

Specification

[Title of Invention] DOUBLE-SIDED POLISHING DEVICE AND DOUBLE-SIDED POLISHING METHOD

[Technical Field]

5 [0001] The present invention relates to a double-sided polishing device and a double-sided polishing method for polishing both front and back surfaces of a disc-shaped workpiece.

[Background Art]

[0002] Hitherto, when the front and back surfaces of disc-shaped workpieces, such as silicon wafers, are polished by upper and lower surface plates, there has been known a double-sided
10 polishing device that controls the operation based on the optimum inter-plate distance obtained by inputting, for example, a desired workpiece flatness into an artificial intelligence model that has learned a relationship between the inter-plate distance and the workpiece flatness (see, for example, Patent Document 1). Furthermore, there has been known a double-sided polishing device that terminates double-sided polishing of the workpiece at the timing when the shape
15 index of the entire workpiece reaches a set value of the shape index of the entire workpiece (see, for example, Patent Document 2).

[Prior Art Documents]

[Patent Literature]

[0003]

20 Patent Literature 1: Japanese Patent Application Publication No. 2022-189524

Patent Literature 2: WO 2022/254856

[Summary of Invention]

[Problem to be solved]

[0004] By the way, in order to polish a workpiece in a double-sided polishing device, firstly,
25 the load applied to the workpiece is gradually increased. When the load reaches a predetermined load or other conditions are met, a main polishing is performed to polish the workpiece for a predetermined time while maintaining the load applied to the workpiece at a

target load. After a lapse of a predetermined time from the start of the main polishing, the main polishing is stopped. Then, the load applied to the workpiece is gradually reduced to complete polishing of the workpiece. Here, even when the load applied to the workpiece is gradually reduced after the main polishing, the shape change in the workpiece occurs.

- 5 Moreover, the amount of shape change is not constant, because it becomes different depending on the polishing conditions, the conditions of secondary materials, and the like. Therefore, the operator of the polishing device estimates the amount of shape change in the workpiece after the main polishing, and manually adjusts the main polishing stopping timing, and the like. However, the adjustment of the main polishing stopping timing, and the like by relying on the
10 operator's judgment causes a problem of variation in qualities of the finished workpieces.

- [0005] On the other hand, the conventional double-sided polishing devices described in Patent Literature 1 and Patent Literature 2 only set the polishing conditions at the main polishing. In other words, at the main polishing, the conventional double-sided polishing devices control the inter-plate distance or stop the main polishing of the workpiece at a timing when the shape
15 index of the entire workpiece becomes a set value. However, they do not take into consideration the fact that the shape of the workpiece changes even when the load applied to the workpiece is gradually reduced after the main polishing. As a result, the workpiece shape after completing the final polishing may not match the target shape, resulting in failure to obtain a desired workpiece shape.

- 20 [0006] The present invention has been made in view of the above problem. An object of the present invention is to provide a double-sided polishing device and a double-sided polishing method that can suppress deviation of the workpiece shape after completing the final polishing from the target shape and can obtain a desired workpiece shape.

[Solution to Problem]

- 25 [0007] To achieve the above object, a double-sided polishing device of the present invention includes:

a polishing machine that is configured to sandwich a disc-shaped workpiece between a lower surface plate and an upper surface plate positioned opposite to the lower surface plate and to polish front and back surfaces of the workpiece by moving the lower surface plate and the upper surface plate relative to the workpiece while applying a load to the workpiece;

5 a thickness measuring apparatus that is configured to measure a thickness of the workpiece while the polishing machine polishes the workpiece; and

a controller that is configured to control the polishing machine based on a measurement result of the thickness measuring apparatus,

 wherein the workpiece includes an outer peripheral area that is in a predetermined
10 range from an outer peripheral edge of the workpiece toward an inner radial direction, and an in-plane area that is in a range from the outer peripheral area to a center of the workpiece,

 wherein the controller includes:

 a first learner that has learned a correlation among a polishing condition of a main polishing for polishing the workpiece while maintaining the load at a target load, an outer
15 peripheral flatness as a flatness of the outer peripheral area, and an in-plane flatness as a flatness of the in-plane area;

 a second learner that has learned a correlation among a polishing condition of an endpoint polishing for polishing the workpiece while gradually reducing the load, a degree of change in the in-plane flatness when the main polishing is stopped, a degree of change in the
20 outer peripheral flatness when the main polishing is stopped, and an amount of change in the outer peripheral flatness during the endpoint polishing;

 a main polishing condition correcting portion that is configured to determine a correction target value of the in-plane flatness based on an estimated value of the in-plane flatness, the estimated value being obtained by inputting, into the first learner, a polishing
25 condition of the main polishing set at a time of correction and the outer peripheral flatness at the time of the correction, and to correct the polishing condition of the main polishing set at the time of the correction by using the polishing condition of the main polishing, the polishing

condition being obtained by inputting, into the first learner, the correction target value of the in-plane flatness and a target value of the outer peripheral flatness; and

a main polishing stop condition setting portion that is configured to obtain the amount of the change in the outer peripheral flatness during the endpoint polishing by inputting, into the second learner, the polishing condition of the endpoint polishing, the degree of the change in the in-plane flatness at a time of calculation, and the degree of the change in the outer peripheral flatness at the time of the calculation, and to set a stopping condition of the main polishing based on the amount of the change in the outer peripheral flatness and the target value of the outer peripheral flatness.

[0008] To achieve the above object, a double-sided polishing method of the present invention is for polishing front and back surfaces of a disc-shaped workpiece, wherein the workpiece is sandwiched between a lower surface plate and an upper surface plate positioned opposite to the lower surface plate and the front and back surfaces of the workpiece are polished by moving the lower surface plate and the upper surface plate relative to the workpiece while applying a load to the workpiece;

wherein the double-sided polishing method uses:

a first learner that has learned a correlation among a polishing condition of a main polishing for polishing the workpiece while maintaining the load at a target load, an outer peripheral flatness as a flatness of the outer peripheral area, and an in-plane flatness as a flatness of the in-plane area, the outer peripheral area being in a predetermined range from an outer peripheral edge of the workpiece toward an inner radial direction, and the in-plane area being in a range from the outer peripheral area to a center of the workpiece; and

a second learner that has learned a correlation among a polishing condition of an endpoint polishing for polishing the workpiece while gradually reducing the load, a degree of change in the in-plane flatness when the main polishing is stopped, a degree of change in the outer peripheral flatness when the main polishing is stopped, and an amount of change in the outer peripheral flatness during the endpoint polishing;

wherein the double-sided polishing method includes:

setting a target value of the outer peripheral flatness and a target value of the in-plane flatness;

conducting an initial polishing for polishing the workpiece while gradually increasing the load, after setting the target values of the outer peripheral flatness and the in-plane flatness; starting the main polishing after completing the initial polishing;

determining a correction target value of the in-plane flatness based on an estimated value of the in-plane flatness, the estimated value being obtained by inputting, into the first learner, a polishing condition of the main polishing set at a time of correction and the outer peripheral flatness at the time of the correction, during the main polishing, and correcting the polishing condition of the main polishing set at the time of the correction by using the polishing condition of the main polishing, the polishing condition being obtained by inputting, into the first learner, the correction target value of the in-plane flatness and the target value of the outer peripheral flatness;

obtaining the amount of the change in the outer peripheral flatness during the endpoint polishing by inputting, into the second learner, the polishing condition of the endpoint polishing, the degree of the change in the in-plane flatness at a time of calculation, and the degree of the change in the outer peripheral flatness at the time of the calculation, during the main polishing, and setting a stopping condition of the main polishing based on the amount of the change in the outer peripheral flatness and the target value of the outer peripheral flatness; and

performing the endpoint polishing after the stopping condition of the main polishing is satisfied.

[Effects of Invention]

[0009] The double-sided polishing device and the double-sided polishing method of the present invention can suppress deviation of the workpiece shape from the target shape after completing the final polishing, and can obtain a desired workpiece shape.

[Brief Description of Drawings]

[0010]

[FIG. 1] FIG. 1 is an explanatory view schematically showing the overall configuration of a double-sided polishing device of a first embodiment.

[FIG. 2] FIG. 2 is an explanatory view showing a positional relationship between a sun gear, an internal gear, and a carrier plate of the first embodiment.

[FIG. 3A] FIG. 3A is an explanatory view showing passing tracks when a measuring hole has passed over the workpiece in the double-sided polishing device of the first embodiment.

[FIG. 3B] FIG. 3B is an explanatory view showing a thickness data group obtained by measuring the thickness of the workpiece polished by the double-sided polishing device of the first embodiment, and outer peripheral areas and in-plane areas set on the workpiece.

[FIG. 4A] FIG. 4A is an explanatory view showing approximate straight lines set for a thickness data group of the workpiece whose outer peripheral areas are in a rolled-up shape.

[FIG. 4B] FIG. 4B is an explanatory view showing approximate straight lines set for a thickness data group of the workpiece whose outer peripheral areas are in a flat shape.

[FIG. 5] FIG. 5 is an explanatory view showing an innermost section and outer sections when the outer peripheral area is divided into a plurality of sections.

[FIG. 6] FIG. 6 is an explanatory view showing calculated values of an in-plane flatness and an outer peripheral flatness by time and their degrees of change.

[FIG. 7] FIG. 7 is an explanatory view showing a dataset to be learned by a first learner of the first embodiment.

[FIG. 8] FIG. 8 is an explanatory view showing a dataset to be learned by a second learner of the first embodiment.

[FIG. 9] FIG. 9 is a flowchart showing a flow of a polishing processing control executed by a controller of the first embodiment.

[FIG. 10] FIG. 10 is a table showing main polishing conditions, and outer peripheral flatness and in-plane flatness under those conditions in an exemplified workpiece.

