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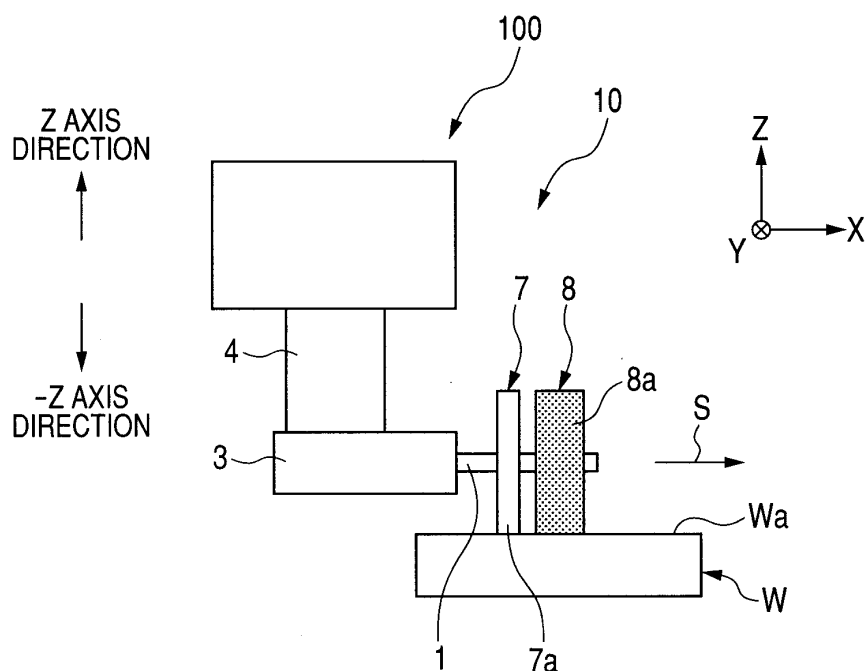
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(54) **Polishing method for a workpiece and polishing tool used for the polishing method**

(57) Provided is a polishing tool capable of forming a high-quality surface of a workpiece in a short period of time. The polishing tool (10) comprises a rotation shaft (1) arranged parallel to a feed direction (S) of the polishing tool relative to a workpiece (W) and at least two polishing bodies (7,8). The first polishing body (8) includes a foamed resin such as a foamed polyurethane resin, and has an outer peripheral surface (8a) having a porosity

higher than the porosity of the second polishing body (7). The second polishing body (7) comprises a non-foamed resin such as a non-foamed polyurethane resin being a material more rigid than the material used for the first polishing body (8). During polishing, the first polishing body (8) removes material from the surface (Wa) of the workpiece (W), and the second polishing body (7) smoothes an unevenness resulting from the material removal with the first polishing body (8).

FIG. 1



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a polishing method and a polishing tool used for polishing workpieces including an optical element such as a lens or a mirror, and a die for molding an optical element.

Description of the Related Art

[0002] Nowadays, in a case of finish-polishing a surface shape of a so-called non-axisymmetric free-form surface different in curvature at each point of a workpiece including an optical element such as a lens or a mirror, and a die for molding an optical element, the polishing-processing is performed with use of a polishing tool having a contact area smaller than an area of a surface of the workpiece. The polishing tool has a configuration having a disk-like polishing body provided onto a rotation shaft, and is mounted to a polishing apparatus. When the polishing-processing is performed by the polishing tool of this type, an outer peripheral surface of the polishing body is brought into press-contact with the surface of the workpiece at a constant pressure while the polishing body is rotated at a constant rpm, and then a sending speed in a forwarding direction is changed based on a standstill period of time calculated in accordance with a removal depth, to thereby partially remove the surface of the workpiece to an arbitrary depth while forming a straight groove. Then, the workpiece or the polishing tool is shifted by a sending pitch in a direction orthogonal to the sending direction, and portions to be removed in this way are partially overlapped to each other, whereby an entire surface of the workpiece is polishing-processed into an arbitrary shape. At this time, a polishing removal amount r is varied as shown in the following Preston's empirical formula.

$$r = P \times V \times K \times T$$

[0003] Note that, r represents a polishing removal amount, P represents a pressure, V represents a relative speed between the polishing tool and the surface of the workpiece, K represents a process variable (including a material and an outer peripheral surface state of the polishing tool), and T represents a standstill period of time. It is known that, when polishing removal is performed based on the above-mentioned formula, due to the pressure, the speed, and a distribution of a tool surface property in one-rotation cycle of the polishing tool, a waviness in the one-rotation cycle of the polishing tool is generated on the surface of the workpiece and thus quality of the surface of the workpiece such as the optical element is

degraded. This is because, due to the pressure, a tool rotation speed, a pore area distribution of a polishing body surface, and a thickness distribution during one-rotation of the tool, process variation in one-rotation cycle of the tool occurs. For that reason, conventionally, degrading of the quality of the surface of the workpiece such as the optical element is suppressed in the following manner. Specifically, after the polishing tool is scanned in an X axis direction and the surface of the workpiece is polished, polishing-processing is performed again with use of a different polishing tool, or the same polishing tool is scanned in a Y axis direction orthogonal to the X axis direction to polish the surface of the workpiece, to thereby smooth the waviness (see Japanese Patent Application Laid-Open No. H11-090806).

[0004] However, in the above-mentioned conventional method, in order to smooth the waviness formed on the surface of the workpiece after performing the polishing-processing by the polishing tool, it is necessary to perform the polishing-processing again with use of a different polishing tool, and hence a polishing period of time is extended. As a result, productivity of the workpiece such as the optical element is reduced, and manufacturing cost of the workpiece is adversely affected.

[0005] Further, in the above-mentioned conventional method, though it is possible to reduce the waviness formed on the surface of the workpiece, the surface of the workpiece is polishing-processed multiple times with the same polishing body. Thus, a target shape is not sometimes obtained so that the quality of the surface of the workpiece such as the optical element is degraded. For example, depending on a processing condition, polishing liquid does not enter uniformly between the polishing body and the workpiece so that polishing removal is sometimes proceeded at variable speed in contact surfaces between the polishing body and the workpiece. As a result, a finished surface having polishing removal depths different from point to point is formed, and thus the quality of the surface of the workpiece is sometimes degraded.

