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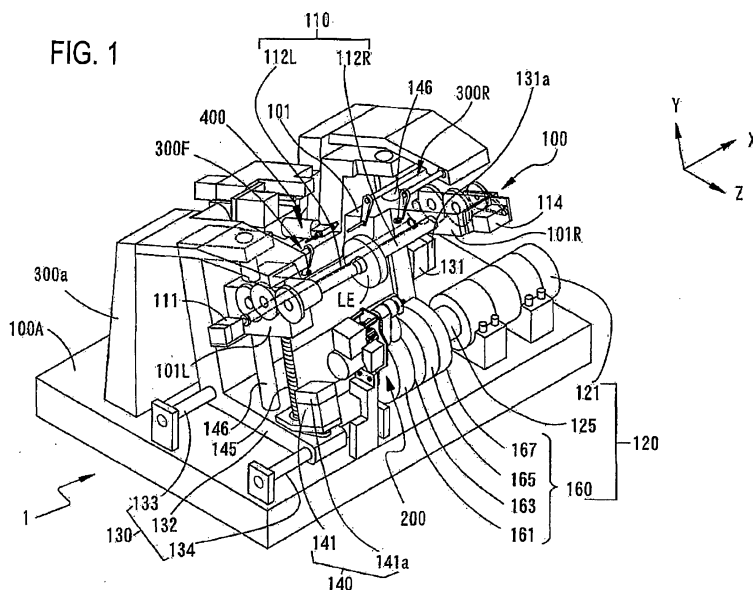
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(54) **Eyeglass lens processing apparatus**

(57) An eyeglass lens processing apparatus is provided with a finishing tool 161 having a bevel groove 161v for beveling and a flat-processing portion 161b; moving means 130, 140 for moving a pair of lens chuck shafts 112L, 112R with respect to a tool rotation shaft in a chuck shafts extending direction (X direction) and in a Y direction in which the axis-to-axis distance between the tool rotation shaft and the chuck shafts is varied; and control means 50 for causing flat finishing to be performed on the periphery of a lens as subjected to rough processing by controlling the moving means on the basis of a target lens shape and detection results of edge position detect-

ing means when a flat-processing mode is selected. If the edge thickness is larger than a first threshold value, the control means divides a process of the flat-finishing into plural stages and, at each stage, determines a processing position of the lens which shifted in the X direction with respect to the flat-processing portion so that an unprocessed portion of the preceding stage will be flat finished on the basis of the front surface edge position and/or a rear surface edge position detected by the edge position detecting means 300F, 300R, and causing the periphery of the lens to be subjected to flat finishing by controlling the moving means on the basis of the determined processing positions.



Description**BACKGROUND OF THE INVENTION**

[0001] The present invention relates to an eyeglass lens processing apparatus for processing the periphery of an eyeglass lens.

[0002] An eyeglass lens processing apparatus is known which is equipped with lens chuck shafts for holding an eyeglass lens, a tool rotation shaft to which plural grindstones such as a roughing grindstone, a finishing grindstone (normal finishing grindstone) having a bevel groove and a flat-processing portion, and a polishing grindstone having a bevel polishing groove and flat-processing portion are attached concentrically (refer to JP-A-2010-280018). Also known is an apparatus in which to enable beveling of a high-curvature lens a finishing grindstone for high-curvature beveling is also attached to the tool rotation shaft (refer to JP-A-2008-254077).

SUMMARY

[0003] Plural grindstones are combined as processing tools to meet the needs of a user. However, when the number of grindstones is increased, the width of each grindstone needs to be reduced to house all the grindstones in the limited space of a processing room. In particular, if the widths of the flat-processing portions of the normal finishing grindstone and the polishing grindstone are reduced, the thickness of processable lenses (lens edges) is decreased and such an eyeglass lens processing apparatus can no longer automatically process a lens whose thickness is larger than the widths of the flat-processing portions. If the widths of the flat-processing portions are increased to enable automatic processing by an eyeglass lens processing apparatus, the size of the apparatus is increased accordingly, which makes it necessary to increase the rigidity of its processing mechanism and thereby causes increase in manufacturing cost. For this reason, flat processing of lenses having large edge thickness values have been performed by manual processing apparatus.

[0004] A technical object of the present invention is to provide an eyeglass lens processing apparatus capable of increasing the thickness of lenses that can be flat finished without the need for increasing the widths of processing tools.

[0005] To attain the above object, the invention provides eyeglass lens processing apparatus that are configured in the following manners:

(1) An eyeglass lens processing apparatus for processing a periphery of an eyeglass lens (LE), the eyeglass lens processing apparatus comprising:

lens rotating means for rotating a pair of lens chuck shafts (112L, 112R) which hold the eyeglass lens;

tool rotating means (120) for rotating a tool rotation shaft (125) to which a finishing tool (161) having a bevel groove (161v) for beveling and a flat-processing portion (161b) are attached;

moving means (130, 140) including first moving means (130) for moving the lens chuck shafts relative to the tool rotation shaft in a first direction which is an axial direction of the lens chuck shafts, and second moving means (140) for moving the lens chuck shafts relative to the tool rotation shaft in a second direction in which an axis-to-axis distance between the tool rotation shaft and the lens chuck shafts is varied;

input means (5, 7) for inputting a target lens shape;

edge position detecting means (300F, 300R) for detecting a front surface edge position and a rear surface edge position of the lens for respective radius vector angles of the lens on the basis of the target lens shape;

processing mode selecting means (5) for selecting one of a flat-processing mode for flat finishing the periphery of the roughed lens by the flat-processing portion and a beveling mode for beveling the periphery of the roughed lens by the bevel groove;

judging means (50) for judging whether or not an edge thickness of the lens for respective vector radius angles based on the front surface edge position and the rear surface edge position detected by the edge position detecting means is larger than a first threshold value which is set as indicating a region of the flat-processing portion, if the flat-processing mode is selected; and

control means (50) for performing flat finishing on the periphery of the roughed lens by controlling the moving means on the basis of the target lens shape and the detection results of the edge position detecting means if the flat-processing mode is selected, and

wherein if the edge thickness is larger than the first threshold value, the control means divides a process of the flat-finishing into plural stages and, at each of the plural stages, the control means determines a processing position of the lens which is shifted in the first direction relative to the flat-processing portion so that an unprocessed portion of the preceding stage will be flat finished on the basis of at least one of the front surface edge position and the rear surface edge position detected by the edge position detecting means, and the control means performs flat finishing on the periphery of the lens by controlling the moving means on the basis of the

determined processing position.

(2) The eyeglass lens processing apparatus according to (1), wherein the plural stages includes at least a first stage and a second stage;
 at the first stage, the control means determines the processing position so that a rear surface edge of the lens at a location of the largest edge thickness falls within a width of the flat-processing portion and a front surface edge of the lens is located outside the width of the flat-processing portion;
 at the second stage, the control means determines the processing position so that the front surface edge of the edge portion at a location of the largest edge thickness falls within the width of the flat-processing portion and the rear surface edge are located outside the width of the flat-processing portion; and
 the control means performs flat finishing on an unprocessed portion of the periphery of the lens successively by controlling the moving means on the basis of the processing positions determined at the first and second stages.