[FIG. 11] FIG. 11 is a table showing a dataset to be learned by a learner according to

a comparative example.

[FIG. 12] FIG. 12 shows polishing results indicating workpiece shapes after completing final polishing, when the workpieces have been polished by setting the target value of the outer peripheral flatness to 0 (nm) in the double-sided polishing device of the first
5 embodiment.

[FIG. 13] FIG. 13 shows polishing results indicating workpiece shapes after completing final polishing in the double-sided polishing device of the first embodiment.

[Detailed Description of Embodiments]

[0011] In the following, a double-sided polishing device and a double-sided polishing method
10 according to the present invention will be described based on the first embodiment shown in the drawings.

[0012] A double-sided polishing device 1 according to the first embodiment is configured to polish both front and back surfaces of thin, disc-shaped workpieces W, such as semiconductor wafers, quartz wafers, sapphire wafers, glass wafers, and ceramic wafers. As shown in FIG.
15 1, the double-sided polishing device 1 includes a polishing machine 10, a thickness measuring apparatus 20, and a controller 30.

[0013] The polishing machine 10 sandwiches the workpiece W between a lower surface plate 11 and an upper surface plate 12 positioned opposite the lower surface plate 11. The polishing machine 10 moves the lower surface plate 11 and the upper surface plate 12 relative to the
20 workpiece W while a load is applied to the workpiece W and polishes the front and back surfaces of the workpiece W at the same time. The polishing machine 10 includes the lower and upper surface plates 11, 12 of a doughnut disc-shape, which are concentrically arranged with an axis L1 at the center, a sun gear 13 that is rotatably arranged in a center portion of the lower surface plate 11, an internal gear 14 that is arranged on an outer peripheral side of the
25 lower surface plate 11, and a carrier plate 15 that is arranged between the lower surface plate 11 and the upper surface plate 12. The carrier plate 15 includes a workpiece-holding hole 15a (see FIG. 2). A polishing pad 11a is attached to an upper surface of the lower surface plate

11, and a polishing pad 12a is attached to a lower surface of the upper surface plate 12. Furthermore, the upper surface plate 12 is provided with multiple supply holes (not shown in the drawings) for supplying a polishing slurry (hereinafter referred to as “slurry”). It may be possible to decide whether or not to supply the slurry for each supply hole or each group of supply holes.

[0014] Here, as shown in FIG. 2, the carrier plate 15 meshes with the sun gear 13 and the internal gear 14. The carrier plate 15 rotates (orbits) around the axis L1 while rotating on its own axis as the sun gear 13 and the internal gear 14 rotate.

[0015] The workpiece W is placed in the workpiece-holding hole 15a of the carrier plate 15.

10 In a condition that the workpiece W is sandwiched between the polishing pad 11a attached to the rotating lower surface plate 11 and the polishing pad 12a attached to the rotating upper surface plate 12, the carrier plate 15 rotates about its own axis and orbits therearound, thereby moving the lower surface plate 11 and the upper surface plate 12 relative to the workpiece W and polishing the workpiece W with the polishing pad 11a and the polishing pad 12a. In other words, the surfaces of the polishing pad 11a and the polishing pad 12a become polishing surfaces to polish the workpiece W.

[0016] The upper surface plate 12 is fixed to a rod 16 via support studs 16a, which are attached to its upper surface, and an attaching member 16b. The rod 16 extends and retracts in the vertical direction by a fifth drive device M5, and the upper surface plate 12 moves vertically as the rod 16 extends and retracts. According to the length of the rod 16 through its extension and retraction, a predetermined load is applied to the workpiece W from the upper surface plate 12. In other words, the load applied to the workpiece W is adjusted by controlling the fifth drive device M5.

25 [0017] A first drive shaft 17a extending along the axis L1 is disposed in the center of the polishing machine 10. The first drive shaft 17a is configured to be rotated by a first drive device M1. A driver 18 is fixed to an upper end of the first drive shaft 17a. As a result, the driver 18 rotates integrally with the first drive shaft 17a. On the other hand, the driver 18

includes a groove (not shown in the drawings) on its outer peripheral surface. The groove receives a hook 12b provided on the upper surface plate 12. The extension of the rod 16 moves the upper surface plate 12 downward, thereby engaging the hook 12b into the groove of the driver 18. As a result, the driver 18 and the upper surface plate 12 rotate integrally. In other words, since the upper surface plate 12 rotates integrally with the first drive shaft 17a which is rotated by the first drive device M1, the rotation speed of the upper surface plate 12 is adjusted by controlling the first drive device M1.

[0018] A second drive shaft 17b is fixed to a hole 13a in the center of the sun gear 13 in a manner to pass therethrough. The second drive shaft 17b is a hollow tube open at both ends, and the first drive shaft 17a extends rotatably through it. The second drive shaft 17b is rotated by a second drive device M2. In other words, since the sun gear 13 rotates integrally with the second drive shaft 17b which is rotated by the second drive device M2, the rotation speed of the sun gear 13 is adjusted by controlling the second drive device M2.

[0019] The lower surface plate 11 is formed, below its center portion, with a third drive shaft 17c. The third drive shaft 17c is a hollow tube open at both ends, and the first drive shaft 17a and the second drive shaft 17b extend rotatably through the third drive shaft 17c. The third drive shaft 17c is rotated by a third drive device M3. In other words, since the lower surface plate 11 rotates integrally with the third drive shaft 17c which is rotated by third drive device M3, the rotation speed of the lower surface plate 11 is adjusted by controlling the third drive device M3.

[0020] The internal gear 14 is formed with a fourth drive shaft 17d. The fourth drive shaft 17d is a hollow tube open at both ends, and the first drive shaft 17a, the second drive shaft 17b, and the third drive shaft 17c extend rotatably through the fourth drive shaft 17d. The fourth drive shaft 17d is rotated by a fourth drive device M4. In other words, since the internal gear 14 rotates integrally with the fourth drive shaft 17d which is rotated by the fourth drive device M4, the rotation speed of the internal gear 14 is adjusted by controlling the fourth drive device M4.

[0021] The double-sided polishing device 1 of the first embodiment polishes the workpiece W by controlling the rotation speeds of the lower surface plate 11, the upper surface plate 12, the sun gear 13, and the internal gear 14, while controlling the load applied to the workpiece W by extending and/or retracting the rod 16, based on a predetermined polishing condition.

5 Extending and/or retracting the rod 16 and adjusting (increasing or decreasing) the rotation speeds of the lower surface plate 11 and other plates and gears require time. Accordingly, the polishing step of the workpiece W is divided into an initial polishing, a main polishing, and an endpoint polishing.

[0022] The “initial polishing” is a step of polishing the workpiece W while gradually
10 increasing the load applied to the workpiece W after the polishing is started. In the initial polishing, the rotation speeds of the lower surface plate 11, the upper surface plate 12, the sun gear 13, and the internal gear 14 are also gradually increased. The polishing condition of the initial polishing (initial polishing condition), including polishing time, termination condition, and the like, is determined based on prerequisite polishing conditions. The “prerequisite
15 polishing conditions” are polishing conditions that are previously determined according to the final processing target (polishing target) of the workpiece W, the type of the workpiece W, and the like.

[0023] The “main polishing” is a step of polishing the workpiece W under a predetermined polishing condition, while maintaining the load applied to the workpiece W at the target load,
20 after completing the initial polishing. In the main polishing, the rotation speeds of the lower surface plate 11, the upper surface plate 12, the sun gear 13, and the internal gear 14 are also maintained at respective target rotation speeds. The polishing condition of the main polishing (main polishing condition), including the target load and the target rotation speeds in the main polishing, is determined by the prerequisite polishing conditions at the start of the main
25 polishing, and is repeatedly and continuously corrected during the execution of the main polishing. Furthermore, a condition to stop the main polishing (main polishing stop condition), which determines the timing to stop the main polishing, is repeatedly determined during the

execution of the main polishing, and the main polishing is stopped when the main polishing stop condition is satisfied. The main polishing may include multiple segments (multiple steps), and the main polishing condition may include a suitable adjustment of the temperature, flow rate, supply destination, and the like of the slurry according to the monitoring results of the change trend of the shape of the workpiece W.

[0024] The “endpoint polishing” is a step of polishing the workpiece W after stopping the main polishing while gradually reducing the load applied to the workpiece W. In the endpoint polishing, the rotation speeds of the lower surface plate 11, the upper surface plate 12, the sun gear 13, and the internal gear 14 are also gradually reduced. The polishing condition of the endpoint polishing (endpoint polishing condition) including the polishing time of the endpoint polishing is determined by the prerequisite polishing conditions. The endpoint polishing condition may include a suitable adjustment of the temperature, flow rate, supply destination, and the like of the slurry according to the monitoring results of the change trend of the shape of the workpiece W.

[0025] The upper surface plate 12 includes a measuring hole 19 at a position radially away from the center by a predetermined distance. The measuring hole 19 passes through the upper surface plate 12 and the polishing pad 12a, and includes a window 19a that transmits laser light as the measuring light.

[0026] The thickness measuring apparatus 20 irradiates the measuring light toward the workpiece W and receives the measuring light reflected by the workpiece W to measure the thickness of the workpiece W (distance between the front and back surfaces of the workpiece W) during polishing. The thickness measuring apparatus 20 of the first embodiment quantifies the shape of the workpiece W from a group of measured thickness data of the workpiece W. The thickness measuring apparatus 20 includes a measuring unit 21, a thickness measuring portion 22, and a shape calculation portion 23.