[0006] Therefore, it is an object of the present invention to provide a polishing tool capable of forming a high-quality surface of a workpiece for a short period of time.

SUMMARY OF THE INVENTION

[0007] According to the present invention, there is provided a polishing tool for polishing-processing a surface of a workpiece, including; a rotation shaft, a disk-like first polishing body, which is provided to the rotation shaft and includes an outer peripheral surface serving as a work surface, and a disk-like second polishing body, which is provided to the rotation shaft so as to be adjacent to the first polishing body and includes an outer peripheral surface serving as a work surface, in which; the outer peripheral surface of the first polishing body is formed into a shape having a porosity higher than a porosity of the outer peripheral surface of the second polishing body,

and the second polishing body includes a material more rigid than a material for the first polishing body.

[0008] Further, according to the present invention, there is provided a workpiece processing method for polishing-processing a surface of a workpiece, including; bringing a disk-like first polishing body and a disk-like second polishing body into press-contact with the workpiece, the first polishing body and the second polishing body being adjacently provided to the same rotation shaft and each including an outer peripheral surface serving as a work surface, and moving the first polishing body and the second polishing body relative to the workpiece in a direction parallel to the rotation shaft, to thereby process the surface of the workpiece, in which; the outer peripheral surface of the first polishing body is formed into a shape having a porosity higher than a porosity of the outer peripheral surface of the second polishing body, the second polishing body includes a material more rigid than a material for the first polishing body, and the second polishing body removes a waviness formed through processing performed by the first polishing body.

[0009] According to the present invention, the outer peripheral surface of the first polishing body is formed into the shape having the high porosity, and hence a film of polishing liquid is less likely to be formed between the surface of the workpiece and the outer peripheral surface of the first polishing body. As a result, floating of the first polishing body caused by the film is suppressed, and thus it is possible to achieve high polishing removal efficiency. Further, the second polishing body different from the first polishing body includes the material more rigid than a material for the first polishing body, and hence the outer peripheral surface of the second polishing body is less likely to be held in contact with a valley portion of the waviness, but more likely to be held in contact with a peak portion of the waviness, whereby the second polishing body has a high performance in smoothing the waviness. Further, the first polishing body and the second polishing body, which have different functions from each other, are adjacently provided to the rotation shaft, and hence it is possible to perform polishing removal and smoothing of the waviness at one time. As a result, it is possible to obtain a high-quality surface of the workpiece for a short period of time.

[0010] Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is an explanation view of a polishing tool according to a first embodiment of the present invention.

[0012] FIGS. 2A and 2B are explanations view of a polishing tool according to a second embodiment of the present invention.

[0013] FIGS. 3A, 3B, and 3C are each an explanation view of a polishing tool according to another embodiment

of the present invention.

DESCRIPTION OF THE EMBODIMENTS

[0014] In the following, embodiments for carrying out the present invention are described in detail with reference to the drawings.

First Embodiment

[0015] A polishing apparatus 100 illustrated in FIG. 1 performs processing, with use of a polishing tool 10 mounted to a polishing apparatus main body, on a surface of a workpiece W placed on an XY stage (not shown). The workpiece W has a surface Wa, which is a flat surface, a spherical surface, or a non-horizontal surface such as a non-axisymmetric free-form surface. The workpiece W is, for example, an optical element such as a lens or a mirror, or a die for molding an optical element. The polishing tool 10 includes a rotation shaft 1, and at least two disk-like polishing bodies 7, 8 provided to the rotation shaft 1 so as to be adjacent to each other. The rotation shaft 1 of the polishing tool 10 is fixed to a tool rotating device 3 of the polishing apparatus 100, whereby the polishing tool 10 is supported to be rotatable relative to the polishing apparatus main body. The first polishing body 8 and the second polishing body 7 respectively have outer peripheral surfaces serving as working surfaces 8a, 7a. The first polishing body 8 and the second polishing body 7 are fixed onto the rotation shaft 1 passing through a center portion of each disk-like surface of each of the polishing bodies. With this configuration, the first polishing body 8 and the second polishing body 7 are fixed onto the rotation shaft 1 so as to be adjacent to each other. The polishing tool 10 is fixed to the tool rotating device 3, and is driven by the tool rotating device 3 to rotate about the rotation shaft 1. Then, the polishing tool 10 is brought into press-contact with the workpiece W, and the first polishing body 8 and the second polishing body 7 are moved relative to the workpiece W in a direction parallel to the rotation shaft, whereby processing is performed. Moving of the polishing bodies is executed, for example, through moving of the workpiece W with the XY stage (not shown).

[0016] The polishing apparatus 100 includes a Z column (not shown) for moving, in upward and downward directions, a support member 4 coupled to the tool rotating device 3. Herein, as illustrated in FIG. 1, the upward direction is referred to as a Z axis direction, and the downward direction is referred to as a -Z axis direction. The polishing apparatus 100 operates in such a manner that the Z column is lowered in the -Z axis direction while the rotation shaft 1 of the polishing tool 10 is rotated at a constant rpm, and thus the outer peripheral surfaces 7a, 8a of the respective polishing bodies 7, 8 of the polishing tool 10, which serve as the working surfaces, are brought into press-contact with the surface Wa of the workpiece W. Then, the polishing apparatus 100 regulates a press-

contact force applied onto the surface Wa of the workpiece W, and a relative speed and a standstill period of time of the outer peripheral surfaces 7a, 8a of the polishing bodies 7, 8 with respect to the surface Wa, and thus controls indentation depths of the respective polishing bodies 7, 8 with respect to the surface Wa of the workpiece W. Then, under a state in which the respective polishing bodies 7, 8 are rotated in a pressing direction parallel to the -Z axis direction while being held in press-contact with the surface Wa of the workpiece W, the polishing tool 10 or the workpiece W is sent in a sending direction S which is a moving direction parallel to the rotation shaft, and thus the following groove is formed in the surface Wa. Specifically, the groove has a predetermined cut depth extending straight in the sending direction S and a predetermined width. As a method of moving the polishing tool 10 relative to the surface Wa of the workpiece W, the workpiece W may be moved relative to the polishing tool 10, or the polishing tool 10 may be moved relative to the workpiece W.

