 μ m or less in both the circular polishing surface and the non-circular polishing surface. In particular, the surface roughness of the polishing surface was 0.2 μ m or less in both the circular polishing surface and the non-circular polishing surface. Furthermore, the waviness was able to be reduced to 0.1 μ m or less in the circular polishing surface.

[0067]

15 [Comparative Example 2]

In Comparative Example 2, the circular polishing surfaces 703a, 703e, and 703j and the non-circular polishing surfaces 705a to 705c in the same object to be polished as the object to be polished used in Example 1 were manually polished by the worker. The polishing process was performed according to the following procedure.

[0068]

First, a masking seal exposing the circular polishing surfaces 703a, 703e, and 703j and the non-circular polishing surfaces 705a to 705c of the object to be polished was adhered to the sealing surface 701 of the object

to be polished. In addition, the reinforcement gabarit was adhered to the masking seal. After that, a Sulclut (manufactured by Kyodo Yushi) was applied to each of the polishing surfaces 703a, 703e, 703j and 705a to 705c, and then each of the polishing surfaces 703a, 703e, 703j and 705a to 705c was manually polished for 1.5 hours using the sponge polishing agent (Fine) manufactured by 3M Company. Next, each of the polishing surfaces 703a, 703e, 703j and 705a to 705c was manually polished for 1.5 hours using the sponge polishing agent (Super Fine) manufactured by 3M Company. After that, each of the polishing surfaces 703a, 703e, 703j and 705a to 705c was wiped with a clean wiper with NEI clean 2, and the masking seal was peeled off from the sealing surface 701.

[0069]

Table 5 below shows the waviness and surface roughness of the circular polishing surfaces 703a, 703e, and 703j after the manual polishing process described above, and Table 6 shows the waviness and surface roughness of the non-circular polishing surfaces 705a to 705c after the manual polishing process described above. The cut-off value for separating the waviness and the surface roughness was set to 200 μ m.

[Table 5]

Polishing surface	Waviness (Wa[μ m])	Standard deviation of waviness (Wq[μ m])	Surface roughness (Arithmetic mean roughness) (Sa[μ m])	Standard deviation of surface roughness (Sq[μ m])
703a	0.310	0.365	0.109	0.143
703e	0.100	0.124	0.224	0.288
703j	0.198	0.243	0.100	0.130

Average	0.203	0.244	0.145	0.187
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[Table 6]

Polishing surface	Waviness (Wa[μm])	Standard deviation of waviness (Wq[μm])	Surface roughness (Arithmetic mean roughness) (Sa[μm])	Standard deviation of surface roughness (Sq[μm])
705a	0.146	0.186	0.182	0.255
705b	0.100	0.122	0.126	0.175
705c	0.10	0.124	0.247	0.385
Average	0.116	0.144	0.185	0.272

[0070]

As shown in Table 5 and Table 6, in Comparative Example 2, the waviness of the polishing surface was larger in both the circular polishing surface and the non-circular polishing surface than in Example 2. In addition, the surface roughness of the non-circular polishing surface and the standard deviation of the surface roughness in Comparative Example 2 was larger than that in Example 2. Although the surface roughness of the circular polishing surface and the standard deviation of the surface roughness in Comparative Example 2 was slightly smaller than that of Example 2, the difference between the surface roughness and the standard deviation of the surface roughness for each polishing position was larger than the difference between the surface roughness and the standard deviation of the surface roughness for each polishing position of the circular polishing surface of Example 2.

[0071]

As described above, comparing Example 2 and Comparative

Example 2, it can be seen that polishing by the polishing device according to the present embodiment can obtain a better result or substantially the same result as polishing by manual operation.

[0072]

5 [Modification]

Although an example of the embodiment of the present disclosure has been described above, the embodiment of the present disclosure is not limited to the above-described embodiment. Hereinafter, a modification of the polishing process performed by the polishing device of the present
10 disclosure will be described.