(3) The eyeglass lens processing apparatus according to (1), wherein the plural stages includes a first stage and a second stage,
 at the first stage, the control means determines the processing position so that a front surface edge of the lens falls within a width of the bevel groove and a rear surface edge of the lens falls within a width of the flat-processing portion, and performs flat finishing on the periphery of the lens by controlling the moving means on the basis of the determined processing position, and
 at the second stage, the control means determines the processing position so that an unprocessed portion of the lens which is not processed at the first stage and which includes a lens bevel portion formed by the bevel groove and the front surface edge falls within the width of the flat-processing portion and the rear surface edge is located outside the width of the flat-processing portion, and performs the flat finishing on the periphery of the lens by controlling the moving means on the basis of the determined processing position.

(4) The eyeglass lens processing apparatus according to any one of (1) to (3) further comprising a warning device (5), wherein the judging means judges whether or not the edge thickness is larger than a second threshold value which is set larger than the first predetermined device to enable two-stage flat processing, and
 wherein if the edge thickness is larger than the second threshold value, the control means stops the processing of the lens and issues a warning by driving the warning device.

(5) The eyeglass lens processing apparatus according to any one of (1) to (4), wherein a polishing tool (163) including a bevel groove for bevel polishing and a flat polishing portion is coaxially attached to the tool rotating means, and
 the control means controls the polishing tool to perform flat polishing on the periphery of the lens which is finished by the finishing tool,
 if the edge thickness is larger than the first threshold value, the control means dividing a process of the flat polishing process into plural stages,
 at each of the plural stages, the control means determines the processing position of the lens which is shifted in the first direction relative to the flat polishing portion so that an unprocessed portion of the preceding stage will be flat polished on the basis of at least one of the front surface edge position and the rear surface edge position detected by the edge position detecting means, and performs flat polishing on the periphery of the lens by controlling the moving means on the basis of the determined processing position.

(6) The eyeglass lens processing apparatus according to any one of (1) to (5), wherein if the edge thickness is smaller than or equal to the first threshold value, the control means determines the processing position in the first direction so that a front surface edge and a rear surface edge of the lens fall within a width of the flat-processing portion and performs flat finishing on the periphery of the lens by controlling the moving means on the basis of the determined processing positions.

(7) The eyeglass lens processing apparatus according to any one of (1) to (6), the edge position detecting means includes a first tracing stylus (306F) for contacting a front surface of the lens, and a second tracing stylus (306R) for contacting a rear surface of the lens, and detecting means (313F, 313R) for detecting positions of the first tracing stylus and the second tracing stylus in the first direction, and
 the edge position detecting means obtains the front surface edge position and the rear surface edge position of the lens for respective radius vector angles based on the detecting result of the detecting means.

(8) The eyeglass lens processing apparatus according to any one of (1) to (7), wherein the first threshold value is a

value corresponding to a width of the flat-processing portion which substantially functions to perform the flat processing.

(9) The eyeglass lens processing apparatus according to any one of (1) to (8), wherein a plurality of processing tools (160) including a roughing tool (167) and the finishing tool are coaxially attached to the tool rotating shaft.

[0006] The invention makes it possible to increase the thickness of lenses that can be subjected to flat finishing without the need for increasing the widths of processing tools.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

Fig. 1 outlines the configuration of a processing mechanism of an eyeglass lens processing apparatus according to an embodiment of the present invention.

Fig. 2 outlines the configuration of a lens edge position detection unit.

Fig. 3 shows structures of plural periphery processing tools that are attached to a tool rotation shaft concentrically.

Fig. 4 is a control block diagram of the eyeglass lens processing apparatus according to the embodiment.

Fig. 5 illustrates flat finishing of a case that edge thickness values are smaller than the width of a flat-processing portion.

Figs. 6A and 6B illustrate how flat finishing is performed in two stages.

Fig. 7 shows an unprocessed portion that is left on the front side of a lens edge after completion of flat finishing of the first stage.

Fig. 8 illustrates a modification of the flat finishing of a first stage.

Figs. 9A and 9B illustrate stepwise flat finishing in a case that a flat-processing portion and a front foot processing portion of a normal finishing grindstone are not tapered.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0008] An embodiment of the present invention will be hereinafter described with reference to the drawings. Fig. 1 outlines the configuration of a processing mechanism of an eyeglass lens processing apparatus according to the embodiment.

[0009] The eyeglass lens processing apparatus includes a lens rotation unit 110 for rotating a pair of lens chuck shafts 112R and 112L which hold an eyeglass lens LE between them, a tool rotation unit 120 for rotating a tool rotation shaft 125 to which a periphery processing tool 160 for processing the periphery of the lens LE are attached, an X-direction moving unit 130 which moving the lens chuck shafts 112R and 112L with respect to the tool rotation shaft 125 in the lens check shaft direction (X direction), a Y-direction moving unit 140 for moving the lens chuck shafts 112R and 112L with respect to the tool rotation shaft 125 in such a direction (Y direction) as to change their axis-to-axis distance, and edge position detection units (lens shape measuring units) 300F and 300R for detecting edge positions of the front surface and the rear surface of the lens LE corresponding to respective radius vector angles of the lens LE.

[0010] As shown in Fig. 1, a carriage unit 100 is mounted on a base 100A of the processing apparatus body 1. The lens chuck shafts 112L and 112R are held rotatably by a left arm 101L and a right arm 101R of a carriage 101, respectively. The lens chuck shaft 112R is moved toward the lens chuck shaft 112L by a motor 114 which is attached to the right arm 101 R, whereby the lens LE is held by the two lens chuck shafts 112L and 112R. The two lens chuck shafts 112L and 112R are rotated so as to be synchronized with each other by a motor 111 which is attached to the left arm 101L, via a rotation transmission mechanism such as gears. The lens rotation unit 110 is configured by the above members etc.

[0011] The edge of the lens LE to be processed which is held by the lens chuck shafts 112L and 112R is processed by the periphery processing tools 160 which are attached to the tool rotation shaft (grindstone spindle) 125 concentrically. The tool rotation shaft 125 is disposed parallel with the lens chuck shafts 112L and 112R. The periphery processing tools 160 are consists of plural grindstones (see Fig. 3). The tool rotation shaft 125 is rotated by a motor 121. The tool rotation unit 120 is configured by the above members etc. The tools 160 may include a cutter.

[0012] The carriage 101 is mounted on an X movement support base 132 which can be moved along shafts 133 and 134 which extend parallel with the lens chuck shafts 112L and 112R. A ball screw (not shown) which extends parallel with the shaft 133 is attached to a rear portion of the support base 132. The ball screw is also attached to the rotary shaft of an X-direction moving motor 131. When the motor 131 is rotated, the lens chuck shafts 112L and 112R are moved linearly in the X direction (i.e., the axis direction of the lens chuck shafts 112L and 112R) together with the support base 132. The X-direction moving unit 130 is configured by the above members etc. The rotary shaft of the motor 131

is provided with an encoder 131a which is a detector for detecting a movement position of the carriage 101 in the X direction.

[0013] Two shafts 146 which extend in the Y direction (the direction in which the axis-to-axis distance between the tool rotation shaft 125 and the lens chuck shafts 112L and 112R is changed) which is perpendicular to the X direction are fixed to the support base 132. The carriage 101 is mounted on the support base 132 so as to be movable in the Y direction along the shafts 146. A Y-direction moving motor 141 is fixed to the support base 132. Rotation of the motor 141 is transmitted to a ball screw 145 which extends in the Y direction. As the ball screw 145 is rotated, the lens chuck shafts 112L and 112R are moved in the Y direction together with the carriage 101. The Y-direction moving unit 140 is configured by the above members etc. The rotary shaft of the motor 141 is provided with an encoder 141a which is a detector for detecting a movement position of the lens chuck shafts 112L and 112R in the Y direction.