[0017] In the first embodiment, the rotation shaft 1 of the polishing tool 10 is arranged in parallel to the moving direction relative to the workpiece W serving as an object to be polished. Each of the polishing bodies 7, 8 is fixed onto the rotation shaft 1 passing through the center portion of each disk-like surface of each of the polishing bodies, and is rotated integrally with the rotation shaft 1 about the center portion.

[0018] The polishing body 8 is a first polishing body made of a foamed resin, and a large number of pores are formed in the outer peripheral surface 8a of the polishing body 8. It is preferred that the foamed resin include a foamed polyurethane resin. In contrast, the polishing body 7 is a second polishing body made of a non-foamed resin, and few pores are formed in the outer peripheral surface 7a of the polishing body 7. In other words, the outer peripheral surface 8a of the polishing body 8 is formed into a shape having a porosity higher than that of the outer peripheral surface 7a of the polishing body 7. It is preferred that the non-foamed resin include a non-foamed polyurethane resin. The polishing body 7 includes the non-foamed polyurethane resin, and hence is more rigid and less likely to be elastically deformed than the polishing body 8 made of the foamed polyurethane resin. In other words, the polishing body 8 is less rigid and more likely to be elastically deformed than the polishing body 7.

[0019] The polishing body 7 is arranged so as to be adjacent to the polishing body 8, and the polishing body 7 is arranged so as to be positioned on an upstream side with respect to the polishing body 8 when the relative moving direction between the polishing tool 10 and the workpiece is along the sending direction (X axis direction). Further, the polishing body 8 is formed to have a diameter slightly larger than that of the polishing body 7. In other words, the polishing body 8 is formed to have a radius larger than that of the polishing body 7 by an amount corresponding to a difference between an elastic

deformation amount of the polishing body 7 and an elastic deformation amount of the polishing body 8 caused by a pressing pressure applied onto the surface Wa of the workpiece W. With this shape, the polishing body 7 and the polishing body 8 are pressed under the same load onto the workpiece W when the pressure is applied.

[0020] Note that, it is preferred that a thickness of the polishing body 7 range from 1.0 mm to 1.5 mm. When the thickness is less than 1.0 mm, rigidity of the polishing body 7 is low, and hence the polishing body 7 is deformed along the shape of the surface Wa of the workpiece W. Thus, it is impossible to remove the waviness. When the thickness is more than 1.5 mm, a length including the thickness of the polishing body 7, the thickness of the polishing body 8, and an interval between the polishing body 7 and the polishing body 8 exceeds 4 mm so that a size of a removal trace is larger than 4 mm. Thus, it is impossible to correct a shape having a short wavelength, and to obtain necessary processing accuracy. Further, it is preferred that a thickness of the polishing body 8 be larger than that of the polishing body 7 and that the length including the thickness of the polishing body 7, the thickness of the polishing body 8, and the interval between the polishing body 7 and the polishing body 8 be 4 mm or less. When the polishing body 7 is thicker than the polishing body 8, the polishing body 8 cannot smooth the waviness generated by the polishing body 7. In other words, the polishing body 8 is formed to be thicker than the polishing body 7. The thickness of the polishing body 7 refers to a distance between disk-like surfaces that are side surfaces of the polishing body crossing perpendicularly to the rotation shaft. Further, in the first embodiment, it is preferred that an interval between the adjacent polishing bodies 7, 8 be 0.5 mm or less. This is to secure the necessary processing accuracy through setting a total length of the thickness of the polishing body 7, the thickness of the polishing body 8, and the interval between the polishing body 7 and the polishing body 8 to be 4 mm or less so as to set the size of the removal trace to be 4 mm or less. In this way, the polishing bodies 7, 8 are arranged onto the rotation shaft 1 with the interval.

[0021] With the above-mentioned configuration, when polishing-processing the surface Wa of the workpiece W with use of the polishing tool 10, the polishing bodies 7, 8 are lowered in the -Z axis direction while being rotated in a rotating direction of the rotation shaft 1, and then the outer peripheral surfaces 7a, 8a of the polishing bodies 7, 8 are brought into press-contact with the surface Wa of the workpiece W. The polishing body 8 includes the foamed polyurethane resin, and hence is rotated while being elastically deformed and held in close contact with the surface of the workpiece W.

[0022] Further, the polishing body 8 includes the foamed polyurethane resin, and hence the large number of pores are formed in the outer peripheral surface 8a. Thus, polishing liquid (abrasive grain) easily enters the formed pores. Therefore, it is possible to suppress formation of a film of the polishing liquid between the outer

peripheral surface 8a of the polishing body 8 and the surface Wa of the workpiece W, and thus possible to suppress floating of the polishing body 8 from the surface Wa. Further, the large number of pores can hold a large amount of abrasive grains so that the number of the abrasive grains supplied between the outer peripheral surface 8a of the polishing body 8 and the surface Wa of the workpiece W is increased. As a result, polishing removal efficiency is increased. Though the surface Wa of the workpiece W is polished by the polishing body 8 effectively in this way, a periodic waviness is sometimes formed by the polishing body 8 on the surface Wa of the workpiece W.

[0023] As illustrated in FIG. 1, in a case where the moving direction of the polishing tool 10 with respect to the workpiece W is along the sending direction S (X axis direction), the waviness formed by the polishing body 8 on the surface Wa of the workpiece W is smoothed by the polishing body 7 passing the workpiece W subsequently to the polishing body 8 (or last). Specifically, the polishing body 7 includes the non-foamed polyurethane resin, and hence is more rigid than the polishing body 8 and less likely to be elastically deformed than the polishing body 8 even when being brought into press-contact with the surface Wa of the workpiece W. Therefore, the outer peripheral surface 7a of the polishing body 7 is less likely to be held in contact with a valley portion of the waviness, but more likely to be held in contact with a peak portion of the waviness, and hence the polishing body 7 has a high performance in smoothing the waviness. The polishing body 7 removes the peak portion of the waviness formed on the surface Wa of the workpiece W, and effectively smoothes the surface Wa of the workpiece W.