[0027] The measuring unit 21 is attached to the upper surface plate 12 and rotates integrally with the upper surface plate 12. The measuring unit 21 includes a laser light source (not shown

in the drawings) and a light receiving portion (not shown in the drawings). The laser light source irradiates laser light as the measuring light toward the workpiece W through the window 19a attached to the measuring hole 19 of the upper surface plate 12. The light receiving portion receives the reflected light, as the received light signals, respectively reflected from the front and back surfaces of the workpiece W. A transmitting portion 21a transmits the received light signals, received by the light receiving portion, to the thickness measuring portion 22.

[0028] The thickness measuring portion 22 measures the thickness of the workpiece W by, for example, a light reflection interference method. The thickness measuring portion 22 includes a receiver 22a that receives the received light signals transmitted from the measuring unit 21 and obtains the thickness data of the workpiece W based on the received light signals received by the receiver 22a.

[0029] Here, as shown in FIG. 3A, the laser light from the measuring unit 21 is continuously irradiated onto the surface of the workpiece W by the rotation of the upper surface plate 12, while the measuring hole 19 passes over the surface of the workpiece W. Therefore, the thickness measuring portion 22 continuously measures the thickness of each in-plane position of the workpiece W on passing tracks Na to Nc of the measuring hole 19. Then, the thickness measuring portion 22 outputs a thickness data group formed of a large number of continuous thickness data for each passage, while the measuring hole 19 passes over each of the passing tracks Na to Nc (during the passage of the measuring hole 19 from one end W1a to W3a to the other end W1b to W3b of the workpiece W). In this way, each time the measuring hole 19 passes over the surface of the workpiece W, the thickness measuring portion 22 outputs a thickness data group formed of multiple continuous data obtained by measuring the thickness of each in-plane position of the workpiece W (see FIG. 3B). The thickness data group output from the thickness measuring portion 22 is input to a shape calculation portion 23.

[0030] When inputting the thickness data group, it is also possible to separately determine a correlation between the thickness data group and measurement data (e.g., such as GBIR, ESFQD) measured by an external measuring apparatus (external measuring apparatus) capable

of measuring the thickness (shape) of the workpiece W and to input the data in consideration of a correction value or the like obtained from the correlation. The “GBIR (Global Backside Ideal Range)” indicates the value representing the difference between the maximum and minimum values of thickness distribution. The “ESFQD (Edge Site Front Least Square)” indicates the value representing a larger absolute value between the maximum and minimum values of the distance from a reference plane at the outer peripheral portion of the wafer.

[0031] Furthermore, the thickness data group and the values of the in-plane flatness and the outer peripheral flatness described later do not necessarily have a high correlation with the measurement data from the external measuring apparatus. For this reason, the thickness data group may be corrected for the thickness data group or in-plane flatness, and outer peripheral flatness, at any time or at a desired timing, based on values such as a value obtained from a difference database in which differences between the thickness data group and measurement data from an external measuring apparatus are stored, a value obtained by inputting the obtained value into a conversion equation, or a value obtained by inputting the measurement data obtained by the external measuring apparatus into the conversion equation.

[0032] The difference database may be updated through learning as needed. As a result, it becomes possible to understand the correlation between the thickness data group measured by the thickness measuring portion 22 and the measurement data from the external measuring apparatus. Thus, for example, it becomes possible to input the target value of the workpiece shape to the controller 30 in accordance with the measurement standard of the external measuring apparatus.

[0033] The shape calculation portion 23 converts the shape of workpiece W (hereinafter referred to as “workpiece shape”) into numerical information, based on the thickness data group of the workpiece W measured by the thickness measuring portion 22. In the first embodiment, the workpiece shape is indicated by the in-plane flatness and the outer peripheral flatness. Information about the in-plane flatness and the outer peripheral flatness output from the shape calculation portion 23 is input to the controller 30.

[0034] Here, the “in-plane flatness” refers to the flatness of an in-plane area G set on the workpiece W, and indicates the slope value of an approximate straight line (approximate straight line indicated by A in FIGS. 4A and 4B) set, for example, by a least-squares method for the thickness data group in the in-plane area G. An approximate straight line indicated by A’ in FIGS. 4A and 4B is also an approximate straight line set for the thickness data group in the in-plane area G. However, when the shape calculation portion 23 converts the shape of the workpiece into numerical information, the right-side area of a workpiece center Wo (in-plane area G’ and outer peripheral area E’) is excluded, when viewing a sectional shape of the workpiece W along a straight line through the workpiece center Wo.

[0035] The approximate straight line is represented by the following formula (1), and the slope value of the approximate straight line corresponds to “a” in the following formula (1).

$$\text{Approximate straight line: } Y = aX + b \quad (1)$$

a: slope value

b: intercept

[0036] When the in-plane flatness is a positive value, the workpiece shape has a convex shape with a projection at the center of the in-plane area G. When the in-plane flatness is a negative value, the workpiece has a concave shape with a depression at the center of the in-plane area G.

[0037] The “outer peripheral flatness” refers to the flatness of the outer peripheral area E set on the workpiece W. The outer peripheral flatness is determined by conducting a successive process on the slope value of the approximate straight line set for the thickness data group of the outer peripheral area E with respect to the in-plane flatness. The “successive process on the slope value of the approximate straight line set for the thickness data group of the outer peripheral area E with reference to the in-plane flatness” refers to a process of adding or subtracting the slope value of the approximate straight line, which is set for the thickness data group of the outer peripheral area E, to or from the in-plane flatness. In other words, the “successive process” includes a process (calculation of a sum value) of adding the in-plane flatness and the slope value of the approximate straight line set for the thickness data group of

the outer peripheral area E, and a process (calculation of a difference value) of obtaining the difference between the in-plane flatness and the slope value of the approximate straight line set for the thickness data group of the outer peripheral area E.

[0038] The outer peripheral flatness of the first embodiment is determined by adding the slope value of the approximate straight line (straight line indicated by B in FIGS. 4A and 4B), which is set for the thickness data group in the outer peripheral area E, to the in-plane flatness, and corresponds to the sum of the in-plane flatness and the slope value of the approximate straight line in the outer peripheral area E.

[0039] When the outer peripheral flatness is a positive value, the workpiece shape becomes a rolled-up shape in which the outer peripheral area E rises from the in-plane area G. When the outer peripheral flatness is a negative value, the workpiece shape becomes a rolled-off shape in which the outer peripheral area E falls from the in-plane area G.

[0040] As shown in FIGS. 3A and 3B, the “outer peripheral area E” is an area of a predetermined range from an outer peripheral edge W_e toward the inner radial direction. As shown in FIGS. 3A and 3B, the “in-plane area G” is an area of a predetermined range from the inner radial edge of the outer peripheral area E to the workpiece center W_o . In other words, as shown in FIG. 3A, the outer peripheral area E is an annular area between the outer peripheral edge W_e of the workpiece W and a circle shown by a dashed line set within the workpiece W, and is set at a peripheral portion of the workpiece W. The in-plane area G is a circular area surrounded by the circle shown by the dashed line set within the workpiece W and is set at a center portion of the workpiece W. As shown in FIG. 3B, when a cross section of the workpiece W is viewed along a straight line passing through the workpiece center W_o , the in-plane areas G and the outer peripheral areas E are symmetrically set with respect to the workpiece center W_o . The setting range of the outer peripheral area E may be determined as desired.

[0041] FIG. 4A shows approximate straight lines created based on the thickness data group of the workpiece W in a first example. In the case shown in FIG. 4A, the slope value of an

approximate straight line A in the in-plane area G is +50 (nm: nanometers), and the slope value of an approximate straight line B in the outer peripheral area E is 0 (nm). Therefore, the in-plane flatness of the workpiece W in the first example is +50 (nm), and the outer peripheral flatness is +50 (= +50 + 0) (nm).

5 [0042] FIG. 4B shows approximate straight lines created based on the thickness data group of the workpiece W in a second example. In the case shown in FIG. 4B, the slope value of an approximate straight line A in the in-plane area G is +30 (nm), and the slope value of an approximate straight line B in the outer peripheral area E is -30 (nm). Therefore, the in-plane flatness of the workpiece W in the second example is +30 (nm), and the outer peripheral flatness
10 is 0 (= +30 + (-30)) (nm).

[0043] As shown in FIG. 5, the outer peripheral area E may be divided into a plurality of sections (three in the example shown in FIG. 5). In this case, the outer peripheral flatness is calculated for each section Ei, Eo1, Eo2 of the outer peripheral area E.

[0044] In other words, in the example shown in FIG. 5, a predetermined section adjacent to
15 the in-plane area G in the outer peripheral area E is defined as an innermost section Ei. A section that is adjacent to the innermost section Ei and located outward of the innermost section Ei in the radial direction is defined as a first outer section Eo1. Furthermore, a section that is adjacent to the first outer section Eo1 and located outward of the first outer section Eo1 in the radial direction is defined as a second outer section Eo2.

20 [0045] The flatness of the innermost section Ei is determined by a successive process on the slope value of the approximate straight line set for the thickness data group of the innermost section Ei with respect to the in-plane flatness. Here, the flatness of the innermost section Ei is determined by adding the slope value of the approximate straight line set for the thickness data group of the innermost section Ei to the in-plane flatness. In other words, the flatness of
25 the innermost section Ei in the first embodiment is the sum of the in-plane flatness and the slope value of the approximate straight line of the innermost section Ei.

[0046] The flatness of the first outer section Eo1 is determined by a successive process on the

slope value of the approximate straight line set for the thickness data group of the first outer section Eo1 with respect to the flatness of the section (innermost section Ei) that is adjacent to the inner radial side of the first outer section Eo1. Here, the flatness of the first outer section Eo1 is determined by adding the slope value of the approximate straight line set for the thickness data group of the first outer section Eo1 to the flatness of the innermost section Ei. In other words, the flatness of the first outer section Eo1 in the first embodiment is the sum of the flatness of the innermost section Ei and the slope value of the approximate straight line of the first outer section Eo1.