[0014] Alternatively, the X-direction moving unit 130 and the Y-direction moving unit 140 may be configured so that the tool rotation shaft 125 is moved in the X direction and the Y direction with respect to the lens chuck shafts 112L and 112R. The Y-direction moving unit 140 may be such as to swing the left arm 101L and the right arm 101R of the carriage 101.

[0015] As shown in Fig. 1, the lens edge position detection units (lens shape measuring units) 300F and 300R are disposed on the top-left and top-right of the carriage 101. Fig. 2 outlines the configuration of the detection unit 300F for detecting edge positions of the front surface (front refraction surface) of the lens LE. A support base 301F is fixed to a block 300a which is fixed to the base 100A. A tracing stylus arm 304F is held by the support base 301F via a slide base 310F so as to be slidable in the X direction. An L-shaped hand 305F is fixed to a tip portion of the tracing stylus arm 304F. A tracing stylus 306F is fixed to the tip of the hand 305F. The tracing stylus 306F is brought into contact with the front surface of the lens LE. A rack 311F is fixed to a bottom end portion of the slide base 310F. The rack 311F is engaged with a pinion 312F of an encoder 313F which is fixed to the support base 301F. Rotation of a motor 316F is transmitted to the rack 311F via a rotation transmission mechanism such as gears 315F and 314F, whereby the slide base 310F is moved in the X direction. Driven by the motor 316F, the tracing stylus 306F which is located at an escape position is moved toward the lens LE and pressed against the front surface of the lens LE at a certain measurement pressure.

[0016] To detect edge positions of the front surface of the lens LE, the lens chuck shafts 112L and 112R are moved in the Y direction while being rotated according to a target lens shape and edge positions of the front surface of the lens LE in the X direction are detected by the encoder 313F for respective radius vector angles of the target lens shape. It is preferable that edge positions be detected along a measurement path of the target lens shape and a measurement path that is a predetermined length (e.g., 1 mm) outside the former. Inclinations of the lens surface with the target lens shape are calculated on the basis of results of the edge position detection along these two measurement paths.

[0017] Since the lens edge position detection units 300L and 300R are left-right symmetrical, the configuration of the lens edge position detection unit 300R for the rear surface (rear refraction surface) of the lens LE will not be described below. The constituent elements of the lens edge position detection unit 300R will be given symbols that are obtained by replacing the suffix "L" of the symbols of the corresponding constituent elements of the lens edge position detection unit 300L shown in Fig. 2 with "R." Edge positions of the rear surface of the lens LE in the X direction are detected by the encoder 313R for the respective radius vector angles of the target lens shape. As in the case of the detection of edge positions of the front surface of the lens LE, inclinations of the lens surface with the target lens shape are calculated on the basis of results of edge position detection along the measurement path of the target lens shape and the measurement path that is the predetermined length outside the former.

[0018] Although the lens edge position detection units 300L and 300R are configured in such a manner that the lens chuck shafts 112L and 112R are moved in the Y direction, the tracing styluses 306F and 306R may be moved in the Y direction.

[0019] As shown in Fig. 1, a chamfering unit 200 is disposed at an operator-side position on the apparatus body 1 and a hole/groove forming mechanism unit 400 is disposed behind the carriage unit 100. In the chamfering unit 200, a chamfering grindstone for a lens front surface and a chamfering grindstone for a lens rear surface are attached to a rotary shaft concentrically. The carriage unit 100, the lens edge position detection units 300F and 300R, the chamfering unit 200, and the hole/groove forming mechanism unit 400 can be configured basically in the same manners as described in JP-A-2003-145328 and hence will not be described in detail.

[0020] Fig. 3 shows example structures of the plural periphery processing tools 160 that are attached to the tool rotation shaft 125 concentrically. In this apparatus, the periphery processing tools 160 are a normal finishing grindstone 161 to be used for beveling and flat processing, a polishing grindstone 163 to be used for bevel polishing and flat processing, a high-curvature bevel finishing grindstone 165 to be used for high-curvature beveling, and a roughing grindstone 167 for plastic lenses (arranged in this order from the front side). In the following description, the terms "front" and "rear" will be used as corresponding to the sides of the front surface and the rear surface, respectively, of the lens LE held by the lens chuck shafts 112L and 112R. The finishing grindstones 161 and 163 are used for processing a low-curvature lens.

[0021] The normal finishing grindstone 161 has a V groove (bevel groove) 161v for beveling, a front foot processing portion (front foot processing surface) 161a for formation of a front bevel foot of the lens front surface (located on the front side of the V groove 161 v), and a flat-processing portion (flat-processing surface) 161 b located on the rear side of the V groove 161v. The front foot processing portion 161a and the flat-processing portion 161b are located adjacent to the V groove 161v. In this example apparatus, the front foot processing portion 161 a, the V groove 161v, and the flat-processing portion 161 b are formed integrally using a grindstone that is uniform in grain size. For example, the groove width of the V groove 161v is 2.5 mm, the width of the front foot processing portion 161a is 4.5 mm, and the width 161wb of the flat-processing portion 161 b is 9 mm. The flat-processing portion 161 b also serves as a processing surface for forming a rear bevel foot of the lens LE when the lens LE is beveled by the V groove 161 v. When the normal finishing grindstone 161 is used, a front bevel slant surface and a rear bevel slant surface are formed simultaneously in the lens LE by the V groove 161 v. For example, the front slant surface and the rear slant surface, arranged in the X direction, of the V groove 161v both have an angle 35° and the depth of the V groove 161v is less than 1 mm.

[0022] The front foot processing portion 161a is a tapered surface having an inclination angle α_f so that the diameter of the front portion of the lens LE increases as the position goes in the positive X direction. The inclination angle α_f is 5.0° , for example. The flat-processing portion 161b is a tapered surface having an inclination angle α_r so that the diameter of the rear portion of the lens LE decreases as the position goes in the positive X direction. The inclination angle α_r is 2.5° , for example. The flat-processing surface 161 b may be parallel with the X direction. However, for a good appearance of the lens LE, it is preferable that the flat-processing surface 161b be inclined so that the diameter of the rear portion of the lens LE decreases as the position goes in the positive X direction.

[0023] The polishing grindstone 163 has a V groove 163v for beveling, a front foot processing portion 163a for formation of a front bevel foot of the lens front surface (located on the front side of the V groove 163v), and a flat-processing portion 163b located on the rear side of the V groove 163v. The front foot processing portion 163a and the flat-processing portion 163b are located adjacent to the V groove 163v. In this example apparatus, the front foot processing portion 163a, the V groove 163v, and the flat-processing portion 163b are formed integrally using a grindstone that is uniform in grain size. The grain size of the polishing grindstone 163 is smaller than that of the normal finishing grindstone 161. The groove width of the V groove 163v, the width of the front foot processing portion 163a, and the width 163wb of the flat-processing portion 163b are set the same as the widths of the front foot processing portion 161 a, the V groove 161v, and the flat-processing portion 161b of the normal finishing grindstone 161, respectively. The shape of the V groove 163v is the same as that of the V groove 161v of the normal finishing grindstone 161.

