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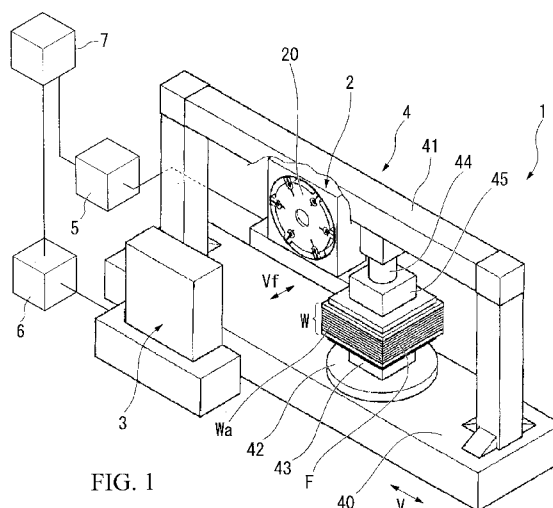


FIG. 1

(57) Abstract: A cutting method to cut an end surface of a workpiece is disclosed. The method includes: providing a cutting unit (20) having a rotary shaft (21) and a cutting blade (24) protruding toward the end surface side of the workpiece; rotating the cutting blade around the rotary shaft; cutting the end surface of the workpiece by bringing the rotating cutting blade into contact with the end surface of the workpiece; measuring a predetermined parameter indicating an overheated condition of the cutting unit after completing a predetermined number of batches of a cutting process; and adjusting a relative position between the cutting blade and an end surface of a workpiece to be cut in a subsequent batch, before beginning the cutting process of the subsequent batch, such that external dimensions of the workpiece, which are to be obtained by the cutting process of the subsequent batch would not be beyond a required allowance. The method can satisfy the required dimensions of a workpiece.

CUTTING METHOD AND CUTTING APPARATUS

5

Technical Field

[0001]

The present invention relates to a cutting method and a cutting apparatus.

10 Background Art

[0002]

In the related art, a cutting method disclosed in PTL 1 has been known as a cutting method of cutting an end surface of a workpiece. In the cutting method in PTL 1, when the end surface of an optical member such as a polarizing plate is cut, and a cutting region formed by a rotating cutting blade is brought into contact with the end surface of the optical member to perform the cutting, a portion apart from a predetermined virtual line within the cutting region is brought into contact with the end surface of the optical member. By this method the depression force caused by the cutting blade is said to be reduced and thereby the end surface of the optical member is said to be finished in a good condition.

20

Citation List

Patent Literature

[0003]

25

[PTL 1] Japanese Patent No. 4954662

Summary of Invention

Technical Problem

[0004]

5 Incidentally, at the time when the related art was filed, an allowance of the product specification was wide, and for example an external dimension tolerance of a polarizing plate was ± 0.15 mm. Therefore, a variation width in external dimensions of the polarizing plate when cutting an end surface of the polarizing plate can be well within the allowance of the product specification and a polarizing plate of the required

10 dimensions can be obtained satisfactorily.

 However, in recent years, in association with making frames of liquid crystal display devices narrower, a request for the variation width in the external dimensions of the polarizing plate has become stricter, and for example the external dimension tolerance of the polarizing plate may be ± 0.05 mm. Therefore, simply cutting the end

15 surface of the polarizing surface by use of a known method such as that disclosed in PTL 1 results in that the variation width in the external dimensions of the polarizing plate may be over the allowance of the required product specification, and, hence, it becomes difficult to satisfy the recent strictly required dimensions.

[0005]

20 According to the findings of the present inventors, when cutting the end surface of an optical member, if a cutting unit is used for a predetermined period of time, it is observed a phenomenon that the external dimensions of the optical member are gradually decreased. As a result of extensive studies, the present inventors have found that a reason for the phenomenon is thermal expansion of a rotary shaft that may be caused by

25 the influence of a rotation drive of the rotary shaft or friction between the rotary shaft and

bearings, and thereby have completed the present invention.

[0006]

The present invention is made in view of such circumstances, and an object is to provide a cutting method and a cutting apparatus which can satisfy the strictly required
5 dimensions of a workpiece.

Solution to Problem

[0007]

In order to achieve the above object, the present invention employs the
10 following means.

(1) According to a first aspect of the present invention there is provided a cutting method to cut an end surface of a workpiece, which comprises providing a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece; rotating the cutting blade around the rotary shaft; cutting the end surface
15 of the workpiece by bringing the rotating cutting blade into contact with the end surface of the workpiece; measuring a predetermined parameter indicating an overheated condition of the cutting unit after completing a predetermined number of batches of a cutting process; and adjusting a relative position between the cutting blade and an end surface of the workpiece to be cut in a subsequent batch, before beginning the cutting
20 process of the subsequent batch.

[0008]

(2) In the cutting method described in the above (1), a relative position between the cutting blade and an end surface of the workpiece to be cut in a subsequent batch may be adjusted such that external dimensions of the workpiece, which are to be
25 obtained by the cutting process of the subsequent batch, are not beyond a required

allowance such as that given by the product specification of the workpiece.

(3) In the cutting method described in the above (1) or (2), a thermal expansion amount of the rotary shaft after cutting may be measured as the predetermined parameter.

5 [0009]

(4) In the cutting method described in the above (1) or (2), a temperature around the rotary shaft after cutting may be measured as the predetermined parameter; and the adjustment may be performed based on data of a thermal expansion amount of the rotary shaft corresponding to the measured temperature.

10 [0010]

(5) In the cutting method described in the above (4), the rotary shaft may be rotatably supported by bearings, and both the rotary shaft and the bearings may be covered with a cover, and the rotary shaft and the cover may be capable of heat conduction via the bearing, and a temperature of the cover may be measured as the
15 temperature around the rotary shaft.

[0011]

(6) According to a second aspect of the present invention, there is provided a cutting method to cut an end surface of a workpiece, which comprises providing a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of
20 the workpiece; rotating the cutting blade around the rotary shaft; and cutting the end surface of the workpiece by bringing the rotating cutting blade into contact with the end surface of the workpiece; wherein the rotary shaft is cooled in order for the rotary shaft not to be thermally expanded.

[0012]

25 (7) In the cutting method described in the above (6), the rotary shaft may be

cooled in order for the rotary shaft not to be thermally expanded, such that external dimensions of the workpiece would not be beyond a required allowance such as that is given in the product specification of the workpiece.

(8) In the cutting method described in the above (6) or (7), the rotary shaft may
5 be rotatably supported by bearings, and both of the rotary shaft and the bearings may be covered with a cover, the rotary shaft and the cover may be capable of heat conduction via the bearing, and the cooling may be performed by an external cooling of the cover by means of a coolant.

[0013]

10 (9) In the cutting method described in the above (6) or (7), the rotary shaft may be rotatably supported by bearings, and both the rotary shaft and the bearings may be covered with a cover, the rotary shaft and the cover may be capable of heat conduction via the bearing, and the cooling may be performed by blowing cooling air onto the cover.

[0014]

15 (10) According to a third aspect of the present invention, there is provided a cutting method to cut an end surface of a workpiece, which comprises providing a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece; rotating the cutting blade around the rotary shaft; cutting the end surface of the workpiece by bringing the rotating cutting blade into contact with the end surface
20 of the workpiece; wherein the rotary shaft has been heated in advance up to a saturated condition where thermal expansion of the rotary shaft no longer occurs.

[0015]

(11) In the cutting method described in the above (10), the rotary shaft may have been heated in advance up to a saturated condition where thermal expansion of the
25 rotary shaft no longer occurs, such that external dimensions of the workpiece would not

be beyond a required allowance such as that given in the product specification of the workpiece.

(12) In the cutting method described in the above (10) or (11), the heating may be performed by allowing an idling rotation of the rotary shaft before performing a cutting process of the workpiece.

[0016]

(13) According to a first aspect of the present invention, there is provided a cutting apparatus to cut an end surface of a workpiece, which comprises a processing device comprising a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece, the cutting blade being rotatable around the rotary shaft and the end surface of the workpiece being cuttable by bringing the rotating cutting blade into contact with the end surface of the workpiece; and a controlling device that controls adjusting a relative position between the cutting blade and an end surface of a workpiece to be cut in the subsequent batch before beginning a cutting process of a subsequent batch, based on a predetermined parameter indicating an overheated condition of the cutting unit after completing a predetermined number of batches of the cutting process.

[0017]

(14) In the cutting apparatus described in the above (13), the controlling device controls adjusting a relative position between the cutting blade and an end surface of a workpiece to be cut in the subsequent batch, such that external dimensions of the workpiece to be obtained by the cutting process of the subsequent batch are not beyond a required allowance such as that given in the product specification of the workpiece.

(15) In the cutting apparatus described in the above (13) or (14), a dimension sensor which measures a thermal expansion amount of the rotary shaft after cutting may

be further provided as the predetermined parameter.

[0018]

(16) In the cutting apparatus described in the above (13) or (14), a temperature sensor which measures a temperature around the rotary shaft after cutting as the
5 predetermined parameter may be further provided, and the controlling device may perform the adjustment based on data of a thermal expansion amount of the rotary shaft corresponding to a measurement result of the temperature sensor.

[0019]

(17) In the cutting apparatus described in the above (16), bearings rotatably
10 supporting the rotary shaft and a cover covering both of the rotary shaft and the bearings may be further provided, the rotary shaft and the cover may be capable of heat conduction via the bearing, and the temperature sensor may measure a temperature of the cover as the temperature around the rotary shaft.

[0020]

15 (18) According to a second aspect of the present invention, there is provided a cutting apparatus to cut an end surface of a workpiece, which comprises a processing device including a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece, the cutting blade being rotatable around the rotary shaft and the end surface of the workpiece being cuttable by bringing the rotating
20 cutting blade into contact with the end surface of the workpiece; and a controlling device that performs a control where the rotary shaft is cooled in order for the rotary shaft not to be thermally expanded.

[0021]

(19) In the cutting apparatus described in the above (18), the controlling
25 device may perform a control where the rotary shaft is cooled in order for the rotary shaft

not to be thermally expanded, such that external dimensions of the workpiece would not be beyond a required allowance.

(20) In the cutting apparatus described in the above (18) or (19), bearings rotatably supporting the rotary shaft, a cover covering both of the rotary shaft and the bearings, and a cooling unit capable of external cooling of the cover by means of a coolant may be further provided, the rotary shaft and the cover may be capable of heat conduction via the bearing, , and the controlling device may control the cooling unit performing the external cooling of the cover.

[0022]

(21) In the cutting apparatus described in the above (18) or (19), bearings rotatably supporting the rotary shaft, a cover covering both the rotary shaft and the bearings, and an air-cooling unit capable of blowing cooling air onto the cover may be further provided, the rotary shaft and the cover may be capable of heat conduction via the bearing, , and the controlling device may control the air-cooling unit of blowing the cooling air onto the cover.

[0023]

(22) According to a third aspect of the present invention, there is provided a cutting apparatus to cut an end surface of a workpiece, which comprises a processing device including a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece, the cutting blade being rotatable around the rotary shaft and the end surface of the workpiece being cuttable by bringing the rotating cutting blade into contact with the end surface of the workpiece; and a controlling device that performs a control where the rotary shaft has been heated in advance up to a saturated condition where thermal expansion of the rotary shaft no longer occurs.

[0024]

(23) In the cutting apparatus described in the above (22), the controlling device may perform a control where the rotary shaft may have been heated in advance up to a saturated condition where thermal expansion of the rotary shaft no longer occurs, such that external dimensions of the workpiece would not be beyond a required allowance.

(24) In the cutting apparatus described in the above (22) or (23), the controlling device may perform a control for allowing an idling rotation of the rotary shaft before performing a cutting process of the workpiece, as the heating.

10 Advantageous Effects of Invention

[0025]

According to the present invention, it is possible to provide a cutting method and a cutting apparatus which are capable of satisfying strictly required dimensions of a workpiece.

15

Brief Description of Drawings

[0026]

FIG. 1 is a perspective view illustrating a cutting apparatus according to a first embodiment.

20 FIG. 2 is a side view of a cutting unit.

FIG. 3 is a schematic diagram illustrating an arrangement relationship of a rotary shaft, bearings and a cover.

FIG. 4 is a perspective view illustrating a cutting apparatus before attaching a rotating body.

25 FIG. 5 is a perspective view illustrating a cutting apparatus after attaching a

rotating body.

FIG. 6 is a view illustrating a cutting method according to the first embodiment.

FIG. 7 is a view illustrating a relationship between the number of batches and a deviated amount from a reference value of external dimensions of a laminated body.

5 FIG. 8 is a perspective view illustrating a dimension sensor.

FIG. 9 is a schematic diagram illustrating an arrangement relationship between a dimension sensor and a cutting unit.

FIG. 10 is a view illustrating variations in external dimensions of a laminated body according to a comparative example.

10 FIG. 11 is a view illustrating variations in external dimensions of a laminated body in a long-side direction of an optical member according to the first embodiment.

FIG. 12 is a view illustrating variations in external dimensions of a laminated body in a short-side direction of an optical member according to the first embodiment.

FIG. 13 is a perspective view illustrating a temperature sensor.

15 FIG. 14 is a view illustrating a preparation method of a thermal expansion table indicating a relationship between a temperature of a cover and a thermal expansion amount of a rotary shaft.