[0047] The flatness of the second outer section Eo2 is determined by a successive process on the slope value of the approximate straight line set for the thickness data group of the second outer section Eo2 with respect to the flatness of the section (first outer section Eo1) that is adjacent to the inner radial side of the second outer section Eo2. Here, the flatness of the second outer section Eo2 is determined by adding the slope value of the approximate straight line set for the thickness data group of the second outer section Eo2 to the flatness of the first outer section Eo1. In other words, the flatness of the second outer section Eo2 in the first embodiment is the sum of the flatness of the first outer section Eo1 and the slope value of the approximate straight line of the second outer section Eo2.

[0048] Furthermore, the shape calculation portion 23 continuously calculates numerical information (in-plane flatness and outer peripheral flatness) indicative of the workpiece shape at any intervals (e.g., every 10 to 15 seconds) during polishing of the workpiece W. This allows the controller 30 to obtain each of the degree of change in the in-plane flatness and the degree of change in the outer peripheral flatness during the polishing.

[0049] Here, the degree of change in the in-plane flatness is indicated by the slope value of the approximate straight line set by, for example, the least-squares method for the data group of the in-plane flatness shown by white circles in FIG. 6, that is, the rate of change in the in-plane flatness over a predetermined period of time. The degree of change in the outer peripheral flatness is indicated by the slope value of the approximate straight line set by, for

example, the least-squares method for the data group of the outer peripheral flatness shown by black circles in FIG. 6, that is, the rate of change in the outer peripheral flatness over a predetermined period of time. Then, the controller 30 determines the change tendency of the workpiece shape based on the degree of change in the in-plane flatness and the degree of change
 5 in the outer peripheral flatness.

[0050] In other words, when the degree of change in the in-plane flatness is a positive value, the controller 30 determines that the change tendency of the in-plane area G is a tendency to change toward a convex shape. When the degree of change in the in-plane flatness is a negative value, it determines that the change tendency of the in-plane area G is a tendency to
 10 change toward a concave shape. For example, in the example shown in FIG. 6, the degree of change in the in-plane flatness at time t_0 (the slope value of the approximate straight line set for the data group of the in-plane flatness over a short period of time including time t_0 as a reference) becomes a negative value as shown by a dotted line. Therefore, it is determined that the change tendency of the in-plane area G after time t_0 is a change tendency to change
 15 toward a concave shape.

[0051] When the degree of change in the outer peripheral flatness is a positive value, the controller 30 determines that the change tendency of the outer peripheral area E is a tendency to change toward roll-up (ascending). When the degree of change in the outer peripheral flatness is a negative value, the controller 30 determines that the change tendency of the outer
 20 peripheral area E is a tendency to change toward roll-off (descending). For example, in the example shown in FIG. 6, the degree of change in the outer peripheral flatness at time t_0 (the slope value of the approximate straight line set for the data group of the outer peripheral flatness over a short period of time including time t_0 as a reference) becomes a positive value as shown by a two-dot chain line. Therefore, it is determined that the change tendency of the outer
 25 peripheral area E after time t_0 is a change tendency to change toward roll-up.

[0052] The controller 30 is formed of a CPU (Central Processing Unit) or the like and includes a first learner 31, a second learner 32, a main polishing condition correcting portion 33, a main

polishing stop condition setting portion 34, a control calculation portion 35, a memory 36, and the like. An input device 41 operable by an operator of the double-sided polishing device 1 and a display 42 viewable by the operator are connected to the controller 30.

[0053] The controller 30 outputs control commands from the control calculation portion 35 to
 5 the first to fifth drive devices M1 to M5 and the like, to control the operation of the polishing machine 10, based on the measurement results of the workpiece W by the thickness measuring apparatus 20 (they may include a corrected value obtained by separately determining a correlation with the measurement data through measurement of the shape of the workpiece W by using an external measuring apparatus), the processing target of the workpiece W, the
 10 prerequisite polishing conditions, the conditions of secondary materials, etc., information about the device conditions of the polishing machine 10, the programs stored in the memory 36, the main polishing condition reset by the main polishing condition correcting portion 33, the main polishing stop condition set by the main polishing stop condition setting portion 34, etc. The processing target of the workpiece W, the prerequisite polishing conditions, the conditions of
 15 secondary materials, and the information about the device conditions of the polishing machine 10 may be input by the operator via the input device 41 or may be previously stored in the memory 36. The controller 30 appropriately displays necessary information on the display 42, while controlling the operation of the polishing machine 10.

[0054] The first learner 31 is a learner that has learned the correlation among the main
 20 polishing condition at any timing during the main polishing, the outer peripheral flatness obtained at that timing, and the in-plane flatness obtained at that timing. In other words, for example, as shown in FIG. 7, the controller 30 causes the first learner 31 of the first embodiment to learn, as a dataset, the main polishing condition at any timing during the main polishing, the outer peripheral flatness included in the main polishing condition, disturbance factors, and the
 25 in-plane flatness obtained at the same timing. Here, the main polishing condition includes, for example, the rotation speed of the lower surface plate 11, the rotation speed of the upper surface plate 12, the rotation speed of the sun gear 13, the rotation speed of the internal gear 14,

the revolution speed of the carrier plate 15, the rotation speed of the carrier plate 15, the load to be applied to the workpiece W, the slurry flow rate, the slurry type, and the like. The disturbance factors include, for example, the usage period (carrier life) of the carrier plate 15, the usage period of the polishing pads 11a, 12a, dressing conditions, and other factors as the state of the secondary materials. The device conditions include the load factor of each drive device, the temperature in an area (drive compartment) where each drive device is disposed, the temperature of the polishing pads 11a, 12a, the temperature of the slurry, the fluctuation value of the load applied to the workpiece W, etc. The main polishing conditions and the disturbance factors may be input by the operator via the input device 41, or may be detected by sensors or the like.

[0055] The second learner 32 is a learner that has learned the correlation among the endpoint polishing condition, the degree of change in the in-plane flatness when stopping the main polishing, the degree of change in the outer peripheral flatness when stopping the main polishing, and the amount of change in the outer peripheral flatness during the endpoint polishing. In other words, for example, as shown in FIG. 8, the controller 30 causes the second learner 32 of the first embodiment to learn, as a dataset, the predetermined endpoint polishing condition, the degree of change in the in-plane flatness when stopping the main polishing, the degree of change in the outer peripheral flatness when stopping the main polishing, and the amount of change in the outer peripheral flatness during the endpoint polishing that has been conducted under the endpoint polishing condition by assuming this degree of change. Here, the endpoint polishing condition includes, for example, the rotation speed of the lower surface plate 11, the rotation speed of the upper surface plate 12, the rotation speed of the sun gear 13, the rotation speed of the internal gear 14, the revolution speed of the carrier plate 15, the rotation speed of the carrier plate 15, the load to be applied to the workpiece W, the slurry flow rate, the slurry type, the endpoint polishing time period (speed reduction time period), and the like. The endpoint polishing conditions may be input by the operator via the input device 41, or may be detected by sensors or the like.

[0056] The “degree of change in the in-plane flatness when stopping the main polishing” is defined as the slope value of the approximate straight line set for the data group of the in-plane flatness over a short time period including the main polishing stop time (timing at which the main polishing is stopped) as a reference. The “degree of change in the outer peripheral flatness when stopping the main polishing” is defined as the slope value of the approximate straight line set for the data group of the outer peripheral flatness over a short time period including the main polishing stop time as a reference. The “amount of change in the outer peripheral flatness during the endpoint polishing” is defined as the difference between the outer peripheral flatness at the main polishing stop time and the outer peripheral flatness at the endpoint polishing completion time.

[0057] The main polishing condition correcting portion 33 determines the correction target value of the in-plane flatness to bring the calculated value of the in-plane flatness closer to the target value, based on the estimated value of the in-plane flatness obtained by inputting, to the first learner 31, the main polishing condition set at the correction time and the calculated value of the outer peripheral flatness at the correction time. Then, the main polishing condition correcting portion 33 corrects the main polishing condition set at the correction time, by the main polishing condition obtained by inputting, into the first learner 31, the correction target value of the in-plane flatness and the final target value of the outer peripheral flatness at the polishing completion time. In other words, the main polishing condition correcting portion 33 uses the first learner 31 to obtain the main polishing condition that satisfies the target value of the outer peripheral flatness and the correction target value, and then resets the obtained main polishing condition as a new main polishing condition in place of the main polishing condition set at the correction time. Under the newly set main polishing condition, changes will be made to at least one of, for example, the rotation speed of the lower surface plate 11, the rotation speed of the upper surface plate 12, the rotation speed of the sun gear 13, the rotation speed of the internal gear 14, the revolution speed of the carrier plate 15, the rotation speed of the carrier plate 15, the load to be applied to the workpiece W, the slurry flow rate, the slurry type and

supply destination of the slurry, or the like.

[0058] The “correction target value of the in-plane flatness to bring the calculated value of the in-plane flatness closer to the target value” is determined by the following procedures. That is, the main polishing condition correcting portion 33 firstly inputs the main polishing condition at the correction time and the calculated value of the outer peripheral flatness at the correction time to the first learner 31 to obtain the estimated value of the in-plane flatness. Then, the main polishing condition correcting portion 33 calculates the difference between the calculated value of the in-plane flatness at the correction time and the estimated value of the in-plane flatness. Then, the main polishing condition correcting portion 33 sets, as the “correction target value”, a value obtained by subtracting the difference in in-plane flatness from the final target value of the in-plane flatness at the time of polishing completion.