[0024] The total widths of the finishing grindstones 161 and 163 are approximately the same as or smaller than the total width of the roughing grindstone 167.

[0025] The high-curvature bevel finishing grindstone 165 has a front beveling slant surface 165a for formation of a front bevel slant surface of the lens LE, a rear beveling slant surface 165b for formation of a rear bevel slant surface of the lens LE, and a rear bevel foot processing slant surface 165c for formation of a rear bevel foot. The processing surfaces 165a, 165b, and 165c are formed integrally using a grindstone that is the same as the normal finishing grindstone 161 in grain size. When beveling is performed using the high-curvature bevel finishing grindstone 165, a front bevel slant surface and a rear bevel slant surface are formed separately. Therefore, the width of the front beveling slant surface 165a and the width of the rear beveling slant surface 165b are larger than the width of the V groove 161v of the normal finishing grindstone 161. For example, the widths of the front beveling slant surface 165a and the rear beveling slant surface 165b are 9 mm and 3.5 mm, respectively. The width of the rear bevel foot processing slant surface 165c is 4.5 mm, for example.

[0026] The angle with respect to the X direction of the front beveling slant surface 165a is smaller than that of the V groove of the normal finishing grindstone 161 and is 30° , for example. The angle with respect to the X direction of the rear beveling slant surface 165b is larger than that of the V groove of the normal finishing grindstone 161 and is 45° , for example. In beveling on a lens to be fitted in a high-curvature frame, to prevent the lens from coming off the frame rearward and to attain reliable holding of the lens by the frame, it is preferable that the angle of a rear bevel slant surface of a low-curvature lens be set large. Furthermore, the angle with respect to the X direction of the rear bevel foot processing slant surface 165c is larger than that of the flat-processing portion 161b of the normal finishing grindstone 161 and is 15° , for example. With these measures, when a lens is fitted in a high-curvature frame, the lens is held reliably and is given a good appearance.

[0027] Data of the positions and widths of the respective processing portions (front foot processing portion 163a, V groove 163v, and flat-processing portion 163b) of the normal finishing grindstone 161 are stored in a memory 51. Likewise, data of the positions and widths of the respective processing portions of the polishing grindstone 163 are also stored in the memory 51.

[0028] Fig. 4 is a control block diagram of the eyeglass lens processing apparatus according to the embodiment. An eyeglass frame shape measuring unit 2 (which can be the same one described in JP-A-4-93164), a touch screen type display 5 which is used as a display unit and an input unit, a switch unit 7, the memory 51, the motors of the carriage unit 100, the lens edge position detection units 300F and 300R, the hole/groove forming mechanism unit 400, etc. are

connected to a control unit 50. An input signal can be input to the apparatus by touching an item displayed on the display 5 with a touch pen or a finger. The control unit 50 receives an input signal through the touch screen function of the display 5 and controls display of a figure and information on the display 5.

[0029] How the above-configured apparatus operates will be described below. A flat-processing operation using the normal finishing grindstone 161 and the polishing grindstone 163 will be described mainly.

[0030] First, fundamental data that are necessary for processing of the periphery of each lens are input. Target lens shape data of an eyeglass frame measured by the eyeglass frame shape measuring unit 2 is input to the apparatus by pushing a switch of the switch unit 7. The target lens shape data is converted into radius vector data (r_n, θ_n) (r_n : radius vector length, θ_n : radius vector angle; $n = 1, 2, \dots, N$), which are stored in the memory 51. Layout data of a lens optical center for the target lens shape are input through the display 5. The target lens shape FT is displayed on the screen 500 of the display 5, and a state is established that layout data such as a pupil distance (PD value) 501 of an eyeglass user, a frame center distance (FPD value) 502 of the eyeglass frame, and a height 503 of the optical center with respect to a geometrical center of the target lens shape can be input. Layout data are input by manipulating predetermined keys displayed on the display 5. Lens processing conditions are input by manipulating predetermined keys such as keys 511-515 displayed on the display 5. The lens processing conditions include a lens material, a frame type, a processing mode (beveling, flat processing, or groove formation), execution/non-execution of polishing processing, execution/non-execution of chamfering, and execution/non-execution of high-curvature beveling. The beveling mode is selected automatically if "metal" or "cell" is selected as a frame type. The flat-processing mode is selected automatically if a rimless frame ("two point" or "half-rim") is selected. The following description will be directed to a case that the flat-processing mode is selected.

[0031] When an operation start signal is input through the switch unit 7, before processing of the lens, the lens edge position detection units 300F and 300R are activated and edge positions of the front surface and the rear surface of the lens are detected. Front surface edge positions L_{cf} of the lens are obtained as data (r_n, θ_n, x_{fn}) ($n = 1, 2, \dots, N$) corresponding to respective radius vector angles by the control unit 50 which serves as parts of the lens edge position detection units 300F and 300R. The data x_{fn} are the values of front surface edge positions with respect to a reference position in the X direction. The measurement points n are set for angles that are separated from each other by a predetermined very small angle and N is equal to 1,000, for example. Likewise, rear surface edge positions L_{cr} of the lens are obtained as data (r_n, θ_n, x_{rn}) ($n = 1, 2, \dots, N$) corresponding to the respective radius vector angles by the control unit 50. The data x_{rn} are the values of rear surface edge positions with respect to the reference position in the X direction.

[0032] The control unit 50 calculates edge thickness values T_n ($n = 1, 2, \dots, N$) corresponding to the respective radius vector angles on the basis of the edge position data of the front surface and the rear surface of the lens, and judges whether or not there exists a portion (radius vector angles) where the edge thickness values T_n are larger than a threshold value $TS1$. The threshold value $TS1$ is a value which is predetermined in connection with the width 161wb of the flat-processing portion 161b and is a maximum value that substantially enables flat processing with the width 161wb. That is, the threshold value $TS1$ is a value corresponding to a width of the flat-processing portion which substantially functions to perform flat processing. For example, for the width 161wb of 9 mm, the maximum substantially processable width is set at 8 mm which is the width of a range defined by positions that are deviated inward by 0.5 mm from the two respective ends of the flat-processing portion 161 b. The width 161 wb and the threshold value $TS1$ are stored in the memory 51.

[0033] If the edge thickness values T_n corresponding to all the radius vector angles θ_n are within the threshold value $TS1$, the control unit 50 judges that the entire periphery of the lens can be processed by the flat-processing portion 161 b. In this case, the control unit 50 calculates X positions corresponding to respective lens rotation angles so that the front surface edges and the rear surface edges of a finished lens both fall within the width of the flat-processing portion 161b. For example, as shown in Fig. 5, the control unit 50 calculates (determines) X positions (processing positions in the X direction) for the respective lens rotation angles so that the front surface edge is always located at a position 161bP1 that is 0.5 mm inside (on the rear side of) the front end 161bf of the flat-processing portion 161 b.

[0034] Where the target lens shape of a lens to be flat-finished is not a perfect circle, as is well known, lens processing points that are based on the target lens shape are not located on the Y axis which connects the center axis of the tool rotation shaft 125 and that of the lens chuck shafts 112L and 112R. Therefore, lens processing points corresponding to the respective lens rotation angles are calculated again. For example, lens processing points corresponding to the respective lens rotation angles can be calculated by the following method. The radius vector data (r_n, θ_n) ($n = 1, 2, \dots, N$) are substituted into the following Equation (1):

Formula 1

$$L = r_n \times \cos \theta_n + \sqrt{R^2 - (r_n \times \sin \theta_n)^2} \quad (n = 1, 2, 3, \dots, N) \quad \dots (1)$$

where L is the distance between the center axis of the tool rotation shaft 125 and that of the lens chuck shafts 112L and

112R and R is the radius of the flat-processing portion 161b.