Second Embodiment

[0024] Next, a second embodiment of the present invention is described. FIG. 2A illustrates a polishing tool 11 according to the second embodiment. Portions identical to those of FIG. 1 are denoted by the same symbols, and description thereof is omitted. The polishing tool 11 includes the rotation shaft 1, and three disk-like polishing bodies 7, 8, and 9 provided to the rotation shaft 1 so as to be adjacent to each other. The rotation shaft 1 of the polishing tool 11 is fixed to the tool rotating device 3 of the polishing apparatus 100, whereby the polishing tool 11 is supported to be rotatable relative to the polishing apparatus main body. The first polishing body 8, the second polishing body 7, and the third polishing body 9 respectively have outer peripheral surfaces serving as working surfaces 8a, 7a, and 9a. The first polishing body 8, the second polishing body 7, and the third polishing body 9 are fixed onto the rotation shaft 1 passing through the center portion of each disk-like surface of each of the polishing bodies. With this configuration, the first polishing body 8, the second polishing body 7, and the third polishing body 9 are fixed onto the rotation shaft 1 so as

to be adjacent to each other, and are each rotated integrally with the rotation shaft 1 about the center portion.

[0025] Similarly to the polishing body 7, the polishing body 9 includes the non-foamed resin, and few pores are formed in the outer peripheral surface 9a of the polishing body 9. In other words, the outer peripheral surface 8a of the polishing body 8 is formed into a shape having a porosity higher than that of the outer peripheral surface 9a of the polishing body 9. It is preferred that the non-foamed resin include the non-foamed polyurethane resin. The polishing body 9 includes the non-foamed polyurethane resin, and hence is more rigid and less likely to be elastically deformed than the polishing body 8 made of the foamed polyurethane resin. In other words, the polishing body 8 is less rigid and more likely to be elastically deformed than the polishing body 9.

[0026] Next, a workpiece processing method according to this embodiment performed with use of the polishing tool 11 is described with reference to FIG. 2B.

[0027] After the polishing tool 11 forms a groove in the surface Wa of the workpiece W in the X axis direction, the polishing tool 11 is shifted by a constant pitch P (sending pitch) in a Y axis direction orthogonal to the sending direction S (X axis direction), and is moved in a returning direction (-X axis direction) while being overlapped to part of the groove which has been already formed. In this embodiment, as described above, the polishing tool 11 is slid by the constant pitch P in the Y axis direction each time. The moving direction of the polishing tool 11 with respect to the workpiece is switched alternately between the sending direction (X axis direction) and the returning direction (-X axis direction), and an entire surface of the workpiece W is polishing-processed into an arbitrary shape. Note that, as a method of moving the polishing tool 11 relative to the surface Wa of the workpiece W, the workpiece W may be moved relative to the polishing tool 11, or the polishing tool 11 may be moved relative to the workpiece W.

[0028] The polishing body 9 is arranged so as to be adjacent to the polishing body 8, and the polishing body 9 is arranged on the upstream side with respect to the polishing body 8 when the moving direction of the polishing tool 11 with respect to the workpiece is along the returning direction (-X axis direction).

[0029] Further, in a case where the polishing tool 11 is moved in the returning direction (-X axis direction) relative to the workpiece W, the waviness formed by the polishing body 8 on the surface Wa of the workpiece W is smoothed by the polishing body 9 passing the workpiece W subsequently to the polishing body 8 (or last). That is, the polishing body 9 includes the non-foamed polyurethane resin, and hence, similarly to the polishing body 7, the polishing body 9 is more rigid and has a higher performance in smoothing the waviness than the polishing body 8, to thereby effectively smooth the surface Wa of the workpiece W. Therefore, in the second embodiment, the polishing bodies 7, 9 more rigid than the polishing body 8 are arranged adjacently on both sides of

the polishing body 8. Thus, in a case where the moving direction of the polishing tool 11 with respect to the workpiece is switched alternately between the sending direction S (X axis direction) and the returning direction (-X axis direction), it is possible to smooth the waviness in any directions after polishing removal.

[0030] As described above, in the case where the moving direction of the polishing tool 11 with respect to the workpiece is along the sending direction (X axis direction), the polishing body 7 smoothes the waviness of the surface Wa after the polishing body 8 performs polishing removal on the surface Wa. Meanwhile, in the case where the moving direction of the polishing tool 11 with respect to the workpiece is along the returning direction (-X axis direction), the polishing body 9 smoothes the waviness of the surface Wa after the polishing body 8 performs polishing removal on the surface Wa. Therefore, while the polishing tool 11 is shifted by the pitch P each time in a direction orthogonal to the moving direction of the polishing tool 11 with respect to the workpiece, the polishing tool 11 is moved under alternate switching of the moving direction, and thus it is possible to perform polishing removal of the entire surface of the workpiece W and smoothing of the waviness at one time. In other words, one-time scanning of the polishing tool 11 with respect to the surface Wa of the workpiece W enables the polishing tool 11 to perform the polishing removal and the smoothing of the waviness. As described above, the polishing bodies have different functions from each other, and hence it is possible to obtain a high-quality surface of the workpiece for a short period of time when polishing a free-form surface shape.

Third Embodiment

[0031] Next, a third embodiment of the present invention is described. FIG. 3A illustrates a polishing tool 12 according to the third embodiment. Portions identical to those of FIG. 2 are denoted by the same symbols, and description thereof is omitted.

[0032] In FIG. 3A, multiple grooves 9b with a depth (for example, 0.35 mm) of from 0.1 mm to a size corresponding to the thickness of the polishing body 9 are formed in the outer peripheral surface 9a of the polishing body 9 at intervals of 2° or less in a direction parallel to the rotation shaft. In the case where the depth of each of the grooves is extremely shallow, when the polishing body 9 is pressed, the polishing body 9 is deformed so that bottoms of the grooves are brought into contact with the surface Wa of the workpiece W. Thus, the polishing body 9 cannot exert an effect of the grooves. The multiple grooves 9b are formed in the outer peripheral surface 9a of the polishing body 9, and hence it is possible to suppress formation of a film of the polishing liquid between the outer peripheral surface 9a of the polishing body 9 and the surface Wa of the workpiece W, and thus possible to suppress floating of the polishing body 9 from the surface Wa. Therefore, the performance in smoothing the

waviness formed on the surface Wa of the workpiece W is further improved. The grooves may be formed also in the polishing body 7, or may be formed only in the polishing body 7 but not in the polishing body 9. The polishing body with the grooves has the improved performance in smoothing the waviness, and hence it is possible to determine whether to form the grooves depending on the required accuracy.