[0059] The main polishing stop condition setting portion 34 obtains the amount of change in the outer peripheral flatness during the endpoint polishing by inputting, into the second learner 32, the endpoint polishing condition, the degree of change in the in-plane flatness at the time of the calculation, and the degree of change in the outer peripheral flatness at the time of the calculation. Then, it sets a condition to stop the main polishing (main polishing stop condition), based on the obtained amount of change in the outer peripheral flatness and the final target value of the outer peripheral flatness at the polishing completion time. Here, the main polishing stop condition is determined by the outer peripheral flatness at the main polishing stop time.

[0060] In other words, the main polishing stop condition setting portion 34 inputs, into the second learner 32, the endpoint polishing condition, the degree of change in the in-plane flatness at the time of the calculation (the slope value of the approximate straight line set for the data group of the in-plane flatness in a short time period including the calculation time as a reference), and the degree of change in the outer peripheral flatness at the time of the calculation (the slope value of the approximate straight line set for the data group of the outer peripheral flatness in a short time period including the calculation time as a reference), thereby obtaining

the amount of change in the outer peripheral flatness during the endpoint polishing in consideration of the degrees of the changes. Then, the main polishing stop condition setting portion 34 calculates the target value of the outer peripheral flatness at the main polishing stop time by performing a back calculation from the obtained amount of change in the outer peripheral flatness, the final target value of the outer peripheral flatness at the polishing completion time, and the endpoint polishing time period. The calculated target value of the outer peripheral flatness is set as the main polishing stop condition.

[0061] During the execution of the initial polishing, the controller 30 outputs control commands from the control calculation portion 35 to the first drive device M1 to the fifth drive device M5 in accordance with the initial polishing condition previously set in the prerequisite polishing conditions.

[0062] When starting the main polishing, the controller 30 outputs control commands from the control calculation portion 35 to the first drive device M1 through the fifth drive device M5 in accordance with the main polishing condition previously set in the prerequisite polishing conditions.

[0063] During the execution of the main polishing, the controller 30 corrects the main polishing condition by using the first learner 31 and the main polishing condition correcting portion 33. When the main polishing condition has been corrected, the controller 30 outputs control commands from the control calculation portion 35 to the first drive device M1 through the fifth drive device M5 in accordance with the corrected main polishing condition (the newly reset main polishing condition).

[0064] Furthermore, during the execution of the main polishing, the controller 30 sets the main polishing stop condition by using the second learner 32 and the main polishing stop condition setting portion 34. When the main polishing stop condition has been satisfied, the controller 30 outputs control commands from the control calculation portion 35 to the first drive device M1 through the fifth drive device M5 to stop the main polishing and execute the endpoint polishing.

[0065] During the execution of the endpoint polishing, the controller 30 outputs control commands from the control calculation portion 35 to the first drive device M1 through the fifth drive device M5 in accordance with the endpoint polishing condition previously set in the prerequisite polishing conditions.

5 [0066] FIG. 9 is a flowchart showing a flow of a polishing process executed by the controller 30 of the double-sided polishing device 1 of the first embodiment. In the following, with reference to FIG. 9, the flow of the polishing process in the first embodiment will be described. The polishing process is executed in a state in which the carrier plate 15 and the workpiece W are set in the polishing machine 10. During the polishing process (from the start of executing
10 the initial polishing to the completion of the endpoint polishing), the thickness measuring apparatus 20 continuously inputs the shape information (information about the in-plane flatness and the outer peripheral flatness) of the workpiece W to the controller 30.

[0067] In Step S1, the controller 30 sets the final target value of the in-plane flatness at the endpoint polishing completion time and the final target value of the outer peripheral flatness at
15 the endpoint polishing completion time, which serve as the final processing targets of the workpiece W, and proceeds to Step S2. The target value of the in-plane flatness and the target value of the outer peripheral flatness are input by an operator by using the input device 41. The processing target of the workpiece W may, for example, be previously set for each type of the workpiece W and may be stored in the memory 36. In this case, the controller 30 reads
20 the processing target of the workpiece W from the memory 36 and sets the target based on the type of the workpiece W input by the operator.

[0068] In Step S2, following the setting of the workpiece processing target in Step S1, the controller 30 sets the prerequisite polishing conditions, and then proceeds to Step S3. The prerequisite polishing conditions are various conditions that are set in advance based on the
25 processing target of the workpiece W and for each type of the workpiece W, and that serve as prerequisites when polishing the workpiece W. The prerequisite polishing conditions include, for example, the initial polishing condition including the polishing time and the polishing

completion condition in the initial polishing, the main polishing condition at the main polishing start time, the endpoint polishing condition including the polishing time and the polishing completion condition in the endpoint polishing, information about the slurry such as slurry flow rate, slurry type, and slurry destination, and information about the status of consumable secondary materials such as carrier life. The prerequisite polishing conditions are input by the operator by using the input device 41 or read from the memory 36.

[0069] In Step S3, following the setting of the prerequisite polishing conditions in Step S2 or the determination that the initial polishing has not been completed in Step S4, the controller 30 outputs control commands from the control calculation portion 35 to the first drive device M1 through the fifth drive device M5 in accordance with the initial polishing condition determined by the prerequisite polishing conditions to execute the initial polishing, and then proceeds to Step S4. During the execution of the initial polishing, the polishing machine 10 polishes the workpiece W, while gradually increasing the load applied to the workpiece W and also gradually increasing the rotation speeds of the lower surface plate 11 and the upper surface plate 12, the rotation speed of the sun gear 13, and the rotation speed of the internal gear 14.

[0070] In Step S4, following the execution of the initial polishing in Step S3, the controller 30 determines whether or not the initial polishing has been completed. If the determination by the controller 30 is YES (the initial polishing is complete), the process proceeds to Step S5. If the determination is NO (the initial polishing is incomplete), the process returns to Step S3. Here, the controller 30 determines that the initial polishing has been completed, if the initial polishing complete condition determined by the prerequisite polishing conditions is satisfied, such as when the load applied to the workpiece W has reached a predetermined load, or when the rotation speed of the lower surface plate 11 or the like has reached a predetermined rotation speed.

[0071] In Step S5, following the determination in Step S4 that the initial polishing has been completed, the controller 30 outputs control commands from the control calculation portion 35 to the first drive device M1 through the fifth drive device M5 in accordance with the main

polishing condition determined by the prerequisite polishing conditions to start the execution of the main polishing, and then the process proceeds to Step S6 and Step S7. During the execution of the main polishing, the polishing machine 10 adjusts the load, which is applied to the workpiece W, to the target load determined by the main polishing condition, and polishes the workpiece W while respectively adjusting the rotation speeds of the lower surface plate 11 and the upper surface plate 12, the rotation speed of the sun gear 13, and the rotation speed of the internal gear 14 to the target rotation speeds.

[0072] In Step S6, following the start of the execution of the main polishing in Step S5, the controller 30 corrects the main polishing condition by using the main polishing condition correcting portion 33. The correction of the main polishing condition is executed in parallel with the setting of the main polishing stop condition in Step S7, which is described later, and is repeatedly executed at constant intervals (e.g., at intervals of around 300 seconds) until it is determined to stop the main polishing in Step S8, which is described later.

[0073] Here, the main polishing condition correcting portion 33 corrects the main polishing condition through the following procedures.

- (1) Input the main polishing condition at the correction time and the calculated value of the outer peripheral flatness at the correction time into the first learner 31 to obtain the estimated value of the in-plane flatness at the correction time under the main polishing condition.
- (2) Subtract the estimated value of the in-plane flatness obtained in (1) from the calculated value of the in-plane flatness at the correction time to calculate the difference in the in-plane flatness (difference between the estimated value of the in-plane flatness and the current value thereof).
- (3) Set the “correction target value” by subtracting the difference in the in-plane flatness, which has been calculated in (2), from the target value of the in-plane flatness set in Step S1.
- (4) Input the “correction target value” set in (3) and the target value of the outer peripheral flatness set in Step S1 into the first learner 31 to obtain the main polishing condition.
- (5) Correct the main polishing condition by resetting the main polishing condition

obtained in (4) as a new main polishing condition in place of the main polishing condition set at the correction time.

[0074] In Step S7, following the start of the execution of the main polishing in Step S5, the controller 30 sets the main polishing stop condition by using the main polishing stop condition setting portion 34. As described above, the setting of the main polishing stop condition is executed in parallel with the correction of the main polishing condition in Step S6 and is repeatedly executed at constant intervals (e.g., at intervals of around 1 second) until it is determined to stop the main polishing in Step S8, which is described later.

[0075] Here, the main polishing stop condition setting portion 34 sets the main polishing stop condition through the following procedures.

(1) Obtain the amount of change in the outer peripheral flatness during the endpoint polishing by inputting, into the second learner 32, the endpoint polishing condition determined based on the prerequisite polishing conditions set in Step S2, the degree of change in the in-plane flatness at the time of the calculation, and the degree of change in the outer peripheral flatness at the time of the calculation (the “time of the calculation” here is the time when setting the main polishing stop condition).

(2) Determine the outer peripheral flatness at the main polishing stop time (target value of the outer peripheral flatness at the main polishing stop time), which is required for the outer peripheral flatness at the polishing completion time to satisfy the final target value, by a back calculation from the amount of change in the outer peripheral flatness during the endpoint polishing obtained in Step S1, the target value of the outer peripheral flatness set in Step S1, and the polishing time period of the endpoint polishing.

(3) Set the outer peripheral flatness determined in (2), as the main polishing stop condition. The calculation of the outer peripheral flatness in (2) is continuously conducted at constant intervals. Therefore, the main polishing stop condition is updated each time when the outer peripheral flatness is calculated.