[0035] A processing point corresponding to one lens rotation angle Φ_i is determined by determining a maximum L value by substituting the radius vector data (r_n, θ_n) ($n = 1, 2, \dots, N$) into Equation (1) successively. The maximum L value corresponding to the lens rotation angle Φ_i is represented by L_i , and x_{fn} for the corresponding radius vector angle θ_n is rewritten as X_{fi} . For the front surface edge position L_{cf} of the lens, L_i and X_{fi} are made fundamental control data in the Y direction and the X direction, respectively, corresponding to the lens rotation angle Φ_i . Control data (Φ_i, L_i, X_{fi}) ($i = 1, 2, 3, \dots, N$) for rotation angles Φ_i of the entire lens perimeter are obtained by successively varying the rotation angle Φ_i around the processing center by a very small unit angle and performing the above calculations. Also for the rear surface edge positions L_{cr} of the lens, x_{rn} corresponding to the radius vector angle θ_n is rewritten as X_{ri} and control data (Φ_i, L_i, X_{ri}) ($i = 1, 2, 3, \dots, N$) for rotation angles Φ_i of the entire lens perimeter are obtained in the same manner.

[0036] A brief description will be made of lens periphery processing of a case that edge thickness values T_n are within the threshold value $TS1$. When control data for flat finishing have been obtained in the above-described manner, first, the control unit 50 causes the roughing grindstone 167 to process the lens roughly. Rough processing data are obtained by adding a predetermined finishing margin ΔL to target lens shape data (finishing data). The control unit 50 causes the lens edge to be placed on the processing surface of the roughing grindstone 167 by drive-controlling the X-direction moving unit 130. Furthermore, the control unit 50 rotates the lens by drive-controlling the lens rotation unit 110 and drive-controls the Y-direction moving unit 140 on the basis of axis-to-axis distances $L_i + \Delta L$ corresponding to the respective lens rotation angles.

[0037] After completion of the rough processing, flat finishing is performed by the flat processing portion 161 b. The control unit 50 determines processing positions (i.e., lens edge positions with respect to the flat-processing portion 161 b) of in the X direction with which the front surface edges and the rear surface edges of the lens fall within the width of the flat-processing portion 161b. And the control unit 50 causes the flat-processing portion 161b to perform flat finishing on the periphery of the roughly processed lens by drive-controlling the X-direction moving unit 130 and the Y-direction moving unit 140 while rotating the lens on the basis of the determined processing positions. Where the edge thickness values T_n are smaller than or equal to the threshold value $TS1$, control data (Φ_i, L_i, X_{fi}) ($i = 1, 2, 3, \dots, N$) corresponding to the front surface edge positions L_{cf} are used. For example, the position in the X direction is controlled so that the front surface edge is located at the processing position 161bP1 every time the lens is rotated by the predetermined rotation angle.

[0038] Next, a description will be made of a case that there is a portion where edge thickness values T_n are larger than the threshold value $TS1$. In this case, the control unit 50 divides a process of a flat-finishing into plural stages. At each stage, the control unit 50 determines processing positions (the lens edge is shifted in the X direction with respect to the flat-processing portion 161b) on the basis of front surface edge positions L_{cf} and/or rear surface edge positions L_{cr} so that a lens portion that has not been flat finished will be processed and causes the flat-processing portion 161 b to perform flat finishing on the periphery of a roughly processed lens by drive-controlling the X-direction moving unit 130 and the Y-direction moving unit 140 on the basis of the determined processing positions. If edge thickness data are available, one of a front surface edge position L_{cf} and a rear surface edge position L_{cr} can be calculated on the basis of the other. In determining processing positions at each stage, positions of the front foot processing portion 161 a, the V groove 161 v, and the flat-processing portion 161b which are stored in the memory 51 are used as fundamental data.

[0039] For example, where the flat-processing portion 161 b and the front foot processing portion 161a are tapered as shown in Fig. 3, the control unit 50 divides a process of a flat-finishing into a first stage and a second stage. The control unit 50 determines sets of processing positions which are shifted in the X direction for the first stage and the second stage on the basis of front surface edge positions L_{cf} and rear surface edge positions L_{cr} of the lens, and causes the flat-processing portion 161b to perform flat finishing on the periphery of the lens in two stages. At the first stage, the control unit 50 determines processing positions in the X direction (X position control data corresponding to respective lens rotation angles) so that the front surface edges of the lens fall within the width of the V groove 161v for beveling (i.e., the front surface edges are located outside the width of the flat-processing portion 161 b) and the rear surface edge of a thickest edge portion of the lens falls within the width of the flat-processing portion 161 b, and causes the flat-processing portion 161b to perform flat finishing on the periphery of the lens by controlling the X-direction moving unit 130 on the basis of the determined processing positions. An example control which is performed at the first stage will be described below.

[0040] For example, the control unit 50 determines a radius vector angle θ_{tmax} of a thickest edge portion on the basis of front surface edge positions $L_{cf}(r_n, \theta_n, x_{fn})$ ($n = 1, 2, \dots, N$) and rear surface edge positions $L_{cr}(r_n, \theta_n, x_{rn})$ ($n = 1, 2, \dots, N$). Then, the control unit 50 determines an X position X_{tm} of the front surface edge (a processing position with respect to the reference position X_0 in the X direction) when as shown in Fig. 6A the rear surface edge corresponding to the determined radius vector angle θ_{tmax} is located at a processing position 161bP2 that is set 0.5 mm inside (on the front side of) the rear end 161br of the flat-processing portion 161b. As shown in Fig. 6A, the front surface edge is located within the width of the V groove 161v for beveling. Then, the control unit 50 determines X positions X_{fi} of the front surface edges corresponding to respective rotation angles Φ_i according to the above-described Equation (1), and

calculates control data X_{tfi} ($i = 1, 2, 3, \dots, N$) of processing positions in the X direction corresponding to the respective rotation angles Φ_i so that the edge positions X_{fi} coincide with the positions X_{tm} .

[0041] The control unit 50 causes the edge of a roughly processed lens (how rough processing is performed is not described here because it is the same as described above) to be placed on the normal finishing grindstone 161, and causes the flat-processing portion 161b to perform flat finishing of the first stage by drive-controlling the X-direction moving unit 130 while rotating the lens on the basis of the X position control data X_{tfi} ($i = 1, 2, 3, \dots, N$). At the finishing stage, the lens is rotated one or more times. As a result, as shown in Fig. 7, a bevel portion L_v which has been formed by the V groove 161v is left on the front side of a lens edge as a non-processed portion.