Fourth Embodiment

[0033] Next, a fourth embodiment of the present invention is described. FIG. 3B illustrates a polishing tool 13 according to the fourth embodiment. Portions identical to those of FIG. 2 are denoted by the same symbols, and description thereof is omitted.

[0034] In FIG. 3B, in the fourth embodiment, the polishing tool 13 includes the polishing body 8 serving as the first polishing body, and disk-like support members 21a, 21b provided for deformation prevention, the support members 21a, 21b being respectively provided to be held in contact with (both) side surfaces 7c, 7c of the polishing body 7 serving as the second polishing body and being formed of a metal plate such as a stainless steel plate. In order to prevent contact with the surface Wa of the workpiece W, each of the support members 21a, 21b is set to have a radius smaller than that of the polishing body 7. An elastic deformation amount of each of the support members 21a, 21b is set to be smaller by 0.1 mm than the elastic deformation amount of the polishing body 7. In the case where the difference is more than 0.1 mm, when the polishing body 7 is deformed, the support members 21a, 21b are brought into contact with the surface Wa of the workpiece W. In the case where the difference is less than 0.1 mm, the support members 21a, 21b cannot obtain rigidity enough to support the polishing body 7. Note that, each of the support members 21a, 21b is set to have a thickness of from 0.1 mm to 0.5 mm. In the case where the thickness is more than 0.5 mm, the support members 21a, 21b are brought into contact with another polishing body. In the case where the thickness is less than 0.1 mm, the support members 21a, 21b cannot obtain the rigidity enough to support the polishing body 7.

[0035] With the above-mentioned configuration, even if the polishing body 7 receives a force in the sending direction S during polishing-processing, the polishing body 7 is supported by the support members 21a, 21b, and hence it is possible to prevent deformation of the polishing body 7. With this configuration, it is possible to suppress unevenness generated during polishing removal due to the deformation of the polishing body 7, and thus possible to obtain a higher-quality surface of the workpiece. Further, owing to the support members 21a, 21b, it is possible to select a less rigid material in terms of rigidity of the polishing body 7. The support members may be formed also in the polishing body 9, or may be formed only in the polishing body 9 but not in the pol-

ishing body 7. When the support members are formed only in one of the polishing body 7 and the polishing body 9, it is possible to suppress the unevenness generated during polishing removal by the polishing body including the support members. When the support members are formed both in the polishing body 7 and the polishing body 9, it is possible to suppress the unevenness generated during polishing removal by both the polishing bodies. Thus, it is possible to obtain a higher-quality surface of the workpiece.

Fifth Embodiment

[0036] Next, a fifth embodiment of the present invention is described. FIG. 3C illustrates a polishing tool 14 according to the fifth embodiment. Portions identical to those of FIG. 2 are denoted by the same symbols, and description thereof is omitted.

[0037] In FIG. 3C, the polishing tool 14 includes three disk-like polishing bodies 22, 23, and 24. The polishing body 23 serves as the first polishing body made of the foamed polyurethane resin exemplified as the foamed resin, and a large number of pores are formed in an outer peripheral surface 23a of the polishing body 23. In contrast, the polishing body 22 serves as the second polishing body made of the non-foamed polyurethane resin exemplified as the non-foamed resin, and the polishing body 24 serves as the third polishing body made of the non-foamed polyurethane resin exemplified as the non-foamed resin. Few pores are formed in an outer peripheral surface 22a of the polishing body 22 and an outer peripheral surface 24a of the polishing body 24. In other words, the outer peripheral surface 23a of the polishing body 23 is formed into a shape having a porosity higher than that of the outer peripheral surface 22a of the polishing body 22 and that of the outer peripheral surface 24a of the polishing body 24.

[0038] Further, each of the polishing bodies 22, 24 includes the non-foamed polyurethane resin, and hence is more rigid and less likely to be elastically deformed than the polishing body 23 made of the foamed polyurethane resin. In other words, the polishing body 23 is less rigid and more likely to be elastically deformed than the polishing bodies 22, 24. Each of the polishing bodies 22, 24 is arranged so as to be adjacent to the polishing body 23. The polishing body 22 is arranged upstream in the moving direction with respect to the polishing body 23 when the moving direction of the polishing tool with respect to the workpiece is along the sending direction S (X axis direction). Meanwhile, the polishing body 24 is arranged upstream in the moving direction with respect to the polishing body 23 when the moving direction is along the returning direction (-X axis direction). The polishing body 23 is formed to have a diameter slightly larger than that of the polishing body 22 and that of the polishing body 24.

[0039] Note that, a thickness of each of the polishing body 22 and the polishing body 24 is, for example, 1.0

mm. A thickness of the polishing body 23 is, for example, 2.0 mm. In other words, the polishing body 23 is formed to be thicker than the polishing body 22 and the polishing body 24. With this configuration, a total thickness of the polishing body 22, the polishing body 23, and the polishing body 24 is set to be as small as possible (to be, for example, 4 mm or less) so that the size of the removal trace is 4 mm or less. Thus, it is possible to obtain the necessary processing accuracy. Further, multiple grooves 22b with a depth of 0.35 mm are formed in the outer peripheral surface 22a of the polishing body 22 at intervals of 2° or less in the direction parallel to the rotation shaft. Similarly, multiple grooves 24b with a depth of 0.35 mm are formed in the outer peripheral surface 24a of the polishing body 24 at intervals of 4° in the direction parallel to the rotation shaft. In the case where the depth of each of the grooves is 0.1 mm or less, when the polishing body 9 is pressed, the polishing body 9 is deformed so that the bottoms of the grooves are brought into contact with the surface Wa of the workpiece W. Thus, the polishing body 9 cannot exert an effect of the grooves. Further, when the interval angle is larger than 2°, the film of polishing liquid is generated to inhibit the polishing body from being held in contact with the surface of the workpiece, and thus processing efficiency is significantly decreased. Further, in the fifth embodiment, an interval between the adjacent polishing bodies 22, 23 and an interval between the adjacent polishing bodies 23, 24 are set to 0 mm, and the polishing bodies 22, 23, and 24 are arranged onto the rotation shaft 1. Without the intervals, the removal trace generated by the entire tool is reduced, and hence it is possible to correct and process even a shape having a shorter wavelength. As a result, it is possible to obtain a high-quality surface of the workpiece.