[0076] In Step S8, following the setting of the main polishing stop condition in Step S7, the

controller 30 determines whether or not to stop the main polishing. If the determination by the controller 30 is YES (main polishing stopping), the process proceeds to Step S9. If the determination is NO (main polishing continuation), the process returns to Step S7. Here, the main polishing stop condition is that the calculated value of the outer peripheral flatness has reached the outer peripheral flatness set as the main polishing stop condition in Step S7.

5 Therefore, in Step S8, it is determined whether or not the current outer peripheral flatness matches the outer peripheral flatness determined in Step S7.

[0077] In Step S9, following the determination of the main polishing stopping in Step S8, the controller 30 stops the main polishing and outputs control commands from the control calculation portion 35 to the first drive device M1 through the fifth drive device M5 in accordance with the endpoint polishing condition determined based on the prerequisite polishing conditions to start executing the endpoint polishing, and the process proceeds to Step S10. During the endpoint polishing, the polishing machine 10 polishes the workpiece W while gradually reducing the load applied to the workpiece W, the rotation speed of the lower surface plate 11, the rotation speed of the upper surface plate 12, the rotation speed of the sun gear 13, and the rotation speed of the internal gear 14.

10

15

[0078] In Step S10, following the start of the execution of the endpoint polishing in Step S9, the controller 30 determines whether or not the endpoint polishing has been completed. If the determination by the controller is YES (endpoint polishing complete), the process proceeds to Step S11. If the determination is NO (endpoint polishing not complete), the process returns to Step S9. Here, the controller 30 determines that the endpoint polishing has been completed when the endpoint polishing complete condition, determined based on the prerequisite polishing conditions, is satisfied, such as when the endpoint polishing time has elapsed or when the load applied to the workpiece W has reached a predetermined value or lower.

20

[0079] In Step S11, following the determination in Step S10 that the endpoint polishing has been completed, the controller 30 stops polishing of the workpiece W with the polishing machine 10, and records various polishing data in the memory 36, and the process proceeds to

25

the end.

[0080] The action of the double-sided polishing device 1 according to the first embodiment is described below, divided into the “correction control action of the main polishing condition”, the “control action of the main polishing stop condition”, and “other control actions”.

5 [0081] [Correction Control Action of Main Polishing Condition] In the double-sided polishing device 1 according to the first embodiment, each of the in-plane flatness and the outer peripheral flatness changes during the main polishing. Therefore, it is difficult to accurately control both the in-plane flatness and the outer peripheral flatness unless the main polishing condition is set in consideration of the correlation between the in-plane flatness and the outer peripheral flatness.

10 [0082] In other words, in a double-sided polishing device in which only the correlation between the in-plane flatness, under a condition where the outer peripheral flatness is 0 (nm), and the main polishing condition in that case is learned by a learner (hereinafter referred to as the “comparative example’s learner”), and in which the main polishing condition is obtained by inputting the target value of the in-plane flatness into the comparative example’s learner
15 (hereinafter referred to as the “comparative example’s double-sided polishing device”), the condition of the outer peripheral flatness is not taken into consideration. As a result, it is not possible to achieve a proper workpiece shape.

[0083] Specifically, for example, assume that there is a workpiece W (hereinafter referred to as “exemplified workpiece W”) whose shape change for each main polishing condition is as
20 shown in FIG. 10. In other words, if the main polishing is executed on the exemplified workpiece W’ under the main polishing condition A, the in-plane flatness becomes +80 (nm) when the outer peripheral flatness is 0 (nm); the in-plane flatness becomes +90 (nm) when the outer peripheral flatness is -20 (nm); the in-plane flatness becomes +100 (nm) when the outer peripheral flatness is -50 (nm). If the main polishing is executed under the main polishing
25 condition B, the in-plane flatness becomes 0 (nm) when the outer peripheral flatness is 0 (nm); the in-plane flatness becomes +10 (nm) when the outer peripheral flatness is -20 (nm); the in-plane flatness becomes +20 (nm) when the outer peripheral flatness is -50 (nm). If the main

polishing is executed under the main polishing condition C, the in-plane flatness becomes -20 (nm) when the outer peripheral flatness is 0 (nm); the in-plane flatness becomes 0 (nm) when the outer peripheral flatness is -20 (nm); the in-plane flatness becomes +10 (nm) when the outer peripheral flatness is -50 (nm).

5 [0084] In contrast, as described above, in the double-sided polishing device according to the comparative example, only the correlation between the in-plane flatness, when the outer peripheral flatness is 0 (nm), and the main polishing condition is learned by the comparative example's learner. Therefore, as shown in FIG. 11, according to the dataset to be learned by the comparative example's learner, the in-plane flatness becomes +80 (nm) for the main
10 polishing condition A; the in-plane flatness becomes 0 (nm) for the main polishing condition B; the in-plane flatness becomes -20 (nm) for the main polishing condition C.

[0085] Here, consider the case where the exemplified workpiece W' is polished such that the in-plane flatness becomes 0 (nm) when the outer peripheral flatness is -20 (nm). In this case, the outer peripheral flatness cannot be taken into account by the double-sided polishing device
15 according to the comparative example. Therefore, when the target value (herein 0 (nm)) of the in-plane flatness is input into the comparative example's learner while ignoring the outer peripheral flatness, the result is the "main polishing condition B". However, when the main polishing is executed on the exemplified workpiece W' under the main polishing condition B, it is assumed that the in-plane flatness becomes +10 (nm) at the timing when the outer peripheral
20 flatness is -20 (nm) during the main polishing in the double-sided polishing device according to the comparative example. It is also assumed that the outer peripheral flatness becomes 0 (nm) if the in-plane flatness is set to 0 (nm). In other words, the double-sided polishing device according to the comparative example cannot make both of the in-plane flatness and the outer peripheral flatness match precisely with their target values.

25 [0086] In contrast, the double-sided polishing device 1 of the first embodiment includes the first learner 31 and the main polishing condition correcting portion 33. The first learner 31 is a learner that has learned a correlation among the main polishing condition, the outer peripheral

flatness, and the in-plane flatness. In other words, as shown in FIG. 10, the dataset to be learned by the first learner 31 of the first embodiment is formed of various main polishing conditions and both the outer peripheral flatness and the in-plane flatness under those conditions. The main polishing condition correcting portion 33 corrects the main polishing condition during the main polishing by the main polishing condition obtained by inputting, into the first learner 31, the final target value of the outer peripheral flatness and the correction target value, which has been determined based on the estimated value of the in-plane flatness obtained by inputting, into the first learner 31, the main polishing condition set at the correction time and the calculated value of the outer peripheral flatness at the correction time.

[0087] In other words, the double-sided polishing device 1 of the first embodiment inputs the main polishing condition at the correction time and the calculated value of the outer peripheral flatness at the correction time into the first learner 31 during the execution of the main polishing. Then, the double-sided polishing device 1 of the first embodiment obtains the estimated value of the in-plane flatness at the correction time from the input information into the first learner 31 and the learning result of the first learner 31, and calculates the difference between the estimated value and the actual in-plane flatness at the correction time. Then, the double-sided polishing device 1 of the first embodiment determines the “correction target value” by subtracting the difference from the target value of the in-plane flatness. Then, the double-sided polishing device 1 obtains a new main polishing condition by inputting the “correction target value” of the in-plane flatness and the target value of the outer peripheral flatness into the first learner 31 to correct the main polishing condition set at the correction time (Step S6).

[0088] Assuming that the dataset to be learned by the first learner 31 is the content shown in FIG. 10, a specific example will be described below in which the main polishing is performed on a predetermined workpiece W with the targets of 0 (nm) in-plane flatness and 0 (nm) outer peripheral flatness at the final polishing completion time in the double-sided polishing device 1 of the first embodiment.

[0089] In this case, since the final target values at the polishing completion time are 0 (nm)

in-plane flatness and 0 (nm) outer peripheral flatness, the main polishing is started by setting under the main polishing condition B. When the main polishing condition is corrected at the timing when the calculated value of the outer peripheral flatness becomes -20 (nm) during the main polishing under the main polishing condition B, the “main polishing condition B” as the
 5 main polishing condition at the correction time and “-20 (nm)” as the calculated value of the outer peripheral flatness at the correction time are input into the first learner 31 (see FIG. 10), and the estimated value of the in-plane flatness becomes “+10 (nm)”.

[0090] In contrast, assume that the calculated value of the in-plane flatness (actual in-plane flatness) is +30 (nm) due to external disturbances or other factors.

10 [0091] In this case, the estimated value of the in-plane flatness is “+10 (nm)”, but the calculated value of the in-plane flatness is “+30 (nm)”. This can lead to an estimation that the actual in-plane flatness during the main polishing becomes +20 (nm) greater than the learning result of the first learner 31.

[0092] Thus, the double-sided polishing device 1 of the first embodiment calculates the
 15 difference (+20 (nm)) between the estimated value “+10 (nm)” of the in-plane flatness and the calculated value “+30 (nm)” of the in-plane flatness. Then, the “difference value (+20 (nm)) is subtracted from the target value (0 (nm)) of the in-plane flatness to obtain the “correction target value (-20 (nm))”. Then, the double-sided polishing device 1 of the first embodiment inputs the correction target value (-20 (nm)) of the in-plane flatness and the target value (0
 20 (nm)) of the outer peripheral flatness. As a result, the “main polishing condition C”, which is a new main polishing condition, is obtained. Then, the “main polishing condition C” is set as the new main polishing condition, in place of the main polishing condition (main polishing condition B) that was set at the correction time.