FIG. 15 is a view illustrating variations in external dimensions of a laminated body in a long-side direction of an optical member according to a second embodiment.

20 FIG. 16 is a view illustrating variations in external dimensions of a laminated body in a short-side direction of an optical member according to the second embodiment.

FIG. 17 is a perspective view illustrating a cooling unit.

FIG. 18 is a perspective view illustrating an air-cooling unit (a blower).

[0027]

Herein, embodiments of the present invention will be described with reference to the accompanying drawings, but the present invention is not limited to the following embodiments.

5 [0028]

In all of the following drawings, for easy understanding of the drawings, dimensions and proportions of each configuration element are appropriately varied. In addition, in the following description and the drawings, the same reference numerals are given to the same or corresponding elements, and the repeated description will be

10 omitted.

[0029]

(First Embodiment)

FIG. 1 is a perspective view illustrating a cutting apparatus 1 using a cutting method according to a first embodiment of the present invention.

15 [0030]

The cutting apparatus 1 is intended to cut an end surface of a workpiece. In the present embodiment, the cut object is an end surface Wa of a rectangular parallelepiped laminated body W in which multiple sheets of an optical member F are superimposed.

This allows end surfaces of the multiple sheets of the optical member F to be cut together.

20 For example, the laminated body W can be obtained by punching a long raw sheet of monolayer sheet or laminated sheet into a rectangular shape. Incidentally, the cut object is not limited to the laminated body W, but may be a single sheet of the optical member F. In addition, the cut object can be other various members in addition to the laminated body W.

25 [0031]

The sheet constituting the laminated body W includes polyvinyl alcohol film, cellulose-based film represented by triacetyl cellulose film, and ethylene acetate vinyl based film, but is not particularly limited thereto. In case where a polarizing plate is configured to have multi-layers of optical film, since the thickness of the polarizing plate is large, the polarizing plate is preferable as the cut object of the cutting apparatus 1 according to the present invention, which is capable of processing end surfaces of a large amount of film.

[0032]

As illustrated in FIG. 1, the cutting apparatus 1 includes a processing device (for example, a first processing device 2 and a second processing device 3 in the present embodiment), a moving device 4, a first position adjusting device 5, a second position adjusting device 6 and a controlling device 7.

[0033]

The first processing device 2 and the second processing device 3 are arranged to oppose each other by interposing the moving device 4. In each of the first processing device 2 and the second processing device 3, a cutting unit 20 capable of cutting the end surface Wa of the laminated body W is arranged on the moving device 4 side. Rotating the cutting units 20 of both the first processing device 2 and the second processing device 3 enables two end surfaces Wa of the four end surfaces Wa of the laminated body W to be cut simultaneously and collectively.

[0034]

Herein, a configuration of the cutting unit 20 will be described.

FIG. 2 is a side view of the cutting unit 20.

[0035]

As illustrated in FIG. 2, the cutting unit 20 includes a rotary shaft 21 extending

along a normal direction of the end surface Wa (refer to FIG. 1) of the laminated body W, a rotating body 22 rotating around the rotary shaft 21, a support 23 supporting the rotary shaft 21 and a plurality of cutting blades disposed on the rotating body 22 (for example, six cutting blades such as a first cutting blade 24a, a second cutting blade 24b, a third cutting blade 24c, a fourth cutting blade 24d, a fifth cutting blade 24e and a sixth cutting blade 24f in the present embodiment). In the following description, the first cutting blade 24a, the second cutting blade 24b, the third cutting blade 24c, the fourth cutting blade 24d, the fifth cutting blade 24e and the sixth cutting blade 24f may be collectively referred to as “cutting blade 24”.

10 [0036]

The rotating body 22 is fixed to the rotary shaft 21 and can be rotated in one direction around the rotary shaft 21. The rotating body 22 has an installation surface 22a which is vertical with respect to the rotary shaft 21. The rotating body 22 has a disk shape, but is not limited to the shape.

15 [0037]

For example, a diameter of the rotating body 22 is approximately 250 mm. However, the diameter of the rotating body 22 is not limited thereto, and may be from 150 mm to 600 mm, for example.

[0038]

20 The cutting blade 24 is disposed on the installation surface 22a of the rotating body 22. The cutting blade 24 protrudes from the installation surface 22a toward the end surface Wa (refer to FIG. 1) side of the laminated body W.

[0039]

25 The cutting blades 24a to 24f, in this order, are configured to have an increased protruding amount from the installation surface 22a. The first cutting blade 24a has the

longest distance from the rotary shaft 21 and the smallest protruding amount from the installation surface 22a, and in contrast the third cutting blade 24c has the shortest distance from the rotary shaft 21 and the largest protruding amount from the installation surface 22a.

5 [0040]

The first cutting blade 24a, the second cutting blade 24b, the fourth cutting blade 24d and the fifth cutting blade 24e are cutting blades for rough cutting and made of polycrystalline diamond. On the other hand, the third cutting blade 24c and the sixth cutting blade 24f are cutting blades for finishing and made of a single crystal diamond.

10 If the material is selected as a preferable form for the material of the cutting blade and is suitable for cutting the end surface Wa (refer to FIG. 1) of the laminated body W, the material is not particularly limited.

[0041]

In the present embodiment, the number of the cutting blades is six, but without
15 being limited thereto, may be appropriately varied depending on various conditions such as a distance from the rotary shaft 21 to the cutting blades. However, from the viewpoint of processing efficiency, it is preferable to increase the number of the cutting blades as the distance from the rotary shaft 21 to the cutting blades becomes longer. In addition, the arrangement of the cutting blades is not particularly limited, but from the
20 viewpoint of processing efficiency, it is preferable to arrange a plurality of the cutting blades at a predetermined interval so as to have an equal distance from the rotary shaft 21.

[0042]

A shape of the cutting blades is not particularly limited, but may be columnar,
25 prismatic, the shape of cylinder whose cross section forms a trapezoidal shape and

hemispherical. The shape or size of the cutting blades may be appropriately set depending on dimensions of optical members and the required processing efficiency. In addition, the cutting blades, if disposed to protrude to the end surface Wa (refer to FIG. 1) side of the laminated body W, the cutting blades may be tilted with respect to the axial
5 direction of the rotary shaft 21.

[0043]

FIG. 3 is a schematic diagram illustrating an arrangement relationship of the rotary shaft 21, bearings 25 and a cover 26. Referring to FIG. 3, for convenience, the rotating body 22, the support 23 and the cutting blades 24 configuring the cutting unit 20
10 are not illustrated.

[0044]

As illustrated in FIG. 3, the cutting apparatus 1 (refer to FIG. 1) includes bearings 25 rotatably supporting the rotary shaft 21, and the cover 26 covering both of the rotary shaft 21 and the bearings 25. The rotary shaft 21 and the cover 26 are
15 configured to be capable of heat conduction via the bearings 25. For example, the material of the rotary shaft 21 is chromium-molybdenum steel, the material of the bearings is high carbon chromium steel and the material of the cover 26 is plain cast iron.

[0045]

FIG. 4 is a perspective view illustrating the cutting apparatus 1 before attaching
20 the rotating body 22.

FIG. 5 is a perspective view illustrating the cutting apparatus 1 after attaching the rotating body 22.

[0046]

As illustrated in FIG. 4, before attaching the rotating body 22 (refer to FIG. 5),
25 one end portion 21a of the rotary shaft 21 protrudes from one end portion of the cover 26.

[0047]

As illustrated in FIG. 5, the rotating body 22 is attached to the one end portion 21a (refer to FIG. 4) of the rotary shaft 21 protruding from one end portion of the cover 26.

5 [0048]

Referring back to FIG. 1, the moving device 4 includes a base 40, a frame 41 with a gate shape, which is disposed on the base 40, a table 42 with a disk shape, which is disposed on the base 40, a first pressing member 43 arranged on the table 42, a cylinder 44 disposed at the base 40 side of the frame 41 and a second pressing member 45 attached to a tip of a rod of the cylinder 44.

[0049]

The moving device 4 moves the laminated body W in a V direction in parallel to the longitudinal direction of the end surface Wa of the laminated body W with respect to the cutting unit 20.

15 [0050]

The table 42 can rotate the first pressing member 43 around a central axis of the table 42. The cylinder 44 can vertically move the second pressing member 45. The laminated body W is fixed by being interposed between the first pressing member 43 and the second pressing member 45.

20 [0051]

The base 40 can be moved so as to pass through between the first processing device 2 and the second processing device 3. When cutting, the first pressing member 43 and the second pressing member 45 fix the laminated body W. At this time, a normal direction of both end surfaces of the laminated body W is caused to match an
25 extending direction of each rotary shaft 21 of the first processing device 2 and the second

processing device 3. Then, the rotating body 22 is rotated and the base 40 is moved such that the laminated body W would pass through between the first processing device 2 and the second processing device 3. The base 40 is moved in the direction V perpendicular to the longitudinal direction of the end surface Wa of the laminated body W to be cut, using a moving mechanism (not illustrated).

In association with the rotation of the rotating body 22, the cutting blade 24, which are disposed on the installation surface 22a of the rotating body 22, are rotated and come into contact with the end surface Wa of the laminated body W, and thereby cut the end surface Wa.

10 [0052]

In this case, firstly, the first cutting blade 24a and the fourth cutting blade 24d which are located at the outermost side of the rotating body 22 come into contact with the laminated body W and cut the end surface Wa thereof. If the base 40 moves ahead, subsequently the second cutting blade 24b and the fifth cutting blade 24e which are
15 disposed at the inner side than the first cutting blade 24a and the fourth cutting blade 24d come into contact with the laminated body W and cut the end surface Wa thereof. Since the second cutting blade 24b and the fifth cutting blade 24e have a larger protruding amount than the first cutting blade 24a and the fourth cutting blade 24d, the end surface Wa cut by the first cutting blade 24a and the fourth cutting blade 24d is cut deeper. In
20 this manner, the first cutting blade 24a, the second cutting blade 24b, the fourth cutting blade 24d and the fifth cutting blade 24e cut the end surface Wa of the laminated body W gradually deeper. Finally, the third cutting blade 24c and the sixth cutting blade 24f which are for the finishing cut the end surface Wa of the laminated body W, to perform mirror finishing. After the processing of a pair of the end surfaces Wa opposing each
25 other is completed in this manner, the table 42 is rotated by 90° to process another end

surface Wa.

[0053]

The first position adjusting device 5 adjusts the position of the first processing device 2. Specifically, the first position adjusting device 5 moves the first processing device 2 only in a direction Vf in parallel to the short-side direction of the optical member F configuring the laminated body W.

[0054]

The second position adjusting device 6 adjusts the position of the second processing device 3. Specifically, the second position adjusting device 6 moves the second processing device 3 only in the direction Vf.

[0055]

The controlling device 7 performs overall control on the first position adjusting device 5 and the second position adjusting device 6. The controlling device 7 performs the control on the first position adjusting device 5 and the second position adjusting device 6, such that each of the first processing device 2 and the second processing device 3 would be moved only in the direction Vf.

[0056]

Herein, a cutting method according to the present embodiment will be described.

[0057]

(Cutting method)

The cutting method according to the present embodiment is a cutting method of the end surface Wa (refer to FIG. 1) of the laminated body W superimposed by multiple sheets of the optical member F, and is performed using the cutting apparatus 1 illustrated in FIG. 1.

[0058]

FIG. 6 is a view illustrating the cutting method according to the present embodiment.

FIG. 6 is a view illustrating the cutting of the end surface Wa of the laminated body W using the cutting unit 20.

5 [0059]

As illustrated in FIG. 6, in the cutting method according to the present embodiment, the end surface Wa of the laminated body W is cut by rotating the rotating body 22 clockwise and moving it in the direction V in parallel to the longitudinal direction of the end surface Wa of the laminated body W.

10 [0060]

The rotating direction of the rotating body 22 is not limited to the (clockwise) direction illustrated in FIG. 6, but the end surface Wa of the laminated body W may be cut by rotating the rotating body 22 counterclockwise and moving it in the direction V in parallel to the longitudinal direction of the end surface Wa of the laminated body W.

15 [0061]

Incidentally, in the related art, the allowance of the product specification was wide, and for example the external dimension tolerance of the polarizing plate was ± 0.15 mm. Therefore, the variation width in external dimensions of the polarizing plate when cutting an end surface of the polarizing plate was able to be within the allowance of the product specification to obtain the polarizing plate which satisfies required dimensions.

However, in recent years, in association with making frames of liquid crystal display devices narrower, a request for the variation width in the external dimensions of the polarizing plate has become stricter, and for example the external dimension tolerance of the polarizing plate may be ± 0.05 mm. Therefore, simply cutting the end

surface of the polarizing plate results in that the variation width in the external dimensions of the polarizing plate may be over the allowance of the required product specification, and, hence, it becomes difficult to satisfy the recent strictly required dimensions.

5 [0062]

FIG. 7 is a view illustrating a relationship between a batch number and a deviated amount from a reference value of the external dimensions of the laminated body W.

[0063]

10 Here, the number of batches means the number of times when the end surface Wa of the laminated body W is subjected to the cutting process, and one batch means a process where four end surfaces Wa of one laminated body W are respectively cut once. For example, in a case where two end surfaces Wa out of the four end surfaces Wa of the laminated body W are cut simultaneously and collectively, two end surfaces Wa of the
15 laminated body W in the longitudinal direction of the optical member F are first cut, and next rotating the table 42 by 90° and cutting the remaining two end surfaces Wa of the laminated body W in the short direction of the optical member F allow one batch to be completed.