[0042] A modification of the control of the first stage will be described with reference to Fig. 8. Whereas in the above example control a position X_{tm} is determined for a reference state that the rear surface edge of a thickest edge portion is located at the processing position 161bP2, in the modification of Fig. 8 a position X_{tm} is determined in advance. As shown in Fig. 8, a line L_t included in the surface of the flat-processing portion 161b is extended forward and an intersecting point P_x of the line L_x and the front bevel slant surface 161vf of the V groove 161v, and the intersecting point P_x (or a position that is slightly shifted rearward from the intersecting point P_x) is determined as a position X_{tm} . If front surface edges of the lens were located on the left (as viewed in Fig. 8) of (on the front side of) a position X_{tm} , the lens would be processed by the front bevel slant surface 161vf and the front foot processing portion 161a. Therefore, to enable flat finishing on lenses that are as large in edge thickness as possible, a position X_{tm} is set at a limit position of the front surface edges. In the flat finishing of the first stage, the control unit 50 drive-controls the X-direction moving unit 130 so that the front surface edges are located at the position X_{tm} . In this method, since the position X_{tm} is fixed, writing of a control program for the apparatus is simplified.

[0043] Flat processing of the second stage will be described below. At the second stage, to perform flat finishing on the unprocessed bevel portion L_v , the control unit 50 determines processing positions in the X direction so that they are shifted from the processing positions employed at the first stage. More specifically, to perform flat finishing on the bevel portion L_v that remains as an unprocessed portion, the control unit 50 calculates X position control data of processing positions in the X direction so that the front surface edges of the lens fall within the width of the flat-processing portion 161b, and causes the flat-processing portion 161b to perform flat finishing by controlling the X-direction moving unit 130 while rotating the lens on the basis of the calculated X position control data.

[0044] For example, the control unit 50 performs the same control as in the case that no edge thickness values T_n are larger than the threshold value TS_1 . That is, as shown in Fig. 6B, the control unit 50 calculates X position control data X_{tfi} ($i = 1, 2, 3, \dots, N$) corresponding to the respective lens rotation angles Φ_i ($i = 1, 2, 3, \dots, N$) so that the front surface edges are located at the processing position 161bP1 and controls the X-direction moving unit 130 on the basis of the calculated X position control data X_{tfi} . The bevel portion L_v remaining at the front end of the periphery (see Fig. 7) is ground away and the flat processing of the entire periphery of the lens is completed.

[0045] The above-described flat processing performed in two stages makes it possible to increase the thickness of lenses that can be flat finished without the need for increasing the width of the flat-processing portion 161b of the flat-finishing tool.

[0046] Where the flat-processing portion 161b is tapered (i.e., has an inclination angle α_r), it is preferable to compensate for the taper of the inclination angle α_r in controlling the axis-to-axis direction L_i in the Y direction in processing of the second stage. That is, the difference ΔX between a processing position 161bP1 and a position X_{tm} is calculated and the axis-to-axis direction L_i in the Y direction is corrected for $\Delta X \cdot \tan \alpha_r$. This enables more accurate flat processing.

[0047] Where a setting to the effect that polishing processing should be performed is made through the display 5 (polishing processing is selected), polishing processing is performed by the polishing grindstone 163 after flat processing by the normal finishing grindstone 161. Also in the polishing processing, if there is a portion where edge thickness values T_n are larger than a threshold value, a plural-stage control is performed in the same manner as in the flat processing by the normal finishing grindstone 161. That is, the control unit 50 divides a flat polishing process into plural stages. At each stage, the control unit 50 determines processing positions (the lens edge is shifted in the X direction with respect to the flat polishing portion 163b) on the basis of front surface edge positions L_{cf} and/or rear surface edge positions L_{cr} so that a lens portion that has not been flat polished will be processed. The control unit 50 causes the flat polishing portion 163b to perform flat polishing on the periphery of the lens in plural stages by controlling the moving unit 130 and 140.

If flat processing was performed in two stages in the above-described manner before the polishing processing, the control unit 50 also divides the flat polishing process into two stages. In polishing processing of the first stage, the control unit 50 calculates X position control data of processing positions in the X direction corresponding to the respective lens rotation angles so that the front surface edges of the lens fall within the width of the V groove 163v for beveling and the rear surface edges of the lens fall within the width of the flat-processing portion 163b, and causes the flat-processing portion 163b to perform flat polishing on the periphery of the lens by controlling the X-direction moving unit 130 on the basis of the calculated X position control data.

In polishing processing of the second stage, the control unit 50 calculates X position control data of processing positions in the X direction corresponding to the respective lens rotation angles so that the front surface edges of the lens fall

within the width of the flat-processing portion 163b, and causes the flat-processing portion 163b to perform flat polishing on the periphery of the lens by controlling the X-direction moving unit 130 on the basis of the calculated X position control data. As a result, also in the polishing processing, it becomes possible to increase the thickness of lenses that can be flat polished without the need for increasing the width of the flat-processing portion 163b of the polishing tool.

[0048] Where the flat-processing portion 161b is tapered (i.e., has an inclination angle α_r) and the front foot processing portion 161a is also tapered (i.e., has an inclination angle α_f), if edge thickness values T_n are larger than the sum of the width of the flat-processing portion 161 b and the width of the V groove 161 v, the front surface edge is ground away by the front foot processing portion 161a. In view of this, the control unit 50 judges whether or not edge thickness values T_n are larger than a threshold value TS2 that is larger than the threshold value TS1 and is determined on the basis of the width of the flat-processing portion 161 b and the width of the V groove 161 v. If edge thickness values T_n are larger than the threshold value TS2, the control unit 50 stops processing the periphery of the lens and display, on the screen 500 of the display 5, a warning to the effect that flat processing is impossible. The display 5 thus functions as a warning device. This allows the operator to recognize in advance that the lens is so thick that this apparatus cannot perform automatic flat processing on it. Meaningless trouble can thus be avoided.

[0049] In the example structure of the processing tool 160 shown in Fig. 3, the thickness of lenses that can be flat finished can be increased further if the flat-processing portion 161 b and the front foot processing portion 161a of the normal finishing grindstone 161 are not tapered and are parallel with the lens chuck shafts 1112L and 112R (the flat-processing portion 161 b and the front foot processing portion 161a are cylindrical and have the same diameter). The same is true of the polishing grindstone 163.

More specifically, as shown in Fig. 9A, flat finishing of the first stage is performed in such a manner that the rear surface edge is located at the position 161 bP2 of the flat-processing portion 161 b. At this time, the front surface edges are located on the left of the V groove 161v and the front foot processing portion 161a. However, in the second stage, as shown in Fig. 9B flat finishing is performed in such a manner that the front surface edge is located at the position 161bP1 of the flat-processing portion 161 b. In this manner, a portion that was left unprocessed by the flat finishing of the first stage is flat finished at the second stage.

[0050] The maximum diameter of the other processing tools such as the high-curvature bevel finishing grindstone 165 and the roughing grindstone 167 which are concentric with the normal finishing grindstone 161 and the polishing grindstone 163 is smaller than the diameter of the flat-processing portion 161 b and the front foot processing portion 161a. If the diameter of the polishing grindstone 163 which is located on the rear side of the flat-processing portion 161b is smaller than that of the flat-processing portion 161b, at the second stage the polishing grindstone 163 is prevented from affecting an edge portion that is located on the rear side of the rear end of the flat-processing portion 161b.

[0051] Where a lens has a large edge thickness value T , a process of the flat-finishing may be divided into more than two stages. And the lens edge may be shifted successively at those stages so that a portion that was left unprocessed by flat finishing of the first two stages is flat finished successively. In this manner, the thickness of lenses that can be flat finished can be increased.