[0093] If the main polishing is executed by correcting the main polishing condition to the main
 25 polishing condition C, it is estimated from the learning result of the first learner 31 that, when the outer peripheral flatness is 0 (nm), the in-plane flatness becomes -20 (nm). However, as mentioned above, it is estimated that the actual in-plane flatness in the main polishing becomes

+20 (nm) greater than the learning result of the first learner 31. Therefore, the double-sided polishing device 1 can set the in-plane flatness to 0 (nm) when the outer peripheral flatness is 0 (nm). In this manner, the double-sided polishing device 1 of the first embodiment can correct the main polishing condition in consideration of the correlation between the in-plane flatness and the outer peripheral flatness and can precisely control both the in-plane flatness and the outer peripheral flatness.

[0094] [Control Action of Main Polishing Stop Condition] In the double-sided polishing device 1 of the first embodiment, it is known that the workpiece shape, particularly the outer peripheral flatness, changes due to the endpoint polishing. Therefore, even if the workpiece shape at the main polishing stop time has reached the target shape, the endpoint polishing may change the outer peripheral flatness, thereby causing the final workpiece shape to deviate from the target shape. Moreover, if the degree of change in the workpiece at the main polishing stop time varies, the amount of change in the outer peripheral flatness during the endpoint polishing differs, even when the endpoint polishing is conducted under the same endpoint polishing condition. As a result, it is assumed that the final workpiece shape becomes different from the workpiece shape at the main polishing stop time and greatly deviates from the target shape. Therefore, it is necessary to stop the main polishing in consideration of the amount of change in the outer peripheral flatness, based on the degree of change in the workpiece shape.

[0095] Regarding this, the double-sided polishing device 1 of the first embodiment includes the second learner 32 and the main polishing stop condition setting portion 34. Here, the second learner 32 is a learner that has learned a correlation among the endpoint polishing condition, the degree of change in the in-plane flatness at the main polishing stop time, the degree of change in the outer peripheral flatness at the main polishing stop time, and the amount of change in the outer peripheral flatness during the endpoint polishing. The main polishing stop condition setting portion 34 sets a condition to stop the main polishing (main polishing stop condition) such that the outer peripheral flatness of the workpiece W becomes the target

outer peripheral flatness calculated based on the target value of the outer peripheral flatness at the endpoint polishing completion time and the amount of change in the outer peripheral flatness during the endpoint polishing, which has been obtained by inputting into, the second learner 32, the endpoint polishing condition, the degree of change in the in-plane flatness at the calculation time, and the degree of change in the outer peripheral flatness at the calculation time.

[0096] In other words, when setting the main polishing stop condition, the double-sided polishing device 1 of the first embodiment inputs the endpoint polishing condition, the degree of change in the in-plane flatness at the calculation time, and the degree of change in the outer peripheral flatness at the calculation time into the second learner 32. Then, the double-sided polishing device 1 of the first embodiment obtains the amount of change in the outer peripheral flatness during the endpoint polishing from the input information to the second learner 32 and the learning result of the second learner 32. Then, it determines the target value of the outer peripheral flatness at the main polishing stop time (target outer peripheral flatness), which is necessary for satisfying the target value of the outer peripheral flatness, by a back calculation from the amount of change in the outer peripheral flatness during the endpoint polishing, the final target value of the outer peripheral flatness, and the endpoint polishing time period. Then, it determines the main polishing stop condition using the target outer peripheral flatness (Step S7).

[0097] In this way, the double-sided polishing device 1 of the first embodiment can stop the main polishing such that the outer peripheral flatness at the main polishing stop time becomes an appropriate shape that takes into account the amount of change in the outer peripheral flatness by the endpoint polishing based on the degrees of change in the in-plane flatness and the outer peripheral flatness. Therefore, the double-sided polishing device 1 of the first embodiment can prevent the workpiece shape from significantly deviating from the target shape at the endpoint polishing completion time (final polishing completion time), even if the shape change in the workpiece W occurs by the endpoint polishing.

[0098] FIG. 12 shows the summarized results of the shape of the workpiece W after the execution of the endpoint polishing, with the target value of the outer peripheral flatness at the polishing completion being set to 0 (nm), in the double-sided polishing device 1 of the first embodiment. As shown in FIG. 12, the first sample workpiece exhibited an in-plane flatness of +34 (nm) and an outer peripheral flatness of -2 (nm). The second sample workpiece exhibited an in-plane flatness of -4 (nm) and an outer peripheral flatness of -5 (nm). The third sample workpiece exhibited an in-plane flatness of +40 (nm) and an outer peripheral flatness of -3 (nm). The fourth sample workpiece exhibited an in-plane flatness of +62 (nm) and an outer peripheral flatness of -3 (nm).

[0099] These results show that the double-sided polishing device 1 of the first embodiment can reduce the difference between the actual outer peripheral flatness and its target value (0 (nm)), regardless of the magnitude of the in-plane flatness. Therefore, it is understood that the double-sided polishing device 1 of the first embodiment can prevent the workpiece shape from significantly deviating from the target shape at the endpoint polishing completion time (final polishing completion time).

[0100] FIG. 13 shows the polishing results of the workpieces W at the final polishing completion time, when the workpieces W were polished by using the double-sided polishing device 1 of the first embodiment. As shown in FIG. 13, in the fifth sample workpiece, when the target values of the in-plane flatness and the outer peripheral flatness were respectively set to 0 (nm) and 0 (nm), the polishing results were -1 (nm) in the in-plane flatness and +3 (nm) in the outer peripheral flatness. In the sixth sample workpiece, when the target values of the in-plane flatness and the outer peripheral flatness were respectively set to 0 (nm) and -20 (nm), the polishing results were -4 (nm) in the in-plane flatness and -20 (nm) in the outer peripheral flatness. In the seventh sample workpiece, when the target values of the in-plane flatness and the outer peripheral flatness were respectively set to -30 (nm) and 0 (nm), the polishing results were -30 (nm) in the in-plane flatness and +2 (nm) in the outer peripheral flatness. In the eighth sample workpiece, when the target values of the in-plane flatness and the outer peripheral

flatness were respectively set to +30 (nm) and 0 (nm), the polishing results were +30 (nm) in the in-plane flatness and +3 (nm) in the outer peripheral flatness. In the ninth sample workpiece, when the target values of the in-plane flatness and the outer peripheral flatness were respectively set to 0 (nm) and 0 (nm), the polishing results were -5 (nm) in the in-plane flatness and -4 (nm) in the outer peripheral flatness.

[0101] From the results shown in FIG. 13, it has become clear that the double-sided polishing device 1 of the first embodiment can prevent both the in-plane flatness and the outer peripheral flatness from significantly deviating from the target values, and can suppress the shape of the workpiece at the final polishing completion time from deviating from the target shape.

[0102] [Other Control Actions] In the double-sided polishing device 1 of the first embodiment, the in-plane area G and the outer peripheral area E are set on the workpiece W, and the shape of the workpiece W is numerically represented by the in-plane flatness and the outer peripheral flatness. In other words, in the first embodiment, the workpiece shape is controlled by dividing it into multiple areas. On the other hand, the workpiece W to be polished by the double-sided polishing device 1 of the first embodiment may be used as a substrate for semiconductor devices on which fine electronic circuits are formed on the surface. Here, the electronic circuits to be formed on the surface of the workpiece W may be formed across a boundary between the in-plane area G and the outer peripheral area E. Therefore, it is desirable that the workpiece shape be smooth at the boundary between the in-plane area G and the outer peripheral area E so that no inflection point is formed at the boundary. To control the workpiece shape so that no inflection point is formed at the boundary between the in-plane area G and the outer peripheral area E, it is necessary to numerically express the flatness (smoothness of the workpiece shape) at the boundary between different areas such as the in-plane area G and the outer peripheral area E, i.e., the slope change in the workpiece shape at the boundary between the in-plane area G and the outer peripheral area E.

[0103] Regarding this, in the double-sided polishing device 1 of the first embodiment, the in-plane flatness is defined as the slope value of an approximate straight line set for the thickness

data group of the in-plane area G. The outer peripheral flatness is determined by conducting a successive process on the slope value of an approximate straight line set for the thickness data group of the outer peripheral area E with reference to the in-plane flatness. In other words, in the double-sided polishing device 1 of the first embodiment, the outer peripheral flatness is defined as the sum of the in-plane flatness and the slope value of the approximate straight line set for the thickness data group of the outer peripheral area E.

[0104] In this way, the double-sided polishing device 1 of the first embodiment separately calculates the in-plane flatness and the outer peripheral flatness. The outer peripheral flatness is determined by conducting a successive process on the slope value of an approximate straight line set for the thickness data group of the outer peripheral area E with respect to the in-plane flatness. While the slope value of the approximate straight line set for the data group of the in-plane area G is defined as a reference line, the slope value of the approximate straight line set for the data group of the outer peripheral area E with respect to the reference line can be numerically expressed as the outer peripheral flatness. Therefore, the outer peripheral flatness can be indicated as an index that represents the degree of roll-off relative to the in-plane flatness, and the flatness (smoothness of the workpiece shape) at the boundary between different areas, such as the in-plane area G and the outer peripheral area E, can be numerically expressed. The double-sided polishing device 1 of the first embodiment can indicate the shape of the workpiece W by numerical values, making it easier for an operator or the like to grasp the workpiece shape.

[0105] The outer peripheral flatness may be determined by subtracting the slope value of the approximate straight line set for the thickness data group of the outer peripheral area E from the in-plane flatness. In other words, the outer peripheral flatness may be the difference between the in-plane flatness and the slope value of the approximate straight line set for the thickness data group of the outer peripheral area E.