[0064]

20 In FIG. 7, variations in the external dimensions of the laminated body W in the long-side direction of the optical member F are illustrated by a solid line, and variations in the external dimensions of the laminated body W in the short-side direction of the optical member F are illustrated by a dashed line. In FIG. 7, the horizontal axis represents the number of batches [Nos.]. The vertical axis represents a deviated amount
25 [mm] from a reference value of the external dimensions of the laminated body W.

[0065]

As illustrated in FIG. 7, cutting the end surfaces Wa of the laminated body W by a conventional method causes the number of batches to be increased and consequently increases the deviated amount from the reference value of the external dimensions of the laminated body W in each of the long-side direction and the short-side direction of the optical member F. Therefore, if the number of batches remains to be increased as it is, a variation width in the external dimensions of the polarizing plate during the cutting is beyond the management range of the product standards (for example, external dimension tolerance of the polarizing plate: ± 0.05 mm). In FIG. 7, it will be apparent that the variation width in the external dimensions of the polarizing plate during the cutting is beyond the external dimension tolerance of the polarizing plate: ± 0.05 mm if the number of batches is 22 or more.

[0066]

According to the findings of the present inventors, when cutting the end surface of an optical member F, if the rotating body 22 is rotated for a predetermined period of time, it is observed a phenomenon that the external dimensions of the optical member F is gradually decreased. As a result of extensive studies, the present inventors have found that a reason for the phenomenon is thermal expansion of the rotary shaft 21 that may be caused by the influence of a rotation drive of the rotary shaft 21 or friction between the rotary shaft 21 and bearings 25, and thereby have invented the following cutting method.

[0067]

The cutting method according to the present embodiment is a cutting method to cut the end surface Wa of the laminated body W, which includes providing the cutting unit 20 having the rotary shaft 21 extending along the normal direction of the end surface

Wa of the laminated body W and having the cutting blade 24 protruding to the end surface Wa side of the laminated body W; rotating the cutting blade 24 around the rotary shaft 21; cutting the end surface Wa of the laminated body W by bringing the rotating cutting blade 24 into contact with the end surface Wa of the laminated body W;

5 measuring a predetermined parameter indicating an overheated condition of the cutting unit 20 after completing a predetermined number of batches of a cutting process; and adjusting a relative position between the cutting blade 24 and the end surface Wa of the laminated body W which is subjected to the cutting process in a subsequent batch based on the predetermined parameter, before beginning the cutting process of the subsequent

10 batch.

[0068]

The controlling device 7 according to the present embodiment, based on the predetermined parameter indicating an overheated condition of the cutting unit 20 after completing the predetermined number of batches of the cutting process, controls for

15 adjusting a relative position between the cutting blade 24 and the end surface Wa of the laminated body W which is subjected to the cutting process in a subsequent batch, before beginning the cutting process of the subsequent batch, such that external dimensions of the laminated body W, which are to be obtained by the cutting process of the subsequent batch, would not be beyond the required allowance defined by the product specification.

20 [0069]

Here, the predetermined number of batches of the cutting process is once or more, preferably once or more and 100 times or less, more preferably once or more and 50 times or less, further preferably once or more and 20 times or less.

The predetermined parameter indicating the overheated condition of the cutting

25 unit 20 means a value indicating the thermal expansion amount of the rotary shaft 21

when the rotary shaft 21 is thermally expanded due to the influence of the rotation drive of the rotary shaft 21 or the friction between the rotary shaft 21 and the bearings 25.

[0070]

In the present embodiment, the thermal expansion amount of the rotary shaft 21
5 after the cutting is measured as the predetermined parameter.

[0071]

FIG. 8 is a perspective view illustrating a dimension sensor 30.

FIG. 9 is a schematic diagram illustrating an arrangement relationship between the dimension sensor 30 and the cutting unit 20.

10 In FIG. 9, for convenience, the rotary shaft 21 and the support 23 which configure the cutting unit 20 are not illustrated, but the rotating body 22 and the cutting blade 24 are illustrated.

[0072]

As illustrated in FIG. 8, in the present embodiment, the thermal expansion
15 amount of the rotary shaft 21 after the cutting is measured using the dimension sensor 30. For example, as the dimension sensor 30, it is possible to use a non-contact type dimension measuring instrument.

[0073]

As illustrated in FIG. 9, a hole 26h passing through the cover 26 is formed at a
20 portion of the cover 26. The hole 26h is arranged opposing an opposite side surface (hereinafter, in some cases, referred to as a rear surface of the rotating body 22) to the side where the cutting blade 24 of the rotating body 22 is disposed.

[0074]

The dimension sensor 30 and a laser light emitting surface 30a are arranged at a
25 position overlapped with the hole 26h when viewed from the normal direction of the rear

surface of the rotating body 22. The laser light is emitted from the laser light emitting surface 30a toward the rear surface of the rotating body 22. The dimension sensor 30 measures a returning distance of the laser light between the laser light emitting surface 30a and the rear surface of the rotating body 22. In this manner, the thermal expansion
5 amount of the rotary shaft 21 after the cutting is measured as a displacement amount in the direction Vf of the rotating body 22.

[0075]

The controlling device 7, based on the measurement result of the dimension sensor 30, controls the first position adjusting device 5 and the second position adjusting
10 device 6, and causes the first processing device 2 and the second processing device 3 to respectively move in the direction Vf.

[0076]

The cutting method according to the present embodiment includes measuring, after completing a predetermined number of batches of a cutting process, the
15 displacement amount in the direction Vf of the rotating body 22 as the thermal expansion amount of the rotary shaft 21 after the cutting process using the dimension sensor 30, and adjusting the relative position between, in the direction Vf, the cutting blade 24 and the end surface Wa of the laminated body W which is subjected to the cutting process in the subsequent batch using the controlling device 7, before beginning the cutting process of
20 the subsequent batch, such that external dimensions of the laminated body W, which are to be obtained by the cutting process of the subsequent batch, would not be beyond the allowance defined by product specification.

[0077]

Herein, a relation between the number of batches and the deviated amount from
25 the reference value of the external dimensions of the laminated body W will be described

with reference to FIGS. 10 to 12.

FIG. 10 is a view illustrating variations in the external dimensions of the laminated body W in the long-side direction of the optical member F according to a comparative example.

5 FIG. 11 is a view illustrating variations in the external dimensions of the laminated body W in the long-side direction of the optical member F according to the present embodiment.

FIG. 12 is a view illustrating variations in the external dimensions of the laminated body in the short-side direction of the optical member F according to the
10 present embodiment.

In FIGS. 10 to 12, the horizontal axis represents the number of batches [Nos.]. The vertical axis represents a deviated amount [mm] from a reference value of the external dimensions of the laminated body W. “The maximum value” represents the largest value out of variations in the deviated amount during one batch, “the minimum
15 value” represents the smallest value out of the variations in the deviated amount during one batch, and “the average value” represents a value obtained by averaging the variations in the deviated amount during one batch. In the comparative example, the relative position between the end surface Wa and the cutting blade 24 in the direction Vf is not adjusted.

20 [0078]

In the comparative example, as illustrated in FIG. 10, cutting the end surfaces Wa of the laminated body W causes the number of batches to be increased and consequently increases the deviated amount from the reference value of the external dimensions of the laminated body W. Therefore, if the number of batches remains to be
25 increased as it is, a variation width in the external dimensions of the polarizing plate

during the cutting is beyond the management range of the product standards (for example, ± 0.05 mm). In FIG. 10, it will be appreciated that the variation width in the external dimensions of the polarizing plate during the cutting is beyond the management range (for example, ± 0.05 mm) of the product standards if the number of batches is four or
5 more.

[0079]

In contrast, the present embodiment includes measuring, after completing the predetermined number of batches of the cutting process, the displacement amount in the direction Vf of the rotating body 22 as the thermal expansion amount of the rotary shaft
10 21 after the cutting, and adjusting the relative position between, in the direction Vf, the cutting blade 24 and the end surface Wa of the laminated body W which is subjected to the cutting process in the subsequent batch, before beginning the cutting process of the subsequent batch, such that external dimensions of the laminated body W, which are to be obtained by the cutting process of the subsequent batch, would not be beyond the
15 pre-specified allowance (for example, ± 0.05 mm) defined by the product specification.

[0080]

In FIG. 11, for every one batch of the cutting process of the end surface Wa of the laminated body W the setting position of the cutting unit 20 is moved to a direction where the deviated amount is offset and thereby the required dimensions are materialized
20 such that the deviated amount from the reference value of the external dimensions of the laminated body W in the long-side direction of the optical member F would not be beyond the required allowance range.

[0081]

In FIG. 12, for every one batch of the cutting process of the end surface Wa of
25 the laminated body W the setting position of the cutting unit 20 is moved to a direction

where the deviated amount is offset and thereby the required dimensions are materialized such that the deviated amount from the reference value of the external dimensions of the laminated body W in the short-side direction of the optical member F would not be beyond the required allowance range.

5 [0082]

According to the present embodiment described above, if the setting position of the cutting unit 20 is moved at a predetermined timing, it is possible to obtain the optical member F satisfying the required dimensions.

[0083]

10 In addition, the displacement amount in the direction Vf of the rotating body 22 is measured as the thermal expansion amount of the rotary shaft 21 after the cutting, using the dimension sensor 30. Therefore, it is possible to accurately obtain an moving amount required for the cutting unit 20.

[0084]

15 In the present embodiment, an example where the moving device 4 moves the laminated body W in the direction V in parallel to the longitudinal direction of the end surface Wa of the laminated body W with respect to the cutting unit 20 has been described, but the embodiment is not limited thereto. The moving device may move the cutting unit in the direction in parallel to the longitudinal direction of the end surface of
20 the laminated body with respect to the end surface of the laminated body. That is, the moving device may be configured to relatively move the cutting unit in the direction in parallel to the longitudinal direction of the end surface of the laminated body with respect to the end surface of the laminated body.

[0085]

25 (Second Embodiment)

Subsequently, a cutting method according to a second embodiment will be described.

In the present embodiment, a temperature around the rotary shaft 21 after cutting is measured as a predetermined parameter, and based on data of the thermal expansion amount of the rotary shaft 21, which corresponds to the measured temperature, a relative position is adjusted between the end surface Wa of the laminated body W which is subjected to the cutting process in the subsequent batch and the cutting blade 24.

[0086]

FIG. 13 is a perspective view illustrating a temperature sensor 31 used in the cutting method of the present embodiment.

In FIG. 13, the same reference numerals are given to the configuration elements common to the first embodiment, and the detailed description thereof will not be repeated.

[0087]

As illustrated in FIG. 13, the temperature sensor 31 is a non-contact type temperature sensor and is arranged close to the cover 26. The temperature sensor 31 measures the temperature of the cover 26 as the temperature around the rotary shaft 21 after the cutting. As the temperature sensor 31, a contact type temperature sensor may be used.

[0088]

As described above, the rotary shaft 21 and the cover 26 are capable of heat conduction via the bearings 25 (refer to FIG. 3). For example, a temperature table indicating a relationship between the temperature of the cover 26 and the temperature of the rotary shaft 21 is set in advance to measure the temperature of the cover 26 using the temperature sensor 31. This enables the temperature of the rotary shaft 21 to be

indirectly measured.

[0089]

In addition, setting a thermal expansion table indicating the relationship between the temperature of the cover 26 and the thermal expansion amount of the rotary shaft 21 in advance can obtain the thermal expansion amount of the rotary shaft 21 after the cutting. That is, measuring the temperature of the cover 26 using the temperature sensor 31 enables the thermal expansion amount of the rotary shaft 21 to be indirectly measured after the cutting.

[0090]

FIG. 14 is a view illustrating a preparation method of the thermal expansion table indicating the relationship between the temperature of the cover 26 and the thermal expansion amount of the rotary shaft 21.

[0091]

For example, as illustrated in FIG. 14, the preparation method of the thermal expansion table can be prepared by setting the temperature of the cover 26 to a predetermined range and by measuring a displacement amount L in the direction Vf of the rotating body 22 as the thermal expansion amount of the rotary shaft 21 after the cutting, in the temperature within the predetermined range. When measuring the displacement amount L, for example, a measuring instrument made by Mitutoyo Corporation, that is, a “Digimatic Indicator” type ID-C1012X may be used.

[0092]

The controlling device 7, based on the data of the thermal expansion amount of the rotary shaft 21 corresponding to the measurement result of the temperature sensor 31, controls the first position adjusting device 5 and the second position adjusting device 6, and causes the first processing device 2 and the second processing device 3 to

respectively move in the direction Vf.

[0093]

In the cutting method according to the present embodiment, after completing the predetermined number of batches of the cutting process, the temperature of the cover 26
5 is measured as the temperature around the rotary shaft 21 after the cutting, using the temperature sensor 31; and based on the data of the displacement amount L in the direction Vf of the rotating body 22 as the thermal expansion amount of the rotary shaft 21 corresponding to the measured temperature, the relative position between, in the direction Vf, the cutting blade 24 and the end surface Wa of the laminated body W which
10 is subjected to the cutting process in the subsequent batch is adjusted using the controlling device 7, before beginning the cutting process of the subsequent batch, such that external dimensions of the laminated body W, which are to be obtained by the cutting process of the subsequent batch, would not be beyond the allowance defined by the product specification.