[0073]

The polishing process of the first step using a brush as the polishing member may include a pre-process of performing roughing and a post-process of performing finishing. In this case, it is preferable that springs
15 with different spring constants are inserted into the jig of the polishing tool in the pre-process and the post-process, and the pressing strength applied to the polishing tool used in the pre-process and the pressing strength applied to the polishing tool used in the post-process are changed. More specifically, the pressing strength of the polishing tool used in the pre-
20 process is preferably greater than the pressing strength of the polishing tool used in the post-process. In other words, the spring constant of the spring inserted into the jig of the polishing tool used in the pre-process is preferably higher than the spring constant of the spring inserted into the jig of the polishing tool used in the post-process.

25 [0074]

Each of the embodiments described above as an embodiment of the present invention and the modification can be appropriately combined and implemented as long as no contradiction is caused. Furthermore, the

addition, deletion, or design change of components, or the addition, deletion, or condition change of processes as appropriate by those skilled in the art based on the configurations shown in the embodiment are also included in the scope of the present invention as long as they are provided
5 with the gist of the present invention.

[0075]

Furthermore, it is understood that, even if the effect is different from those provided by each of the above-described embodiments, the effect obvious from the description in the specification or easily predicted by
10 persons ordinarily skilled in the art is apparently derived from the present invention.

REFERENCE SIGNS LIST

[0076]

15 10: polishing device, 101: supporting unit, 103: stage, 105: first drive unit, 107: second drive unit, 109: first moving unit, 111: first guide, 112: first moving mechanism, 113: second guide, 115: second moving unit, 117: third guide, 118: second moving mechanism, 119: body, 121: input operation unit, 122: controller, 201: polishing tool, 203: object to be polished, 303: jig, 305
20 (305A to 305C): polishing member, 307: polishing member holding unit, 308: hollow, 309: fixture, 311: holder, 312: storage area, 313: cover, 315: coil spring, 317: opening, 319: steel ball, 321: snap ring, 701: sealing surface, 703a to 703j: circular polishing surface, 705a to 705c: non-circular polishing surface

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CLAIMS

1. A polishing device comprising:
 - a supporting unit supporting a polishing tool;
 - a stage holding an object to be polished;
 - 5 a first drive unit moving the supporting unit and the stage relative to each other along a shape of a polished surface; and
 - a second drive unit synchronized with the first drive unit and rotating the supporting unit so that one end of a polishing member attached to the polishing tool faces in a movement direction.
- 10 2. The polishing device according to claim 1, wherein the first drive unit moves the supporting unit and the stage relative to each other in a non-circular pattern along the shape of the polishing surface.
- 15 3. A polishing method for a polishing surface on a hard anodized aluminum, the polishing method comprising:
 - a first step of polishing the polishing surface with a first polishing member at a first pressing strength; and
 - a second step of polishing the polishing surface with a second
 - 20 polishing member at a second pressing strength after the first step,
 - wherein the first pressing strength is lower than the second pressing strength.
- 25 4. The polishing method for the polishing surface on the hard anodized aluminum according to claim 3, wherein the second step comprises:
 - pressing the second polishing member onto the polishing surface
 - and moving the second polishing member and the polishing surface relative to each other; and

rotating the second polishing member so that one end of the second polishing member faces in the movement direction.

5. The polishing method for the polishing surface on the hard anodized aluminum according to claim 3 or claim 4, wherein the first polishing member is a brush, and the second polishing member is a sponge.

6. The polishing method for the polishing surface on the hard anodized aluminum according to any one of claims 3 to 5, wherein
the first polishing member and the second polishing member are held by a jig, and
the first pressing strength and the second pressing strength are controlled by a spring constant of the jig.

7. A machine component comprising:
a hard anodized aluminum surface; and
a polishing surface on a part of the hard anodized aluminum surface, wherein a waviness of the polishing surface is $0.2\mu\text{m}$ or less and a surface roughness of the polishing surface is $0.4\mu\text{m}$ or less.

8. The machine component according to claim 7, wherein a standard deviation of the waviness of the polishing surface is $0.2\mu\text{m}$ or less, and a standard deviation of the surface roughness is $0.3\mu\text{m}$ or less.

9. The machine component according to claim 7 or claim 8, wherein the waviness of the polishing surface is $0.1\mu\text{m}$ or less.