[0052] The above-described embodiment can be modified in various manners. For example, in an X position control of the first stage, X position control data corresponding to respective lens rotation angles may be calculated so that the rear surface edges are located at the processing position 161bP2. In this case, a bevel portion L_v is formed only in a radius vector angle range where the front surface end position L_{cf} is located on the front side of the front end 161 bf of the flat-processing portion 161b. However, the lens position in the X direction is varied to a larger extent when the rear surface edges are fixed than when the front surface ends are fixed. To suppress rapid variation of the X position, it is necessary to decrease the lens rotation speed, resulting in a disadvantage of a long processing time. For this reason, it is preferable to employ the method of the above-described embodiment.

[0053] The processing of the first stage and the processing of the second stage may be performed in order that is opposite to the order of the above-described embodiment. Where the polishing grindstone 163 is not disposed behind the normal finishing grindstone 161 or the diameter of the former is smaller than the diameter of the latter, there does not occur a phenomenon that flat finishing is affected by processing of an edge portion located on the rear side of the normal finishing grindstone 161 by the polishing grindstone 163. Likewise, where the diameter of the grindstone (processing tool) disposed immediately behind the polishing grindstone 163 is smaller than that of the polishing grindstone 163, there does not occur a phenomenon that polishing is affected by processing by the grindstone disposed immediately behind the polishing grindstone 163.

Claims

1. An eyeglass lens processing apparatus for processing a periphery of an eyeglass lens (LE), the eyeglass lens processing apparatus comprising:

lens rotating means for rotating a pair of lens chuck shafts (112L, 112R) which hold the eyeglass lens;
 tool rotating means (120) for rotating a tool rotation shaft (125) to which a finishing tool (161) having a bevel groove (161v) for beveling and a flat-processing portion (161b) are attached;
 moving means (130, 140) including first moving means (130) for moving the lens chuck shafts relative to the tool rotation shaft in a first direction which is an axial direction of the lens chuck shafts, and second moving means (140) for moving the lens chuck shafts relative to the tool rotation shaft in a second direction in which an axis-to-axis distance between the tool rotation shaft and the lens chuck shafts is varied;
 input means (5, 7) for inputting a target lens shape;
 edge position detecting means (300F, 300R) for detecting a front surface edge position and a rear surface edge position of the lens for respective radius vector angles of the lens on the basis of the target lens shape;
 processing mode selecting means (5) for selecting one of a flat-processing mode for flat finishing the periphery of the roughed lens by the flat-processing portion and a beveling mode for beveling the periphery of the roughed lens by the bevel groove;
 judging means (50) for judging whether or not an edge thickness of the lens for respective vector radius angles based on the front surface edge position and the rear surface edge position detected by the edge position detecting means is larger than a first threshold value which is set as indicating a region of the flat-processing portion, if the flat-processing mode is selected; and
 control means (50) for performing flat finishing on the periphery of the roughed lens by controlling the moving means on the basis of the target lens shape and the detection results of the edge position detecting means if the flat-processing mode is selected, and
 wherein if the edge thickness is larger than the first threshold value, the control means divides a process of the flat-finishing into plural stages and, at each of the plural stages, the control means determines a processing position of the lens which is shifted in the first direction relative to the flat-processing portion so that an unprocessed portion of the preceding stage will be flat finished on the basis of at least one of the front surface edge position and the rear surface edge position detected by the edge position detecting means, and the control means performs flat finishing on the periphery of the lens by controlling the moving means on the basis of the determined processing position.

2. The eyeglass lens processing apparatus according to claim 1, wherein the plural stages includes at least a first stage and a second stage;
 at the first stage, the control means determines the processing position so that a rear surface edge of the lens at a location of the largest edge thickness falls within a width of the flat-processing portion and a front surface edge of the lens is located outside the width of the flat-processing portion;
 at the second stage, the control means determines the processing position so that the front surface edge of the edge portion at a location of the largest edge thickness falls within the width of the flat-processing portion and the rear surface edge are located outside the width of the flat-processing portion; and
 the control means performs flat finishing on an unprocessed portion of the periphery of the lens successively by controlling the moving means on the basis of the processing positions determined at the first and second stages.
3. The eyeglass lens processing apparatus according to claim 1, wherein the plural stages includes a first stage and a second stage,
 at the first stage, the control means determines the processing position so that a front surface edge of the lens falls within a width of the bevel groove and a rear surface edge of the lens falls within a width of the flat-processing portion, and performs flat finishing on the periphery of the lens by controlling the moving means on the basis of the determined processing position, and
 at the second stage, the control means determines the processing position so that an unprocessed portion of the lens which is not processed at the first stage and which includes a lens bevel portion formed by the bevel groove and the front surface edge falls within the width of the flat-processing portion and the rear surface edge is located outside the width of the flat-processing portion, and performs the flat finishing on the periphery of the lens by controlling the moving means on the basis of the determined processing position.
4. The eyeglass lens processing apparatus according to any one of claims 1 to 3 further comprising a warning device (5), wherein the judging means judges whether or not the edge thickness is larger than a second threshold value which is set larger than the first predetermined device to enable two-stage flat processing, and
 wherein if the edge thickness is larger than the second threshold value, the control means stops the processing of the lens and issues a warning by driving the warning device.
5. The eyeglass lens processing apparatus according to any one of claims 1 to 4, wherein

a polishing tool (163) including a bevel groove for bevel polishing and a flat polishing portion is coaxially attached to the tool rotating means, and
the control means controls the polishing tool to perform flat polishing on the periphery of the lens which is finished by the finishing tool,

if the edge thickness is larger than the first threshold value, the control means dividing a process of the flat polishing process into plural stages,