15 [0094]

Herein, a relation between the number of batches and the deviated amount from the reference value of the external dimensions of the laminated body W will be described with reference to FIGS. 15 and 16.

FIG. 15 is a view illustrating variations in the external dimensions of the
20 laminated body W in the long-side direction of the optical member F according to the present embodiment.

FIG. 16 is a view illustrating variations in the external dimensions of the laminated body W in the short-side direction of the optical member F according to the present embodiment.

25 In FIGS. 15 and 16, the horizontal axis represents the number of batches [Nos.].

The vertical axis represents a deviated amount [mm] from a reference value of the external dimensions of the laminated body W. “The maximum value” represents the largest value out of variations in the deviated amount during one batch, “the minimum value” represents the smallest value out of the variations in the deviated amount during one batch, and “the average value” represents a value obtained by averaging the variations in the deviated amount during one batch.

[0095]

In the present embodiment, after completing the predetermined number of batches of the cutting process, the temperature of the cover 26 is measured as the temperature around the rotary shaft 21 after the cutting; and based on the data of the displacement amount L in the direction Vf of the rotating body 22 as the thermal expansion amount of the rotary shaft 21 corresponding to the measured temperature, the relative position between, in the direction Vf, the cutting blade 24 and the end surface Wa of the laminated body W which is subjected to the cutting process in the subsequent batch is adjusted, before beginning the cutting process of the subsequent batch, such that external dimensions of the laminated body W, which are to be obtained by the cutting process of the subsequent batch, would not be beyond the required allowance (for example ± 0.05 mm) defined by the product specification.

[0096]

In FIG. 15, for every one batch of the cutting process of the end surface Wa of the laminated body W the setting position of the cutting unit 20 is moved to a direction where the deviated amount is offset and thereby the required dimensions are materialized such that the deviated amount from the reference value of the external dimensions of the laminated body W in the long-side direction of the optical member F would not be beyond the required allowance range.

[0097]

In FIG. 16, for every one batch of the cutting process of the end surface Wa of the laminated body W the setting position of the cutting unit 20 is moved to a direction where the deviated amount is offset and thereby the required dimensions are materialized
5 such that the deviated amount from the reference value of the external dimensions of the laminated body W in the short-side direction of the optical member F would not be beyond the required allowance range.

[0098]

Even in the present embodiment, if the setting position of the cutting unit 20 is
10 moved at a predetermined timing, it is possible to obtain the optical member F satisfying the required dimensions.

[0099]

In addition, according to the present embodiment, the temperature of the cover 26 is measured as the temperature around the rotary shaft 21 after the cutting, using the
15 temperature sensor 31, and the displacement amount L in the direction Vf of the rotating body 22 is obtained as the thermal expansion amount of the rotary shaft 21, which corresponds to the measured temperature. Therefore, it is possible to accurately obtain an moving amount required for the cutting unit 20.

[0100]

20 (Third Embodiment)

Subsequently, a cutting method according to a third embodiment will be described.

The cutting method according to the present embodiment is a cutting method for the end surface Wa of the laminated body W, which includes providing the cutting unit 20
25 having the rotary shaft 21 extending along the normal direction of the end surface Wa of

the laminated body W and having the cutting blade 24 protruding toward the end surface Wa side of the laminated body W; rotating the cutting blade 24 around the rotary shaft 21; and cutting the end surface Wa of the laminated body W by bringing the rotating cutting blade 24 into contact with the end surface Wa of the laminated body W; wherein
5 the rotary shaft 21 is cooled in order for the rotary shaft 21 not to be thermally expanded.

[[0101]

The controlling device 7 according to the present embodiment performs a control where the rotary shaft 21 is cooled in order for the rotary shaft 21 not to be thermally expanded, such that the external dimensions of the laminated body W would
10 not be beyond the required allowance defined by the product specification.

[0102]

In the present embodiment, the cooling is performed by an external cooling be means of a coolant. Specifically, the cooling is performed by winding a cooling unit 32 circulating the coolant around the cover 26.

15 [0103]

The cooling unit 32 capable of circulating the coolant to the cover 26 is wound around the cover 26. The controlling device 7, as a method of the cooling, performs a control for circulating the coolant to the cooling unit 32.

[0104]

20 FIG. 17 is a perspective view illustrating the cooling unit 32 used in the cutting method of the present embodiment.

In FIG. 17, the same reference numerals are given to the configuration elements common to the first embodiment, and the detailed description thereof will not be repeated.

25 [0105]

Examples of the coolant includes a cooling water.

As illustrated in FIG. 17, the cooling unit 32 is arranged in contact with the cover 26. For example, the cooling unit 32 is a hose circulating the cooling water.

[0106]

5 As described above, the rotary shaft 21 and the cover 26 are capable of heat conduction via the bearings 25 (refer to FIG. 3). For example, a temperature table indicating a relationship between the temperature of the cooling water and the temperature of the rotary shaft 21 is set in advance to set the temperature of the cooling water to a temperature which does not allow the rotary shaft 21 to be thermally expanded
10 in excess, and the cooling unit 32 is wound around the cover 26. This enables the rotary shaft 21 to be indirectly cooled via the cover 26 and the bearings 25.

[0107]

According to the present embodiment, the cooling unit 32 cools the cover 26 in order for the rotary 21 not to be thermally expanded and the rotary shaft 21 is indirectly
15 cooled. Therefore, it is possible to obtain the optical member F satisfying the required dimensions.

[0108]

(Fourth Embodiment)

Subsequently, a cutting method according to a fourth embodiment will be
20 described.

In the above-described third embodiment, the cooling is performed by winding the cooling unit 32 circulating the coolant around the cover 26.

In contrast, in the present embodiment, the cooling is performed by blowing cooling air to the cover 26 using an air-cooling unit (in the example a blower 33).

25 [0109]

The blower 33 capable of blowing the cooling air to the cover 26 is disposed at the cover 26. The controlling device 7, as the cooling, performs a control for causing the blower 33 to blow the cooling air.

[0110]

5 FIG. 18 is a perspective view illustrating the blower 33 used in the cutting method of the present embodiment.

In FIG. 18, the same reference numerals are given to the configuration elements common to the first embodiment, and the detailed description thereof will not be repeated.

10 [0111]

As illustrated in FIG. 18, an outlet of the blower 33 for the cooling air is arranged opposing the rotary shaft 21.

[0112]

As described above, the rotary shaft 21 and the cover 26 are capable of heat
15 conduction via the bearings 25 (refer to FIG. 3). For example, a temperature table indicating a relationship between the temperature of the cooling air and the temperature of the rotary shaft 21 is set in advance to set the temperature of the cooling air to a temperature which does not allow the rotary shaft 21 to be thermally expanded in excess, and the blower 33 is used to blow the cooling air to the cover 26. This enables the
20 rotary shaft 21 to be indirectly cooled.

[0113]

According to the present embodiment, the blower 33 cools the cover 26 using the cooling air in order for the rotary 21 not to be thermally expanded and the rotary shaft 21 is indirectly cooled. Therefore, it is possible to obtain the optical member F
25 satisfying the required dimensions.

[0114]

In the third and fourth embodiments, cooling by the cooling unit 32 and cooling by the blower 33 are respectively described as an example of the cooling, but the cooling is not limited thereto. In addition, an example of indirectly cooling the rotary shaft 21 has been described as the cooling, but the rotary shaft 21 may be directly cooled.

[0115]

In addition, the cooling may be performed in combination with the cooling by the cooling unit 32 and the cooling by the blower 33.

[0116]

10 (Fifth Embodiment)

Subsequently, a cutting method according to a fifth embodiment will be described.

The cutting method according to the present embodiment is a cutting method to cut the end surface Wa of the laminated body W, which includes providing the cutting unit 20 having the rotary shaft 21 extending along the normal direction of the end surface Wa of the laminated body W and having the cutting blade 24 protruding toward the end surface Wa side of the laminated body W; rotating the cutting blade 24 around the rotary shaft 21; and cutting the end surface Wa of the laminated body W by bringing the rotating cutting blade 24 into contact with the end surface Wa of the laminated body W; wherein the rotary shaft 21 has been heated in advance up to a saturated condition where the thermal expansion of the rotary shaft 21 no longer occurs.

[0117]

The controlling device 7 according to the present embodiment performs a control where the rotary shaft 21 has been heated in advance up to the saturated condition where the thermal expansion of the rotary shaft 21 no longer occurs, such that the

external dimensions of the laminated body W would not be beyond the required allowance defined by the product specification.

[0118]

In the present embodiment, the heating is performed by allowing an idling
5 rotation of the rotary shaft 21 before performing the cutting process of the laminated body W.

[0119]

The controlling device 7, as the heating, performs a control for allowing the idling rotation of the rotary shaft 21 before performing the cutting process of the
10 laminated body W.

[0120]

For example, a thermal expansion table indicating a relationship between the number of rotations (rotating time) of the rotary shaft 21 and the temperature allowing the saturated condition where the thermal expansion of the rotary shaft 21 no longer
15 occurs is set in advance. As illustrated in FIG. 1, before the moving device 4 moves the laminated body W to the cutting unit 20 in the direction V, the idling rotation of the rotary shaft 21 may be allowed in advance until the saturated condition where the thermal expansion of the rotary shaft 21 no longer occurs.

[0121]

20 According to the present embodiment, the idling rotation of the rotary shaft 21 is allowed until the saturated condition where the thermal expansion of the rotary shaft 21 no longer occurs. Therefore, it is possible to eliminate the influence due to the thermal expansion of the rotary shaft 21 with respect to the phenomenon where the external dimensions of the optical member are gradually decreased. Consequently, it is possible
25 to obtain the optical member F satisfying the required dimensions.

[0122]

In the present embodiment, the idling rotation of the rotary shaft 21 before performing the cutting process of the laminated body W has been described as the heating by way of example, the heating is not limited thereto. For example, the heating
5 may be performed using various methods such as heating the rotary shaft 21 using a heater and the like before performing the cutting process of the laminated body W. In addition, the rotary shaft 21 may be directly heated or indirectly heated as the heating.

[0123]

In addition, in the above-described embodiments, the example of controlling the
10 configuration elements of the cutting apparatus 1 using the controlling device 7 has been described by way of example, but the method is not limited thereto. For example, a cutting method may be adopted where workers use the cutting apparatus 1.

[0124]

Each of the above-described embodiments are explained by example in which
15 the rotary shaft 21 extends along a normal direction of the end surface Wa (refer to FIG. 1) of the laminated body W, but are not limited thereto. For example, the rotary shaft 21 may tilt obliquely against the end surface Wa of the laminated body W. That is, it can be configured to cut obliquely the end surface Wa of the laminated body W by the cutting blade 24.

20 [0125]

Hitherto, preferred embodiments according to the present embodiments have been described with reference to the accompanying drawings, but the present invention of course is not limited to the embodiments. The various shapes or combinations of the respective configuration members illustrated in the above-described embodiments are
25 merely an example, and may be diversely modified depending on the design

requirements within the scope without departing from the gist of the present invention.

Reference Signs List

[0126]

- | | | |
|----|----|---|
| 5 | 1 | Cutting Apparatus |
| | 2 | First Processing Device (Processing Device) |
| | 3 | Second Processing Device (Processing Device) |
| | 7 | Controlling Device |
| | 20 | Cutting unit |
| 10 | 21 | Rotary Shaft |
| | 24 | Cutting Blade |
| | 25 | Bearings |
| | 26 | Cover |
| | 32 | Cooling unit |
| 15 | 33 | Air cooling unit (Blower) |
| | W | Laminated Body (Object) |
| | Wa | End Surface of Laminated Body (End Surface of Object) |

CLAIMS

1. A cutting method to cut an end surface of a workpiece, the method comprising:

5 providing a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece;

rotating the cutting blade around the rotary shaft;

cutting the end surface of the workpiece by bringing the rotating cutting blade into contact with the end surface of the workpiece;

10 measuring a predetermined parameter indicating an overheated condition of the cutting unit after completing a predetermined number of batches of a cutting process of; and

adjusting a relative position between the cutting blade and an end surface of a workpiece to be cut in a subsequent batch, before beginning the cutting process of the
15 subsequent batch.

2. The cutting method according to claim 1, wherein a relative position between the cutting blade and an end surface of a workpiece to be cut in a subsequent batch is adjusted such that external dimensions of the workpiece, which are to be
20 obtained by the cutting process of the subsequent batch, would not be beyond a required allowance.

3. The cutting method according to claim 1 or 2, wherein a thermal expansion amount of the rotary shaft after cutting is measured as the predetermined parameter.

4. The cutting method according to claim 1 or 2, wherein a temperature around the rotary shaft after cutting is measured as the predetermined parameter; and

the adjusting is performed based on data of a thermal expansion amount of the rotary shaft corresponding to the measured temperature.

5

5. The cutting method according to claim 4,

wherein the rotary shaft is rotatably supported by bearings, and both the rotary shaft and the bearings are covered with a cover,

wherein the rotary shaft and the cover are capable of heat conduction via the

10 bearing, and

wherein a temperature of the cover is measured as the temperature around the rotary shaft.

6. A cutting method to set an end surface of a workpiece, the method

15 comprising:

providing a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece;

rotating the cutting blade around the rotary shaft; and

cutting the end surface of the workpiece by bringing the rotating cutting blade

20 into contact with the end surface of the workpiece;

wherein the rotary shaft is cooled in order for the rotary shaft not to be thermally expanded.