[0040] In the fifth embodiment, the polishing body 22 and the polishing body 24 are made of the same material and formed into the same shape (with the same diameter, the same width, and the same groove intervals), and are configured to be symmetric with respect to the polishing body 23. Therefore, in the fifth embodiment, the same operation and effect as those of the first embodiment are provided. In addition, in each of the polishing bodies 22, 24, when the moving direction of the polishing tool with respect to the workpiece is along any of the +X axis direction and the -X axis direction, it is possible to similarly smooth the waviness generated by the polishing body 23. Therefore, it is possible to obtain a higher-quality surface of the workpiece for a short period of time when polishing a free-form surface shape. Further, in the fifth embodiment, the grooves 22b, 24b are formed in the polishing bodies 22, 24, respectively. Thus, when the moving direction of the polishing tool with respect to the workpiece is along any of the +X axis direction and the -X axis direction, it is possible to suppress floating of each of the polishing bodies 22, 24, and to effectively smooth the waviness.

[0041] Note that, though the present invention is described based on the above-mentioned embodiments,

the present invention is not limited thereto.

[0042] Further, in the fourth embodiment, the shape of the support members 21a, 21b is set to a disk-like shape, and the material of the support members 21a, 21b is set to stainless steel. However, as long as it is possible to prevent the deformation of the polishing body 7, the shape and the material thereof may be set arbitrarily. Further, in the fourth embodiment, the polishing body 7 is provided with the support members 21a, 21b. However, similarly, the polishing body 8 or the polishing body 9 may be provided with support members (that is, at least one of the first polishing body and the second polishing body may be provided with support members). Also in this case, the same effect is provided.

[0043] Further, in the first embodiment, the interval between the adjacent polishing bodies 7, 8 is set to 0.5 mm. However, the interval may be set arbitrarily, and the same effect is provided even when any interval is set. Further, in the fifth embodiment, the interval between the polishing bodies 22, 23 and the interval between the polishing bodies 23, 24 are set to 0 mm. However, the intervals may be set arbitrarily as long as the polishing bodies are arranged symmetrically, and the same effect is provided even when any intervals are set.

[0044] Further, in the second to fifth embodiments, the case where the three polishing bodies are used is described. However, the present invention is not limited thereto. In the second to fifth embodiments, the case where the moving direction of the polishing tool with respect to the workpiece is switched alternately between the X axis direction and the -X axis direction is described. However, in a case where the moving direction is along one direction, it is possible to omit the polishing body situated downstream in the sending direction with respect to the polishing body 8 (polishing body 23).

[0045] Further, another polishing body may be interposed between the polishing body 8 and the polishing body 7, and still another polishing body may be interposed between the polishing body 8 and the polishing body 9. Similarly, another polishing body may be interposed between the polishing body 23 and the polishing body 22, and still another polishing body may be interposed between the polishing body 23 and the polishing body 24. In this case, the polishing body 7, 22 or the polishing body 9, 23 passes the surface of the workpiece last, and thus it is possible to effectively smooth the waviness. Note that, in this case, it is preferred that the same number of polishing bodies be provided on each side of the polishing body 8, 23 so as to be symmetric with respect to the polishing body 8, 23.

[0046] Further, in the first to fifth embodiments, the case where the foamed polyurethane resin is exemplified as the foamed resin is described. However, the foamed resin may include a foamed epoxy resin and a foamed phenolic resin. Similarly, the case where the non-foamed polyurethane resin is exemplified as the non-foamed resin is described. However, the non-foamed resin may include a non-foamed epoxy resin and a non-foamed phe-

nolic resin.

[0047] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

Provided is a polishing tool capable of forming a high-quality surface of a workpiece for a short period of time. A polishing tool (10) includes: a rotation shaft (1) arranged parallel to a sending direction (S) of moving the polishing tool relative to a workpiece (W); and at least two polishing bodies (7, 8). The polishing body (8) includes a foamed resin such as a foamed polyurethane resin, and has an outer peripheral surface (8a) having a porosity higher than that of the polishing body (7). The polishing body (7) includes a non-foamed resin such as a non-foamed polyurethane resin being a material more rigid than that for the polishing body (8). When polishing-processing, the polishing body (8) performs polishing removal on a surface (Wa) of the workpiece (W), and the polishing body (7) smoothes a waviness formed on the surface (Wa) through the polishing removal.

Claims

1. A polishing tool for polishing-processing a surface of a workpiece, comprising:

a rotation shaft;
a disk-like first polishing body, which is provided to the rotation shaft and includes an outer peripheral surface serving as a work surface; and
a disk-like second polishing body, which is provided to the rotation shaft so as to be adjacent to the first polishing body and includes an outer peripheral surface serving as a work surface, wherein:

the outer peripheral surface of the first polishing body is formed into a shape having a porosity higher than a porosity of the outer peripheral surface of the second polishing body; and
the second polishing body comprises a material more rigid than a material for the first polishing body.

2. The polishing tool according to claim 1, further comprising a support member provided for deformation prevention on a side surface of at least one of the first polishing body and the second polishing body.
3. The polishing tool according to claim 1, wherein the first polishing body comprises a foamed resin.

4. The polishing tool according to claim 1, wherein the outer peripheral surface of the second polishing body comprises multiple grooves formed parallel to a direction of the rotation shaft.