[0106] Furthermore, in the double-sided polishing device 1 of the first embodiment, the outer peripheral area E may be divided into a plurality of sections in the radial direction of the workpiece W, and the outer peripheral flatness may be calculated for each of the divided outer

peripheral areas (innermost section Ei and outer section Eo). By dividing the outer peripheral area E into a plurality of sections, the double-sided polishing device 1 of the first embodiment can correct the main polishing condition or set the main polishing stop condition according to the shape variation in each section. As a result, it is possible to make the workpiece shape at the final polishing completion more precisely match the target shape.

[0107] When the outer peripheral area E is divided into a plurality of sections in the double-sided polishing device 1 of the first embodiment, the section adjacent to the in-plane area G is defined as the innermost section Ei, and the section located outside the innermost section Ei in the radial direction is defined as the outer section Eo.

[0108] The flatness of the innermost section Ei is determined by conducting a successive process on the slope value of an approximate straight line set for the thickness data group of the innermost section Ei with reference to the in-plane flatness. The flatness of the innermost section Ei of the first embodiment is defined as the sum of the in-plane flatness and the slope value of the approximate straight line set for the thickness data group of the innermost section Ei. The flatness of the outer section Eo is determined by conducting a successive process on the slope value of an approximate straight line set for the thickness data group of the outer section Eo with reference to the flatness of a section (e.g., the innermost section Ei) adjacent to the inner side of the outer section Eo in the radial direction. The flatness of the outer section Eo of the first embodiment is defined as the sum of the slope value of the approximate straight line set for the thickness data group of the outer section Eo and the flatness of a section (e.g., the innermost section Ei) adjacent to the inner side of the outer section Eo in the radial direction.

[0109] As a result, according to the double-sided polishing device 1 of the first embodiment, even when the outer peripheral area E is divided into a plurality of sections, it is possible to appropriately express the flatness (smoothness of the workpiece shape) of the outer peripheral area E and to precisely control the workpiece shape.

[0110] The flatness of the innermost section Ei may be determined by subtracting the slope value of the approximate straight line set for the thickness data group of the innermost section

E_i from the in-plane flatness. In other words, the flatness of the innermost section E_i may be the difference between the in-plane flatness and the slope value of the approximate straight line set for the thickness data group of the innermost section E_i.

[0111] The flatness of the outer section E_o may be determined by subtracting the slope value of the approximate straight line set for the thickness data group of the outer section E_o from the flatness of a section (e.g., the innermost section E_i) adjacent to the inner side of the outer section E_o in the radial direction. In other words, the flatness of the outer section E_o may be the difference between the flatness of a section (e.g., the innermost section E_i) adjacent to the inner side of the outer section E_o in the radial direction and the slope value of the approximate straight line set for the thickness data group of the outer section E_o.

[0112] The outer section E_o of the first embodiment is divided into two sections, the first outer section E_{o1} and the second outer section E_{o2}. However, the outer section E_o may not be divided or may be divided into three or more sections.

[0113] The double-sided polishing device of the present invention has been described with reference to the first embodiment. However, the specific configuration is not limited to the embodiment, and design modifications and additions are allowed as long as they do not depart from the gist of inventions defined by the claims.

[0114] According to the double-sided polishing device 1 of the first embodiment, in Step S1 of the polishing processing control shown in FIG. 9, when setting the target values of the in-plane flatness and the outer peripheral flatness, an example has been shown in which the final target value of the in-plane flatness at the endpoint polishing completion time and the final target value of the outer peripheral flatness at the endpoint polishing completion time are set as the final processing targets of the workpiece W. However, the target values of the in-plane flatness and the outer peripheral flatness are not limited to these target values. For example, multiple target values may be set in accordance with the polishing state and the like of the workpiece W, and the target values may be suitably changed when correcting the main polishing condition and when setting the main polishing stop condition.

CROSS-REFERENCE TO RELATED APPLICATION

[0115] The present application is based upon and claims the benefit of priority from Japanese Patent Application No. 2023-204053 filed with the Japan Patent Office on December 1, 2023, the entire disclosure of which is incorporated in its entirety in the present specification by
5 reference.

CLAIMS

[Claim 1] A double-sided polishing device, comprising:

a polishing machine that is configured to sandwich a disc-shaped workpiece between a lower surface plate and an upper surface plate positioned opposite to the lower surface plate and to polish front and back surfaces of the workpiece by moving the lower surface plate and
5 the upper surface plate relative to the workpiece while applying a load to the workpiece;

a thickness measuring apparatus that is configured to measure a thickness of the workpiece while the polishing machine polishes the workpiece; and

a controller that is configured to control the polishing machine based on a measurement
10 result of the thickness measuring apparatus,

wherein the workpiece comprises an outer peripheral area that is in a predetermined range from an outer peripheral edge of the workpiece toward an inner radial direction, and an in-plane area that is in a range from the outer peripheral area to a center of the workpiece,

wherein the controller comprises:

15 a first learner that has learned a correlation among a polishing condition of a main polishing for polishing the workpiece while maintaining the load at a target load, an outer peripheral flatness as a flatness of the outer peripheral area, and an in-plane flatness as a flatness of the in-plane area;

a second learner that has learned a correlation among a polishing condition of an
20 endpoint polishing for polishing the workpiece while gradually reducing the load, a degree of change in the in-plane flatness when the main polishing is stopped, a degree of change in the outer peripheral flatness when the main polishing is stopped, and an amount of change in the outer peripheral flatness during the endpoint polishing;

a main polishing condition correcting portion that is configured to determine a
25 correction target value of the in-plane flatness based on an estimated value of the in-plane flatness, the estimated value being obtained by inputting, into the first learner, a polishing condition of the main polishing set at a time of correction and the outer peripheral flatness at

the time of the correction, and to correct the polishing condition of the main polishing set at the time of the correction by using the polishing condition of the main polishing, the polishing condition being obtained by inputting, into the first learner, the correction target value of the in-plane flatness and a target value of the outer peripheral flatness; and

- 5 a main polishing stop condition setting portion that is configured to obtain the amount of the change in the outer peripheral flatness during the endpoint polishing by inputting, into the second learner, the polishing condition of the endpoint polishing, the degree of the change in the in-plane flatness at a time of calculation, and the degree of the change in the outer peripheral flatness at the time of the calculation, and to set a stopping condition of the main
10 polishing based on the amount of the change in the outer peripheral flatness and the target value of the outer peripheral flatness.

- [Claim 2] The double-sided polishing device according to claim 1, wherein the in-plane flatness is a slope value of an approximate straight line set for a thickness data group of the in-
15 plane area, and the outer peripheral flatness is obtained by performing a successive process of a slope value of an approximate straight line set for a thickness data group of the outer peripheral area with reference to the in-plane flatness.

- [Claim 3] The double-sided polishing device according to claim 1 or 2, wherein the outer
20 peripheral area is divided into a plurality of sections in a radial direction of the workpiece, and the outer peripheral flatness is calculated for each of the divided sections of the outer peripheral area.

- [Claim 4] The double-sided polishing device according to claim 3, wherein when a section
25 adjacent to the in-plane area is defined as an innermost section and a section radially outward from the innermost section is defined as an outer section,

a flatness of the innermost section is obtained by performing a successive process of a slope value of an approximate straight line set for a thickness data group of the innermost section with reference to the in-plane flatness, and

a flatness of the outer section is obtained by performing a successive process of a slope
5 value of an approximate straight line set for a thickness data group of the outer section with reference to a flatness of a section adjacent to an inner radial side of the outer section.

[Claim 5] A double-sided polishing method for polishing front and back surfaces of a disc-shaped workpiece, wherein the workpiece is sandwiched between a lower surface plate and an
10 upper surface plate positioned opposite to the lower surface plate and the front and back surfaces of the workpiece are polished by moving the lower surface plate and the upper surface plate relative to the workpiece while applying a load to the workpiece;

wherein the double-sided polishing method uses:

a first learner that has learned a correlation among a polishing condition of a main
15 polishing for polishing the workpiece while maintaining the load at a target load, an outer peripheral flatness as a flatness of the outer peripheral area, and an in-plane flatness as a flatness of the in-plane area, the outer peripheral area being in a predetermined range from an outer peripheral edge of the workpiece toward an inner radial direction, and the in-plane area being in a range from the outer peripheral area to a center of the workpiece; and

20 a second learner that has learned a correlation among a polishing condition of an endpoint polishing for polishing the workpiece while gradually reducing the load, a degree of change in the in-plane flatness when the main polishing is stopped, a degree of change in the outer peripheral flatness when the main polishing is stopped, and an amount of change in the outer peripheral flatness during the endpoint polishing;

25 wherein the double-sided polishing method comprises:

setting a target value of the outer peripheral flatness and a target value of the in-plane flatness;

conducting an initial polishing for polishing the workpiece while gradually increasing the load, after setting the target values of the outer peripheral flatness and the in-plane flatness;

starting the main polishing after completing the initial polishing;

determining a correction target value of the in-plane flatness based on an estimated value of the in-plane flatness, the estimated value being obtained by inputting, into the first learner, a polishing condition of the main polishing set at a time of correction and the outer peripheral flatness at the time of the correction, during the main polishing, and correcting the polishing condition of the main polishing set at the time of the correction by using the polishing condition of the main polishing, the polishing condition being obtained by inputting, into the first learner, the correction target value of the in-plane flatness and the target value of the outer peripheral flatness;

obtaining the amount of the change in the outer peripheral flatness during the endpoint polishing by inputting, into the second learner, the polishing condition of the endpoint polishing, the degree of the change in the in-plane flatness at a time of calculation, and the degree of the change in the outer peripheral flatness at the time of the calculation, during the main polishing, and setting a stopping condition of the main polishing based on the amount of the change in the outer peripheral flatness and the target value of the outer peripheral flatness; and

performing the endpoint polishing after the stopping condition of the main polishing is satisfied.