7. The cutting method according to claim 6, wherein the rotary shaft is cooled

25 in order for the rotary shaft not to be thermally expanded, such that external dimensions

of the workpiece would not be beyond a required allowance.

8. The cutting method according to claim 6 or 7,

wherein the rotary shaft is rotatably supported by bearings, and both the rotary
5 shaft and the bearings are covered with a cover,

wherein the rotary shaft and the cover are capable of heat conduction via the
bearing, and

wherein the cooling is performed by an external cooling of the cover by means
of a coolant..

10

9. The cutting method according to claim 6 or 7,

wherein the rotary shaft is rotatably supported by bearings, and both the rotary
shaft and the bearings are covered with a cover,

wherein the rotary shaft and the cover are capable of heat conduction via the
15 bearing, and

wherein the cooling is performed by blowing cooling air onto the cover using an
air-cooling unit.

10. A cutting method to cut an end surface of a workpiece, the method

20 comprising:

providing a cutting unit having a rotary shaft and a cutting blade protruding
toward the end surface side of the workpiece;

rotating the cutting blade around the rotary shaft; and

cutting the end surface of the workpiece by bringing the rotating cutting blade
25 into contact with the end surface of the workpiece;

wherein the rotary shaft has been heated in advance up to a saturated condition where thermal expansion of the rotary shaft no longer occurs.

11. The cutting method according to claim 10, wherein the rotary shaft has
5 been heated in advance up to a saturated condition where thermal expansion of the rotary shaft no longer occurs, such that external dimensions of the workpiece would not be beyond a required allowance.

12. The cutting method according to claim 10 or 11,
10 wherein the heating is performed by allowing an idling rotation of the rotary shaft before performing a cutting process of the workpiece.

13. A cutting apparatus to cut an end surface of a workpiece, comprising:
a processing device comprising a cutting unit having a rotary shaft and a cutting
15 blade protruding toward the end surface side of the workpiece, wherein the cutting blade is rotatable around the rotary shaft and the end surface of the workpiece is cuttable by bringing the rotating cutting blade into contact with the end surface of the workpiece; and
a controlling device that controls adjusting a relative position between the
cutting blade and an end surface of a workpiece to be cut in a subsequent batch, before
20 beginning a cutting process of the subsequent batch, based on a predetermined parameter indicating an overheated condition of the cutting unit, after completing a predetermined number of batches of the cutting process.

14. The cutting apparatus according to claim 13, wherein the controlling
25 device controls adjusting the relative position between the cutting blade and an end

surface of a workpiece to be cut in a subsequent batch, such that external dimensions of the workpiece to be obtained by the cutting process of the subsequent batch would not be beyond a required allowance.

5 15. The cutting apparatus according to claim 13 or 14, further comprising:
a dimension sensor which measures a thermal expansion amount of the rotary
shaft after cutting as the predetermined parameter.

16. The cutting apparatus according to claim 13 or 14, further comprising:
10 a temperature sensor which measures a temperature around the rotary shaft after
cutting as the predetermined parameter,

wherein the controlling device performs the adjustment based on data of a
thermal expansion amount of the rotary shaft corresponding to a measurement result of
the temperature sensor.

15 17. The cutting apparatus according to claim 16, further comprising:
bearings rotatably supporting the rotary shaft and a cover covering both the
rotary shaft and the bearings,

wherein the rotary shaft and the cover are capable of heat conduction via the
20 bearing, and

wherein the temperature sensor measures a temperature of the cover as the
temperature around the rotary shaft.

18. A cutting apparatus to cut an end surface of a workpiece, comprising:
25 a processing device comprising a cutting unit having a rotary shaft and a cutting

blade protruding toward the end surface side of the workpiece, wherein the cutting blade is rotatable around the rotary shaft and the end surface of the workpiece is cuttable by bringing the rotating cutting blade into contact with the end surface of the workpiece; and
a controlling device that performs a control where the rotary shaft is cooled in
5 order for the rotary shaft not to be thermally expanded.

19. The cutting apparatus according to claim 18, wherein the controlling device performs the control where the rotary shaft is cooled in order for the rotary shaft not to be thermally expanded, such that external dimensions of the workpiece would not
10 be beyond a required allowance.

20. The cutting apparatus according to claim 18 or 19, further comprising:
bearings rotatably supporting the rotary shaft,
a cover covering both of the rotary shaft and the bearings, and
15 a cooling unit capable of external cooling of the cover by means of a coolant;
wherein the rotary shaft and the cover are capable of heat conduction via the bearing, and
wherein the controlling device controls the cooling unit performing the external cooling of the cover.

20

21. The cutting apparatus according to claim 18 or 19, further comprising:
bearings rotatably supporting the rotary shaft,
a cover covering both of the rotary shaft and the bearings, and
an air-cooling unit capable of blowing cooling air onto the cover;
25 wherein the rotary shaft and the cover are capable of heat conduction via the

bearing, and

wherein the controlling device controls the air-cooling unit of blowing the cooling air onto the cover.

5 22. A cutting apparatus to cut an end surface of a workpiece, comprising:

a processing device comprising a cutting unit having a rotary shaft and a cutting blade protruding toward the end surface side of the workpiece, wherein the cutting blade is rotatable around the rotary shaft and the end surface of the workpiece is cuttable by bringing the rotating cutting blade into contact with the end surface of the workpiece; and

10 a controlling device that performs a control where the rotary shaft has been heated in advance up to a saturated condition where thermal expansion of the rotary shaft no longer occurs.

23. The cutting apparatus according to claim 22, wherein the controlling
15 device performs a control where the rotary shaft has been heated in advance up to a saturated condition where thermal expansion of the rotary shaft no longer occurs, such that external dimensions of the workpiece would not be beyond a required allowance.

24. The cutting apparatus according to claim 22 or 23,
20 wherein the controlling device performs a control for allowing an idling rotation of the rotary shaft before performing a cutting process of the workpiece, as the heating.

FIG. 1

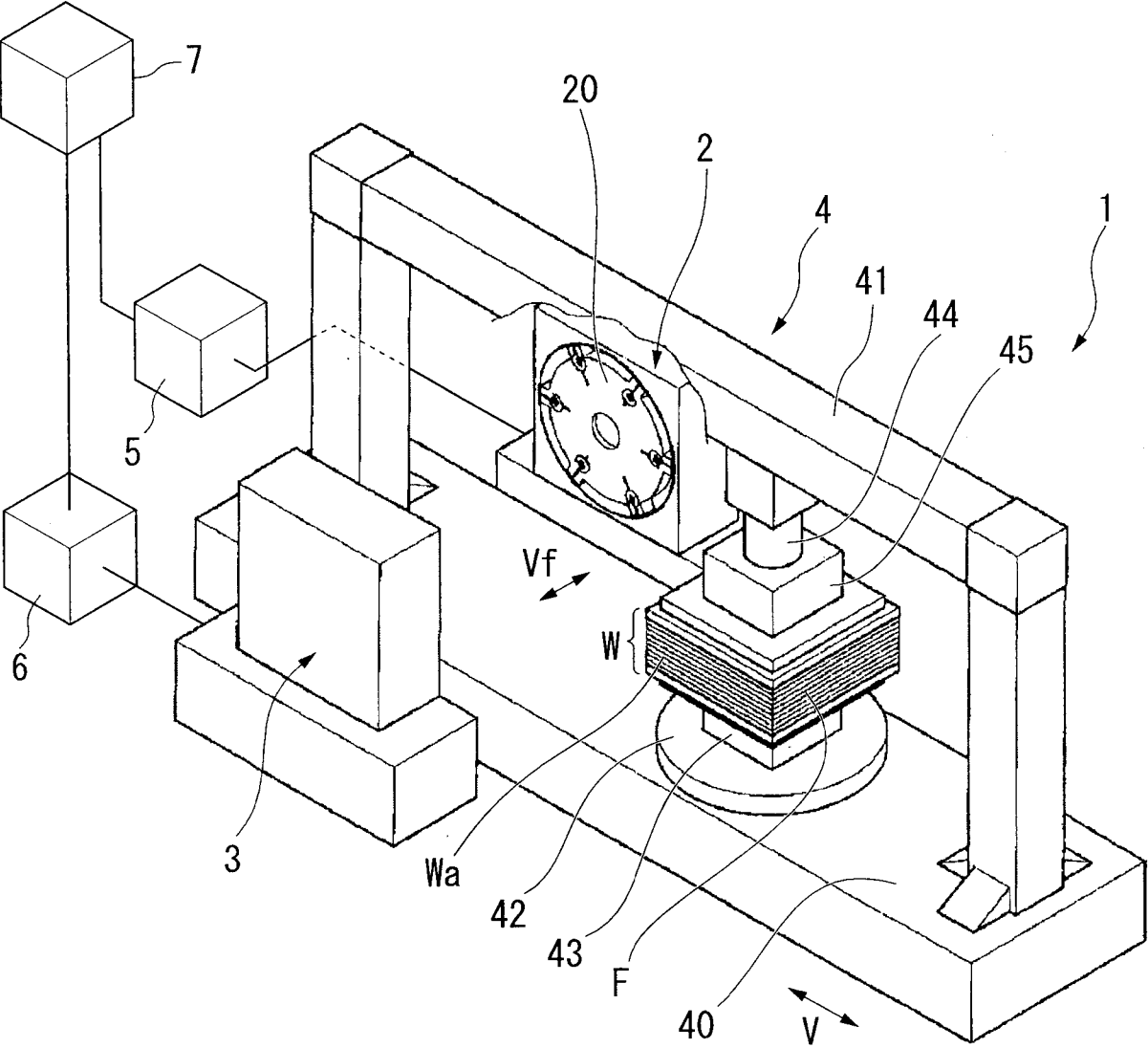


FIG. 2

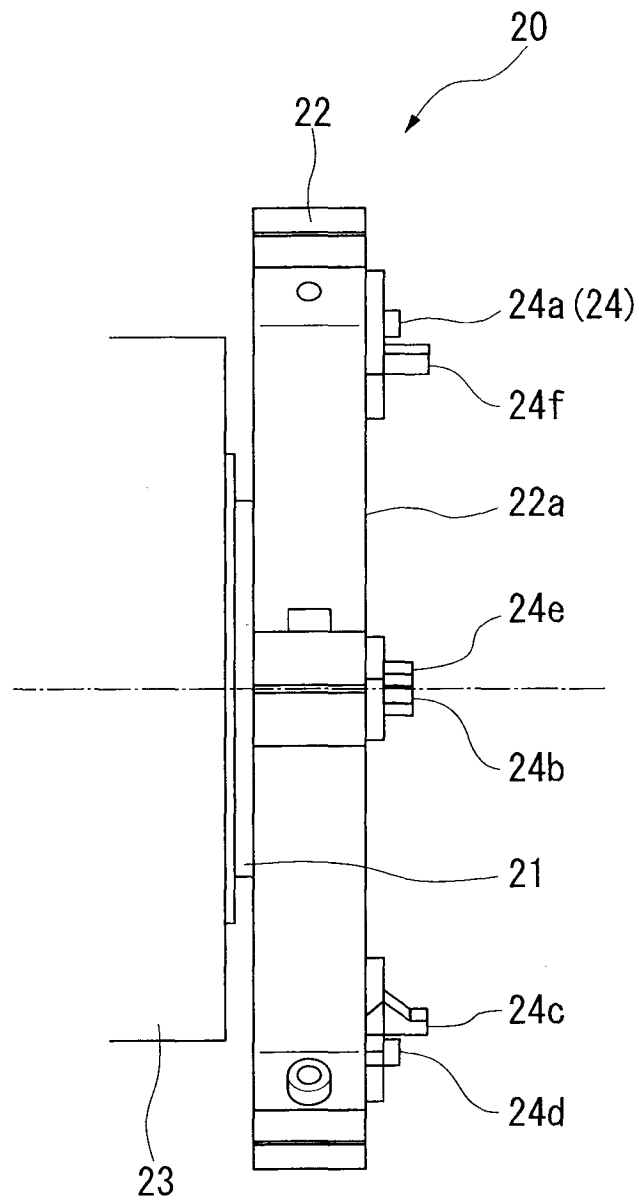
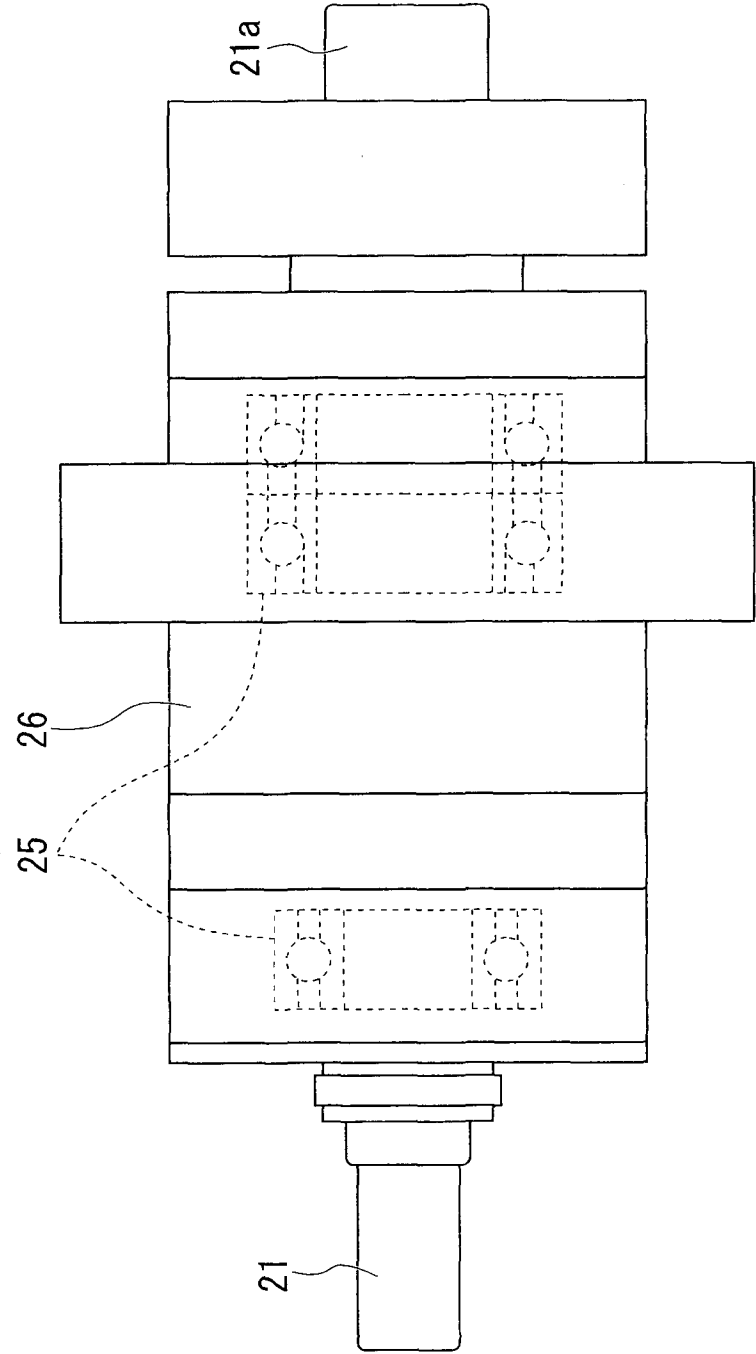