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5. A workpiece processing method for polishing-processing a surface of a workpiece, comprising:

bringing a disk-like first polishing body and a disk-like second polishing body into press-contact with a workpiece, the first polishing body and the second polishing body being adjacently provided to a same rotation shaft and each including an outer peripheral surface serving as a work surface; and

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moving the first polishing body and the second polishing body relative to the workpiece in a direction parallel to the rotation shaft, to thereby process the surface of the workpiece, wherein:

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the outer peripheral surface of the first polishing body is formed into a shape having a porosity higher than a porosity of the outer peripheral surface of the second polishing body;

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the second polishing body comprises a material more rigid than a material for the first polishing body; and

the second polishing body removes a waviness formed through processing performed by the first polishing body.

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6. The workpiece processing method according to claim 5, wherein the second polishing body is arranged, with respect to the first polishing body, upstream in a direction of moving the first polishing body and the second polishing body.

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FIG. 1

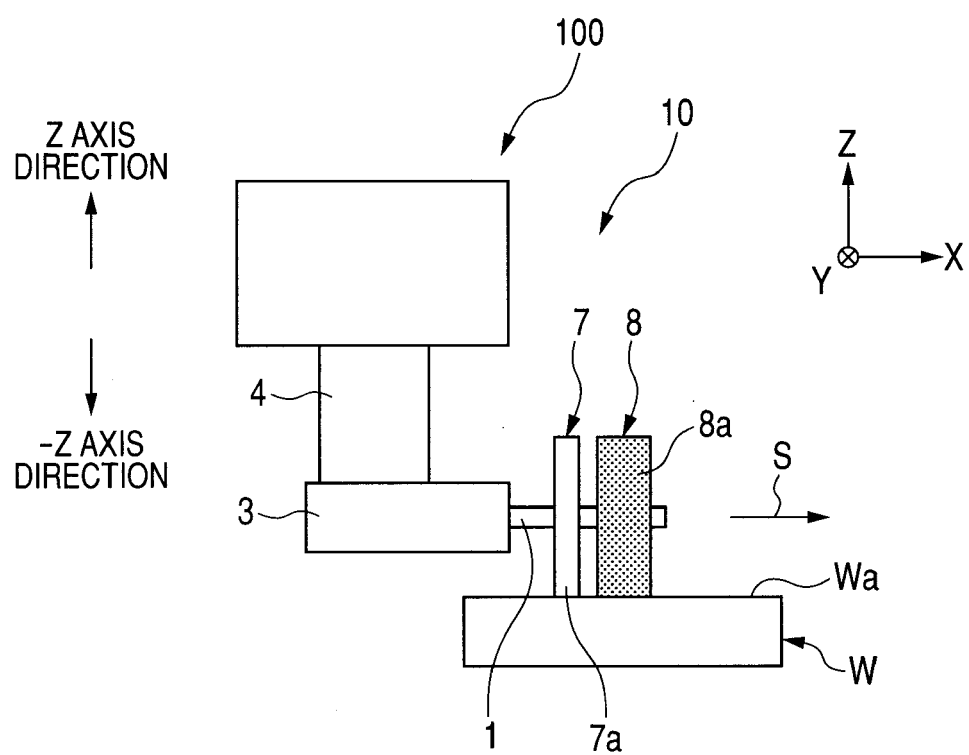


FIG. 2A

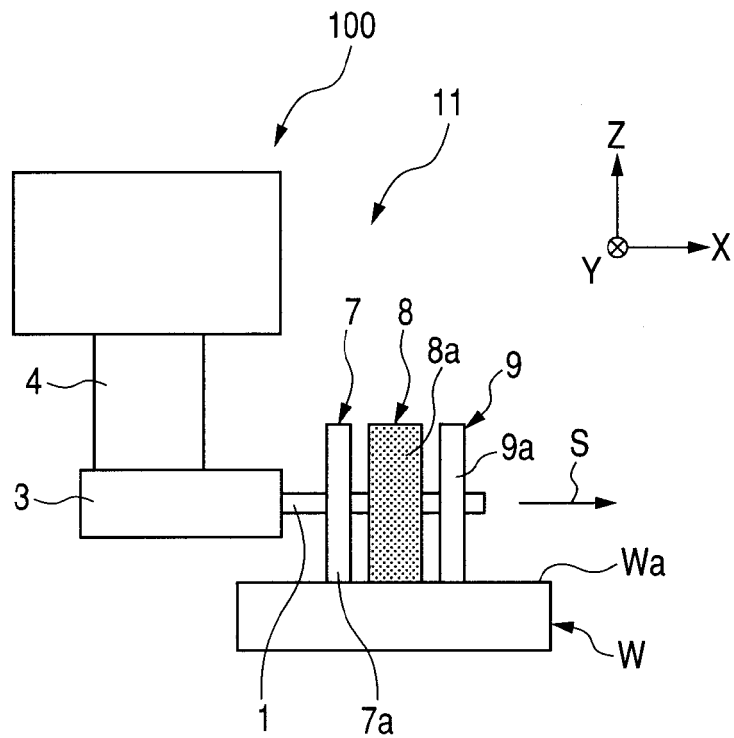


FIG. 2B

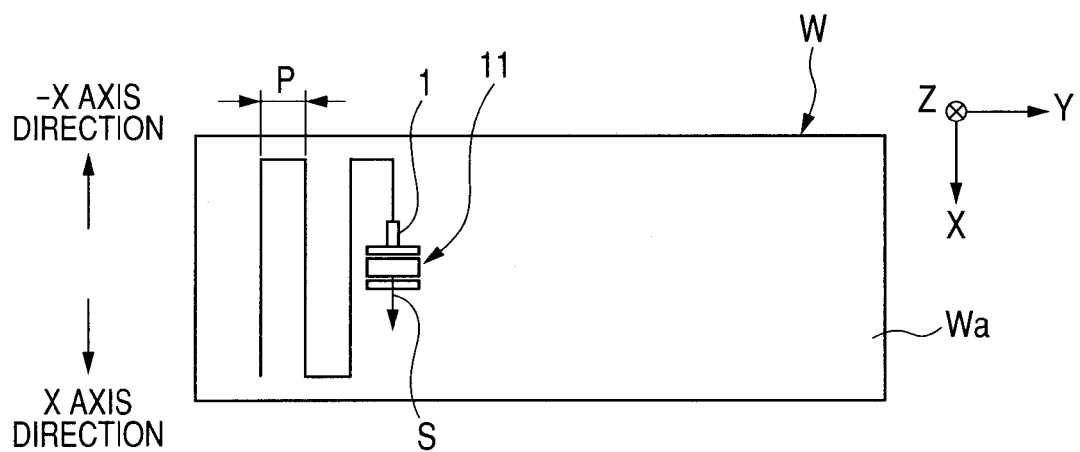


FIG. 3A

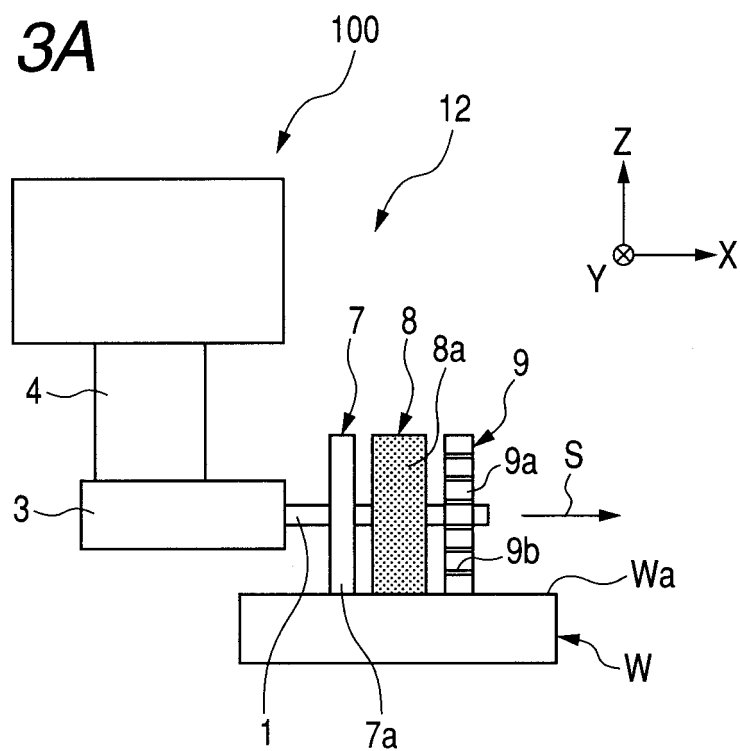


FIG. 3B

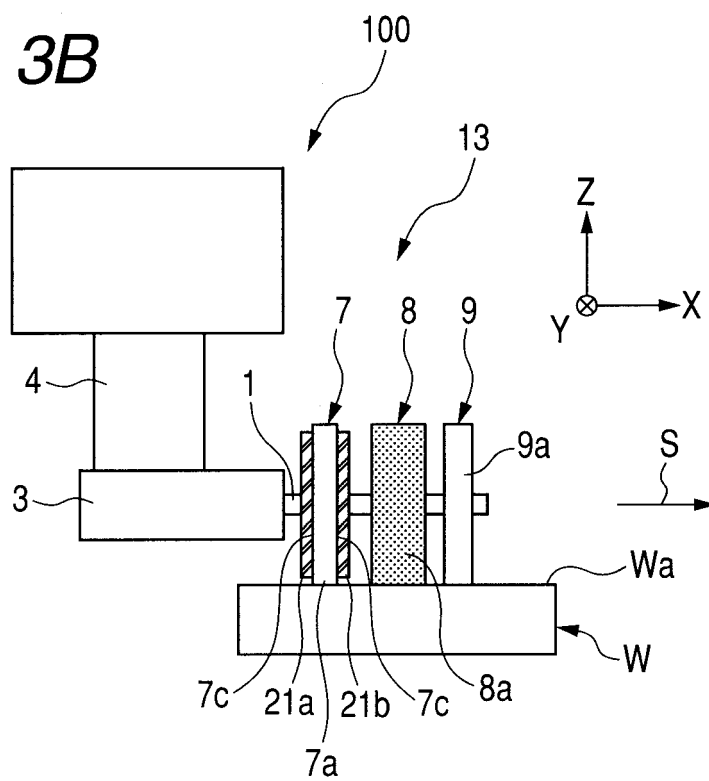
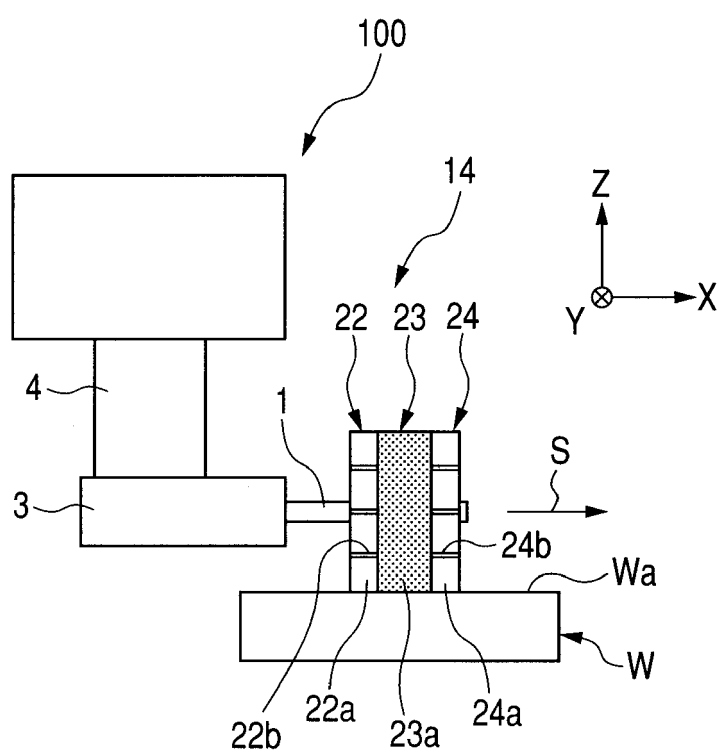


FIG. 3C



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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