FIG. 3



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FIG. 4

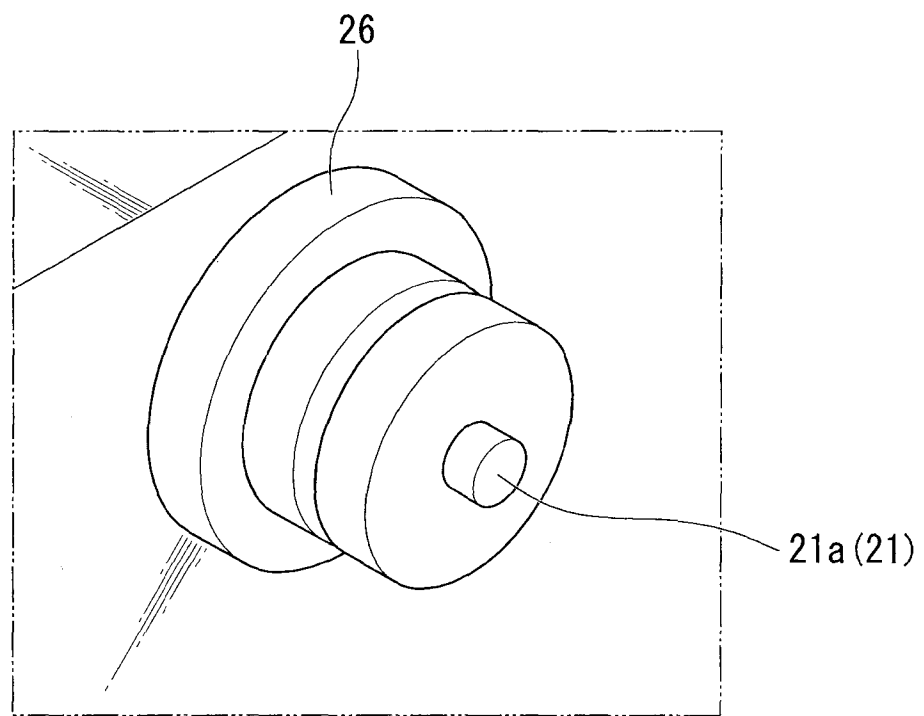
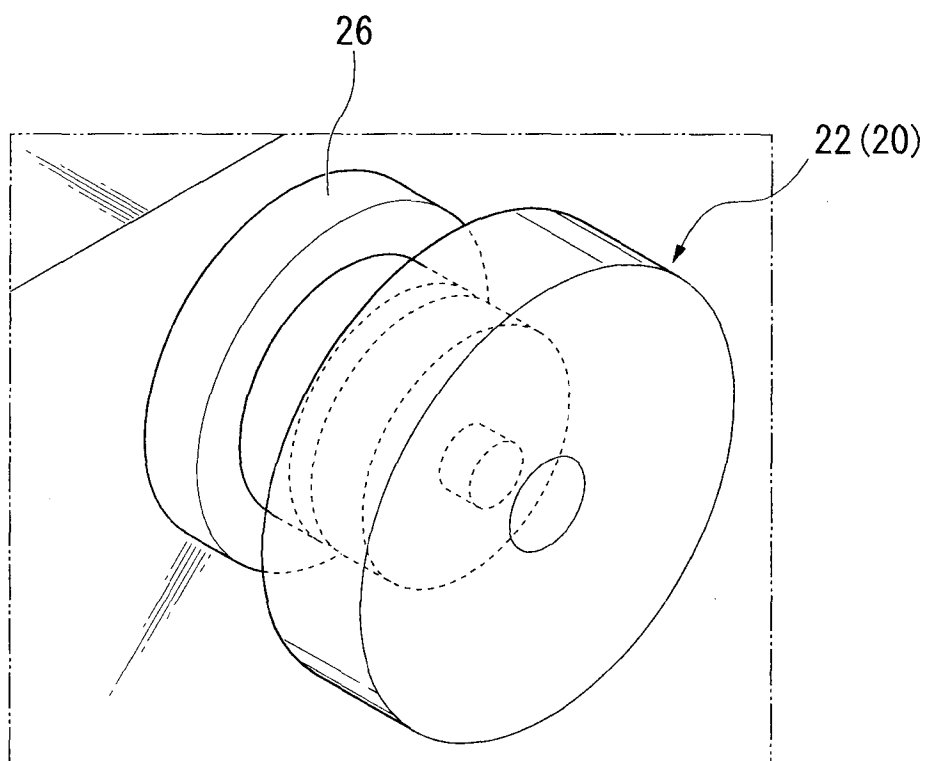


FIG. 5



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FIG. 6

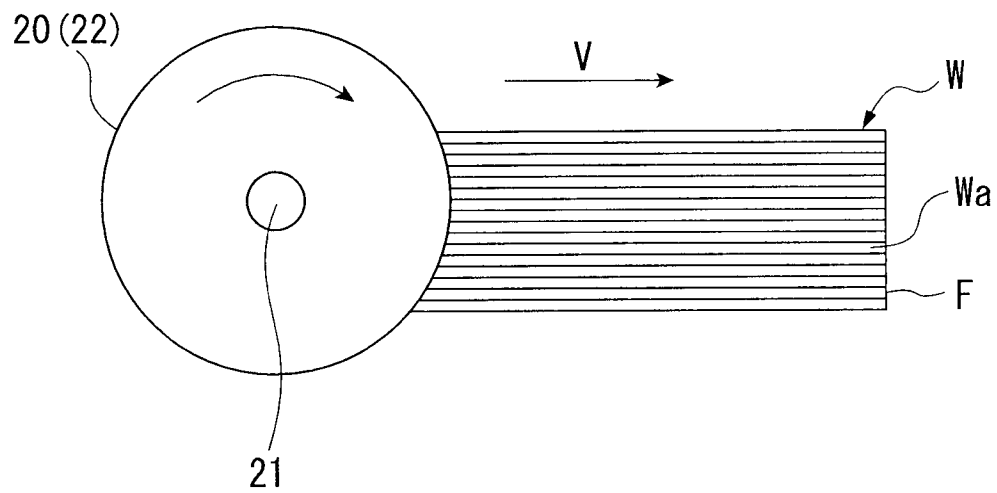


FIG. 7

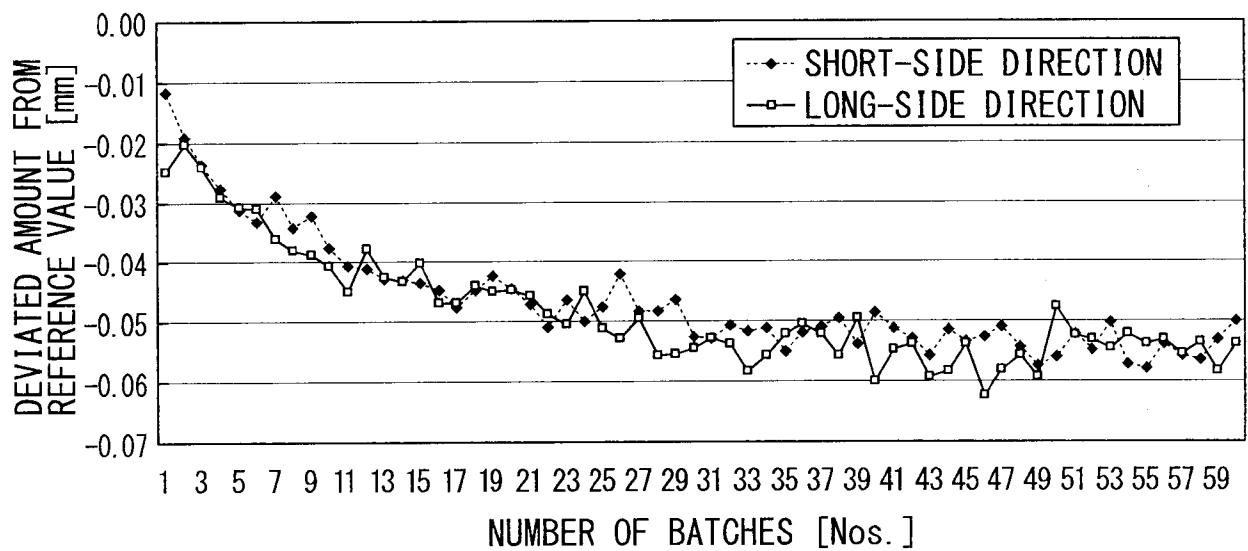


FIG. 8

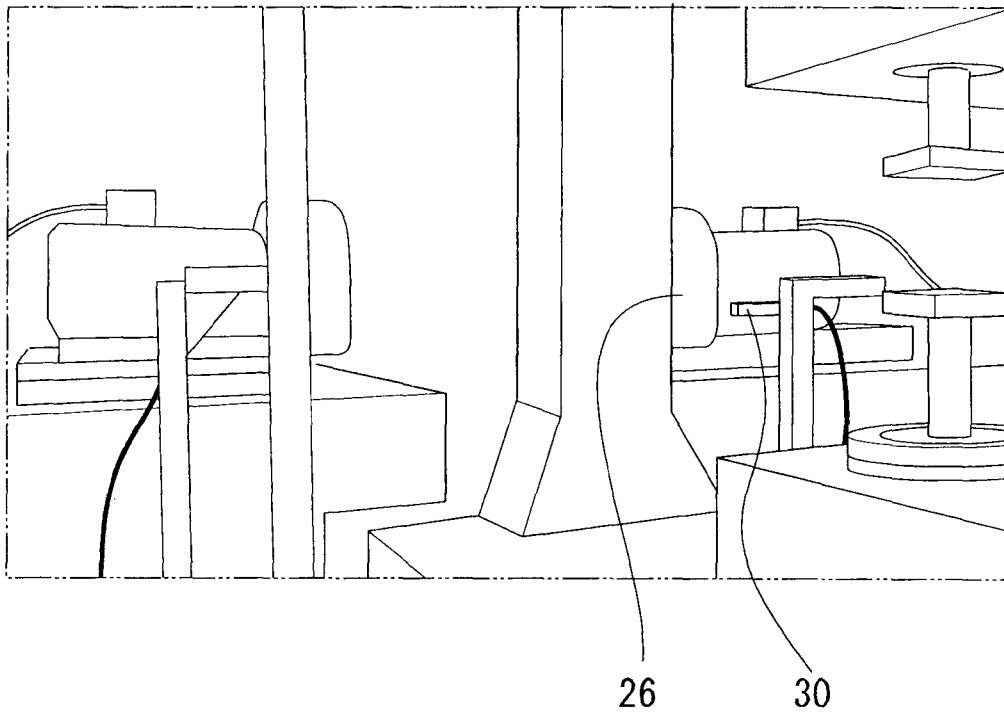
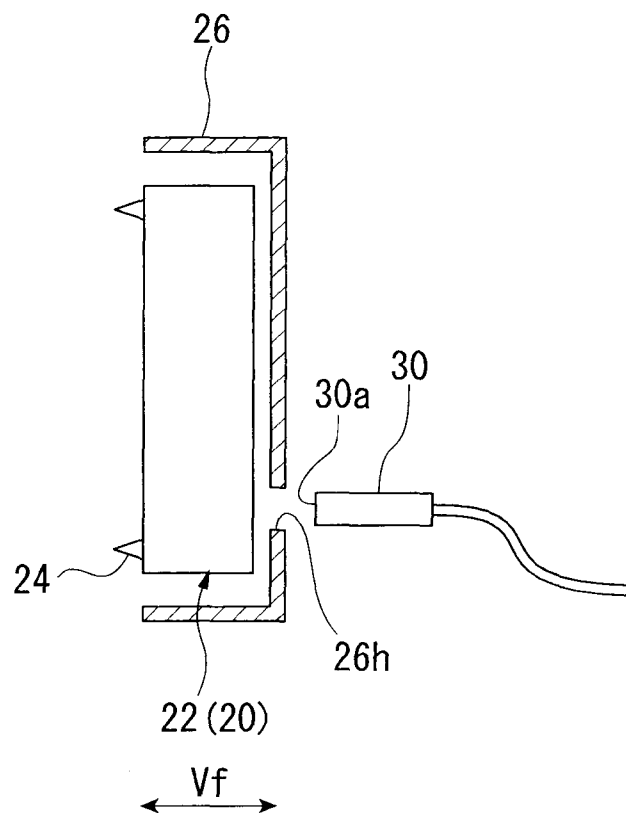
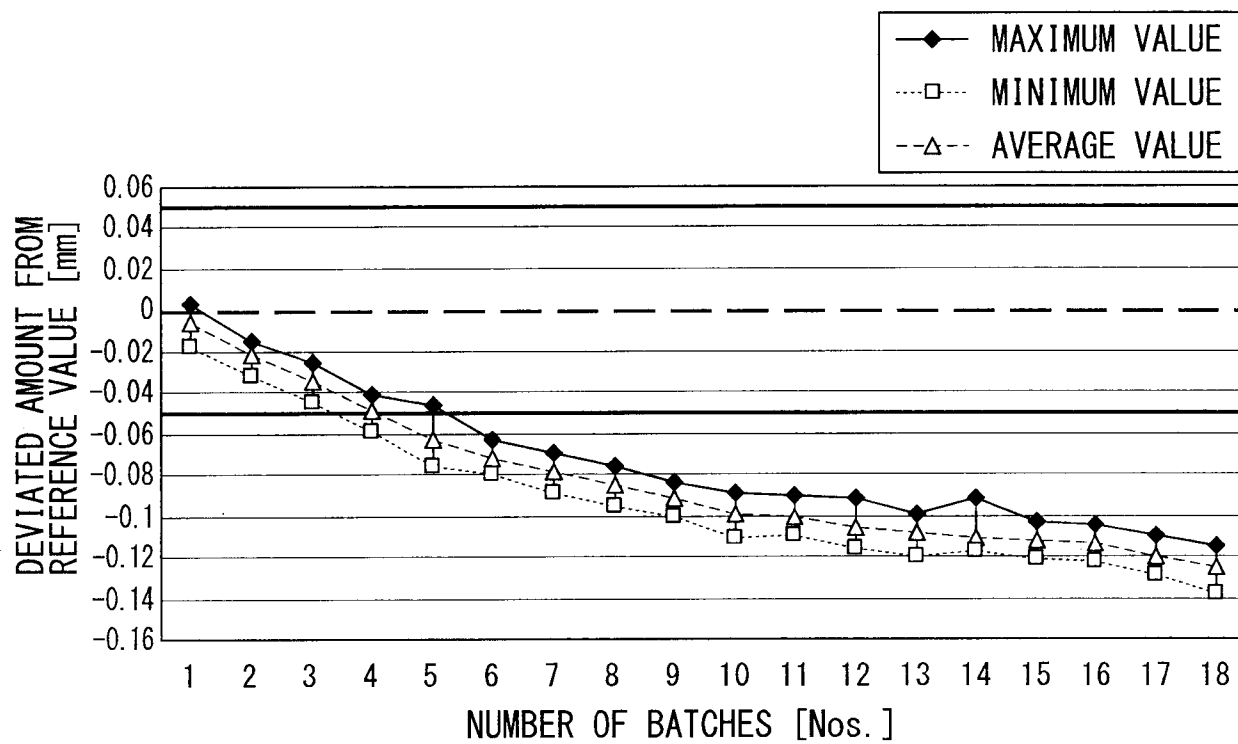


FIG. 9



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FIG. 10



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FIG. 11

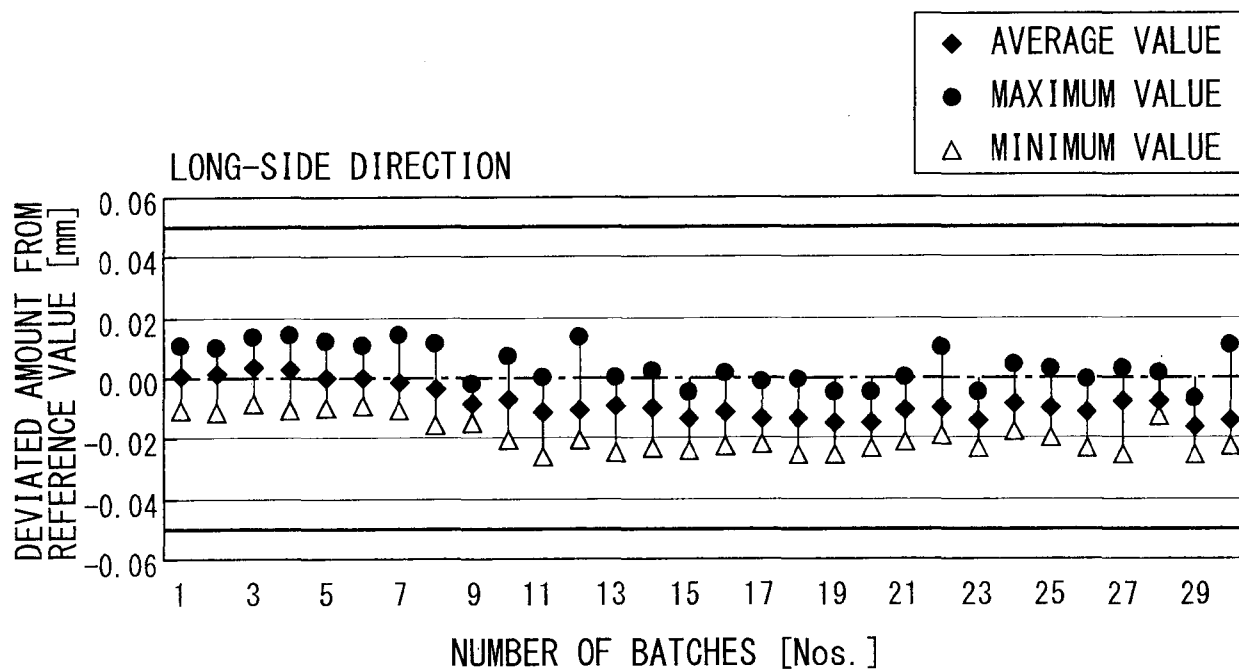


FIG. 12

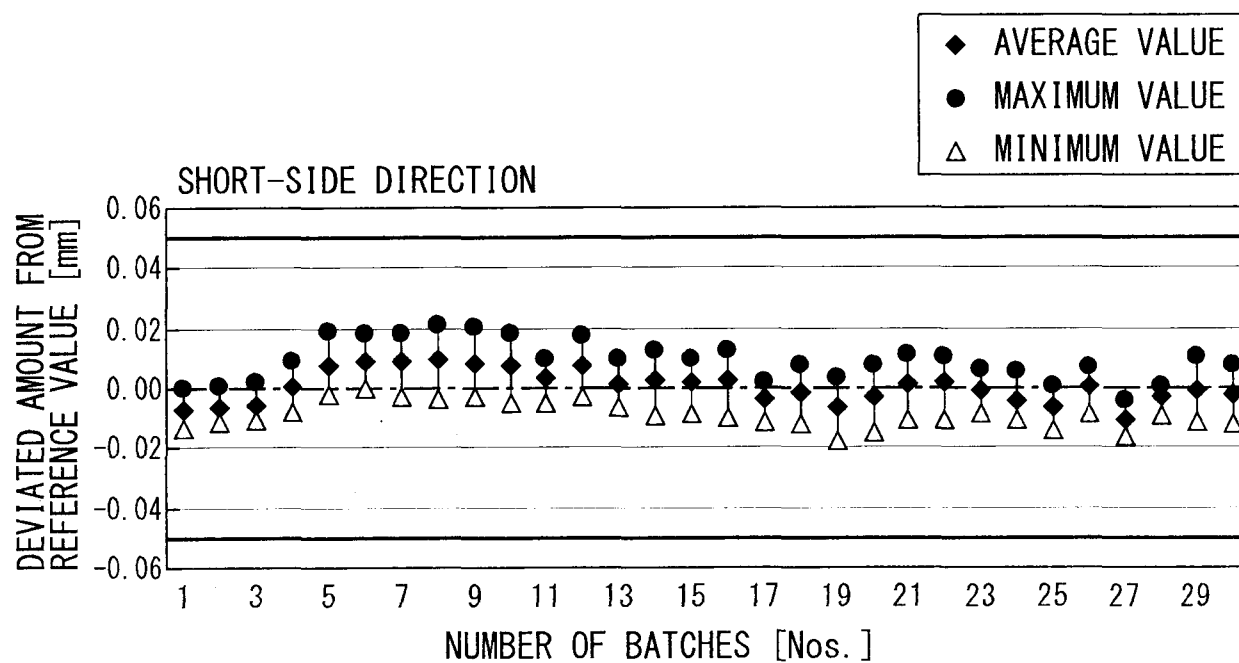


FIG. 13

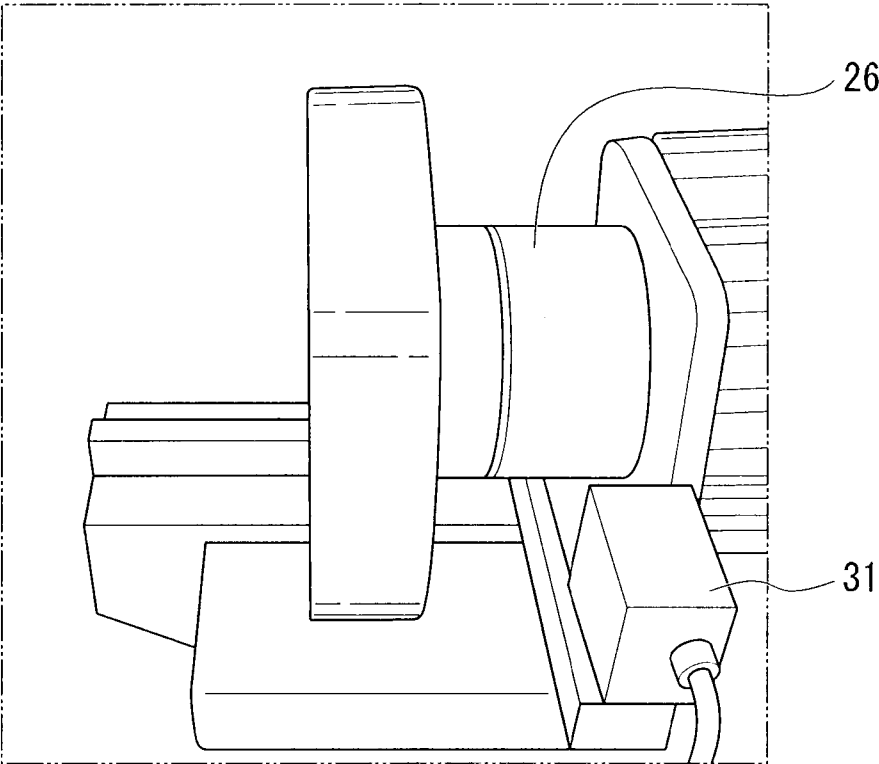
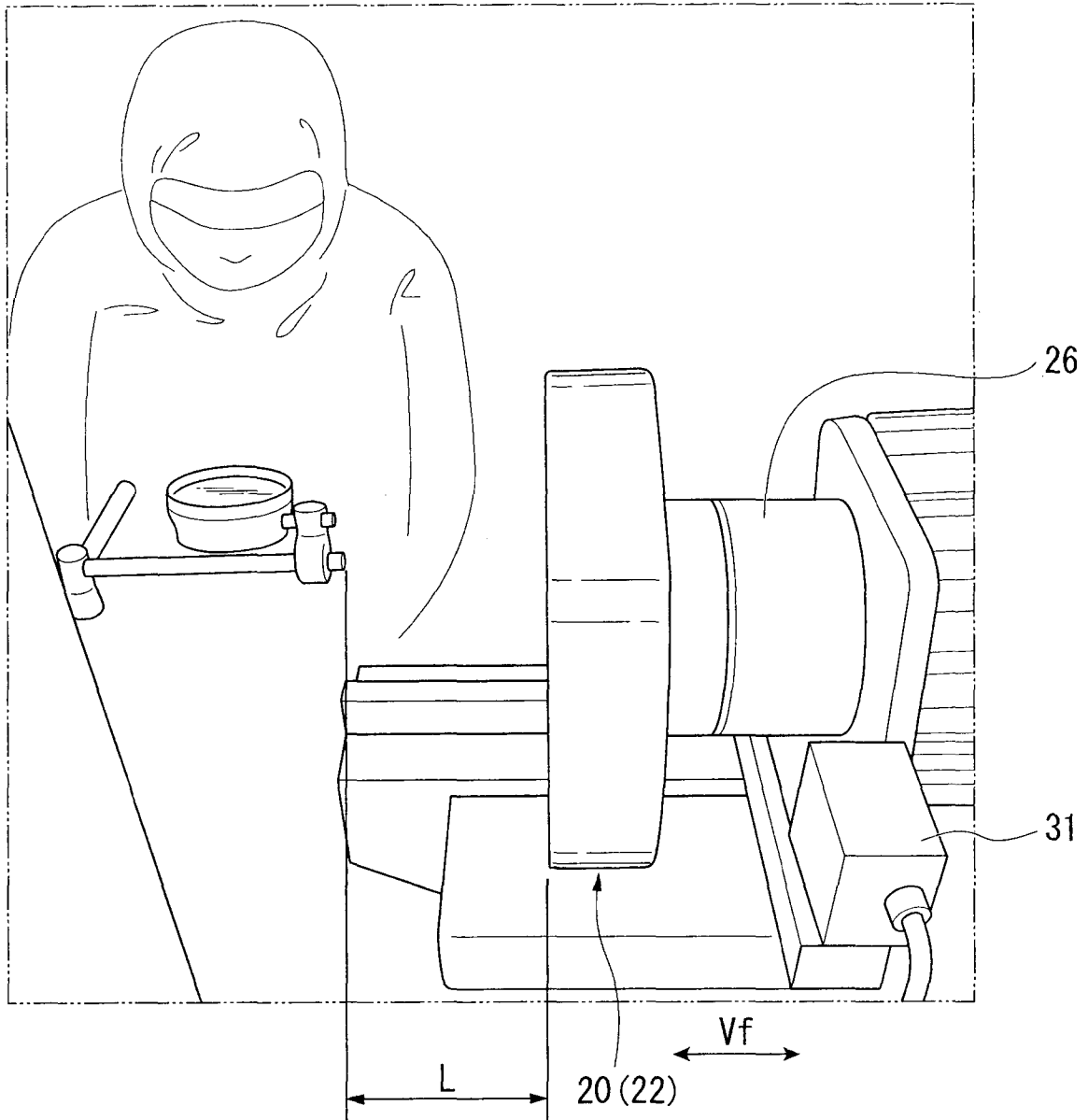


FIG. 14



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FIG. 15

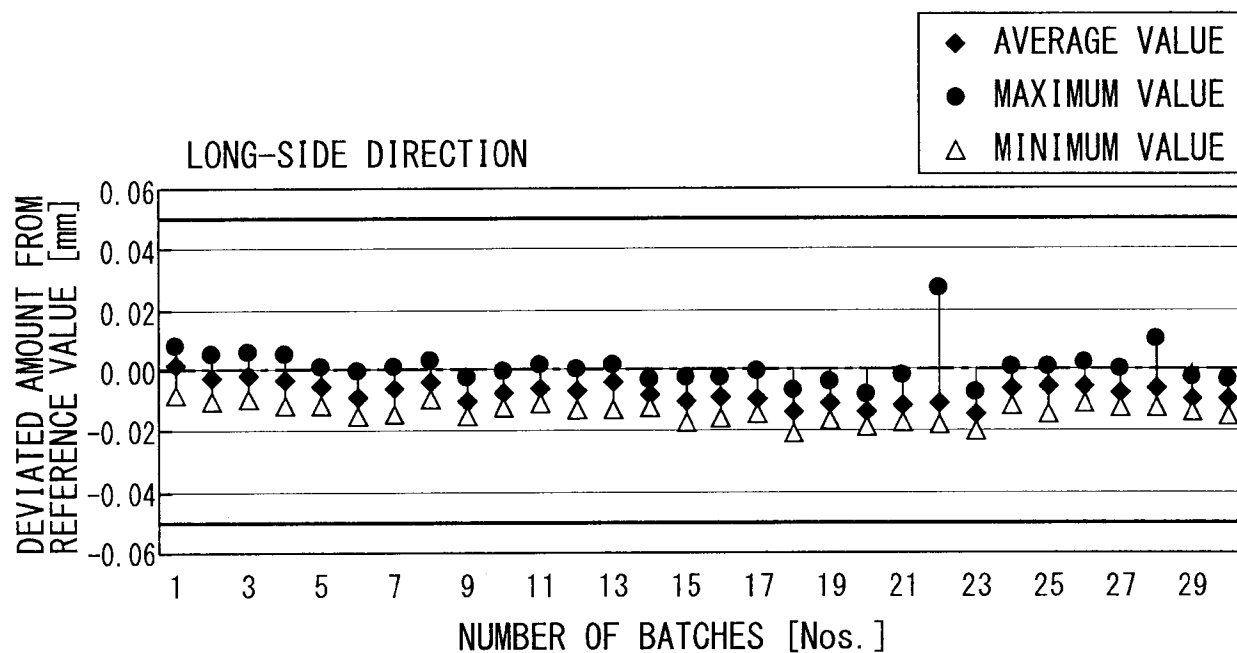
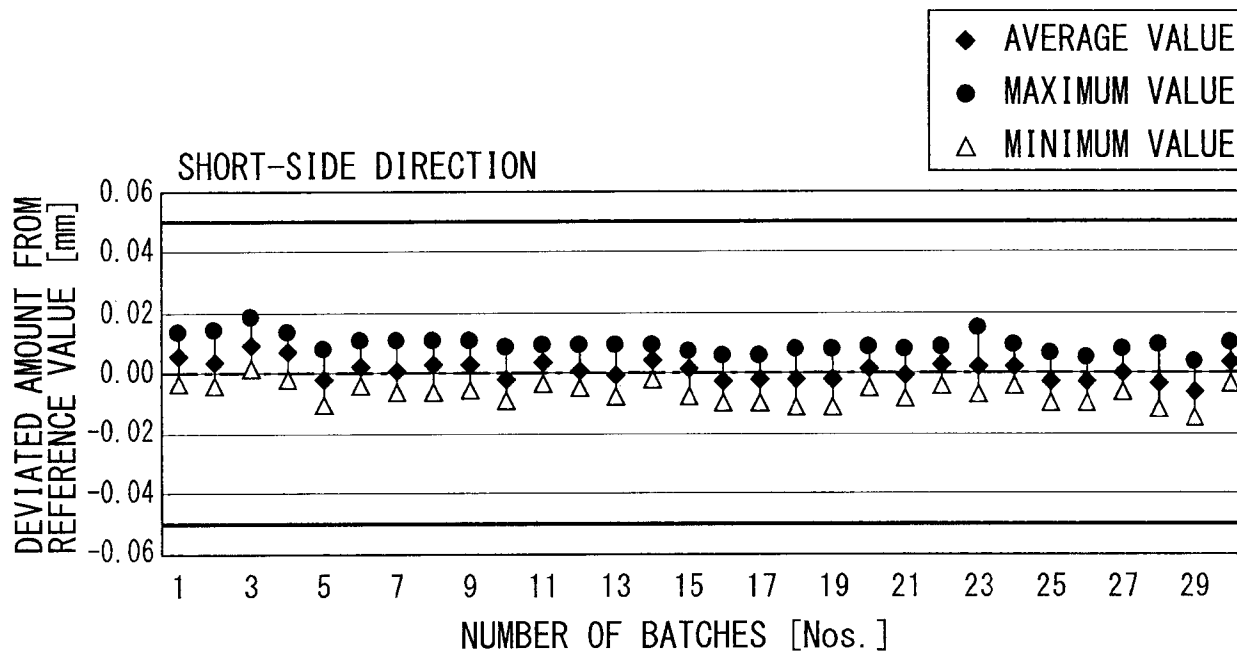


FIG. 16



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FIG. 17

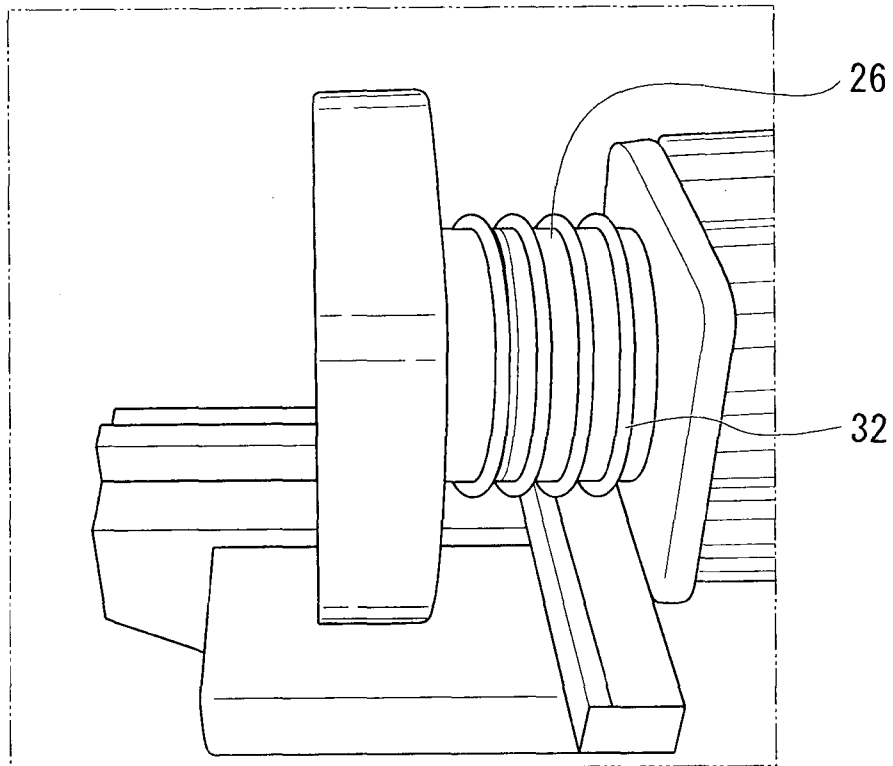
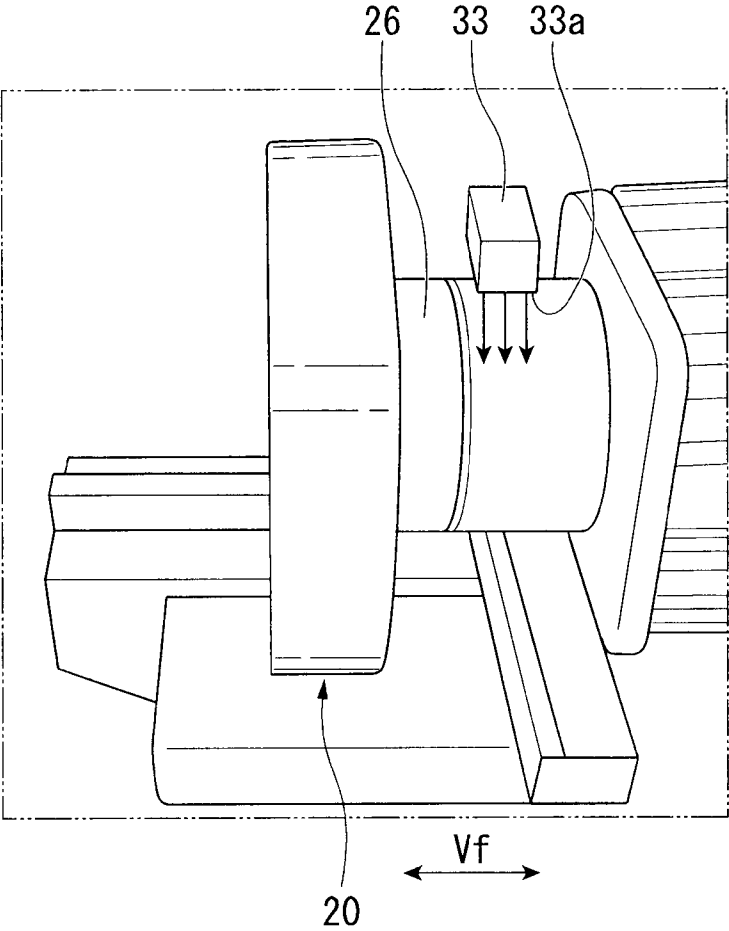


FIG. 18



INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/000449

A. CLASSIFICATION OF SUBJECT MATTER

See the extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B23B3/-, B23Q15/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI, CNPAT: overheated, preheat+, cool+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN201023135Y (PU H)20 Feb. 2008(20.02.2008) see the description page 3 and figure 2	1-24
Y	JP2010188505A (FUJI KIKAI SEIZO KK)2 Sep. 2010(02.09.2010) see the abstract	1-5,13-17
Y	CN102120266A (UNIV DONGGUAN TECHNOLOGY)13 Jul. 2011(13.07.2011) see the abstract	6-9,18-21
Y	US3897535A (UNITED AIRCRAFT CORP)29 Jul. 1975(29.07.1975) see the description, column 1, lines 63-67	10-12,22-24
A	CN1093959A (CANON KK)26 Oct. 1994(26.10.1994) see the whole document	1-24

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“L” document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&” document member of the same patent family
“O” document referring to an oral disclosure, use, exhibition or other means	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
14 Jan. 2014(14.01.2014)Date of mailing of the international search report
23 Jan. 2014 (23.01.2014)Name and mailing address of the ISA/CN
The State Intellectual Property Office, the P.R.China
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Telephone No. (86-10)62085415

International application No.
PCT/CN2013/000449

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/000449

Continuation of second sheet: **A. CLASSIFICATION OF SUBJECT MATTER**

B23B 3/22 (2006.01) i

B23Q 15/18 (2006.01) i