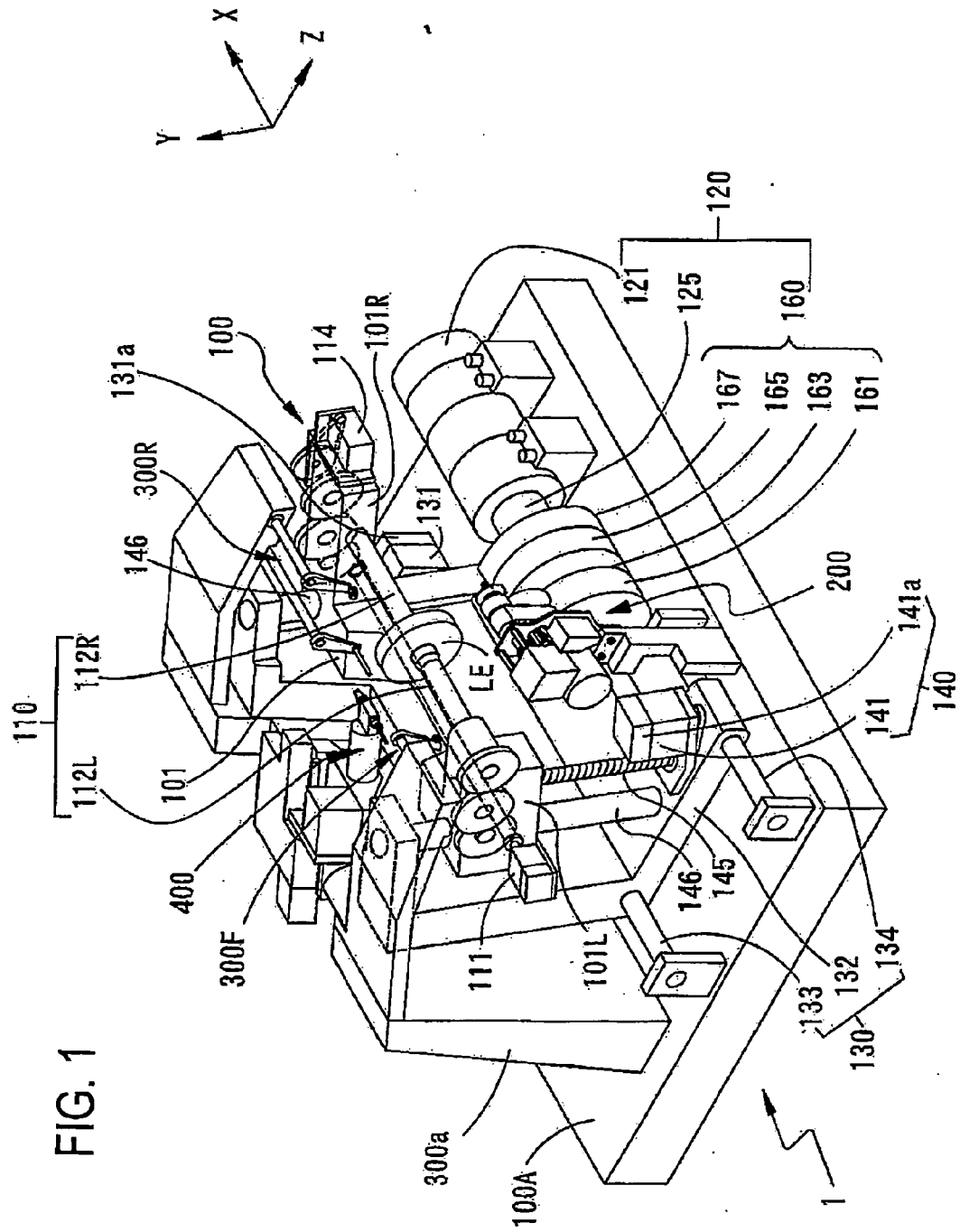
at each of the plural stages, the control means determines the processing position of the lens which is shifted in the first direction relative to the flat polishing portion so that an unprocessed portion of the preceding stage will be flat polished on the basis of at least one of the front surface edge position and the rear surface edge position detected by the edge position detecting means, and performs flat polishing on the periphery of the lens by controlling the moving means on the basis of the determined processing position.

6. The eyeglass lens processing apparatus according to any one of claims 1 to 5, wherein if the edge thickness is smaller than or equal to the first threshold value, the control means determines the processing position in the first direction so that a front surface edge and a rear surface edge of the lens fall within a width of the flat-processing portion and performs flat finishing on the periphery of the lens by controlling the moving means on the basis of the determined processing positions.

7. The eyeglass lens processing apparatus according to any one of claims 1 to 6,
the edge position detecting means includes a first tracing stylus (306F) for contacting a front surface of the lens, and a second tracing stylus (306R) for contacting a rear surface of the lens, and detecting means (313F, 313R) for detecting positions of the first tracing stylus and the second tracing stylus in the first direction, and
the edge position detecting means obtains the front surface edge position and the rear surface edge position of the lens for respective radius vector angles based on the detecting result of the detecting means.

8. The eyeglass lens processing apparatus according to any one of claims 1 to 7, wherein the first threshold value is a value corresponding to a width of the flat-processing portion which substantially functions to perform the flat processing.

9. The eyeglass lens processing apparatus according to any one of claims 1 to 8, wherein
a plurality of processing tools (160) including a roughing tool (167) and the finishing tool are coaxially attached to the tool rotating shaft.



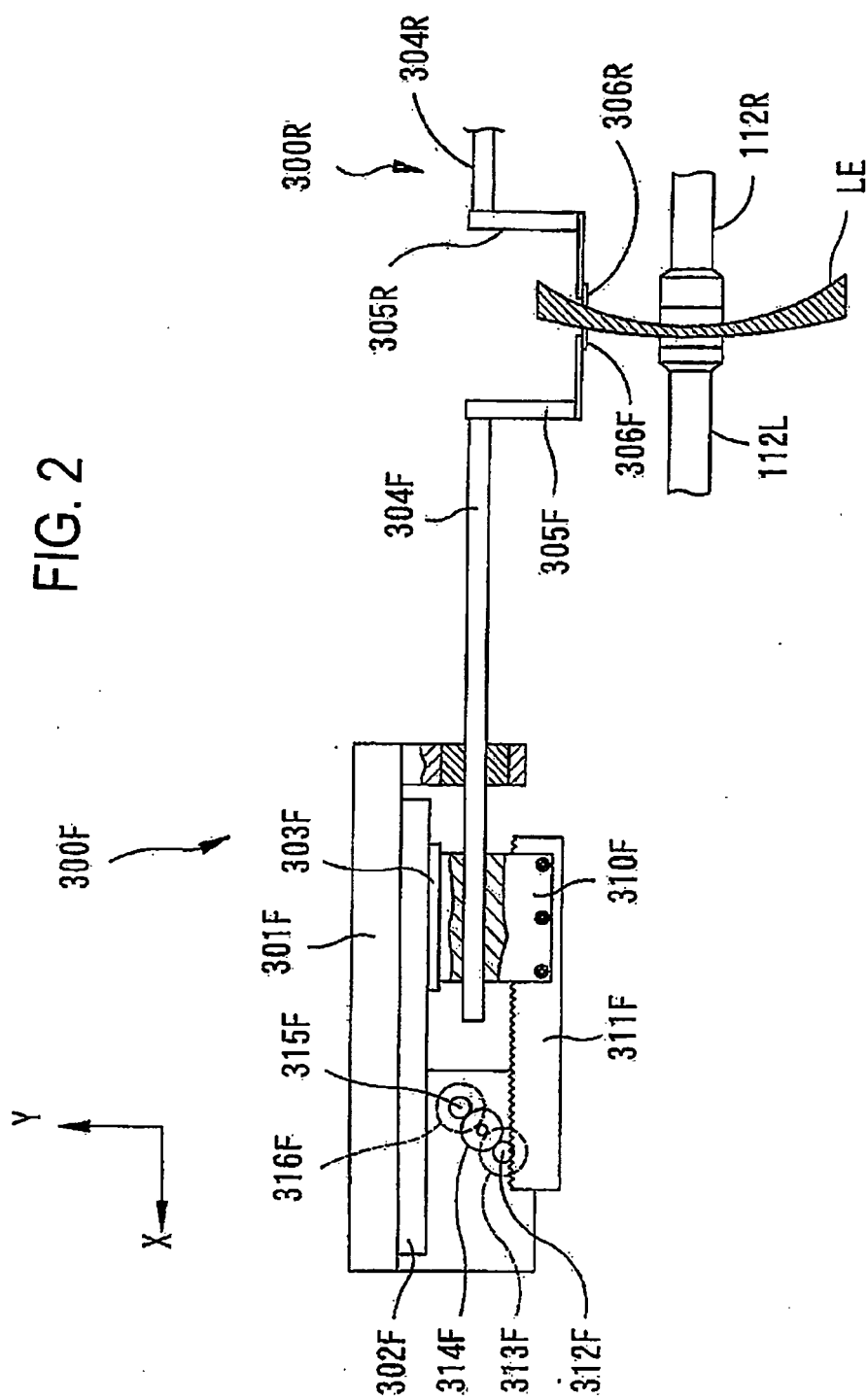


FIG. 3

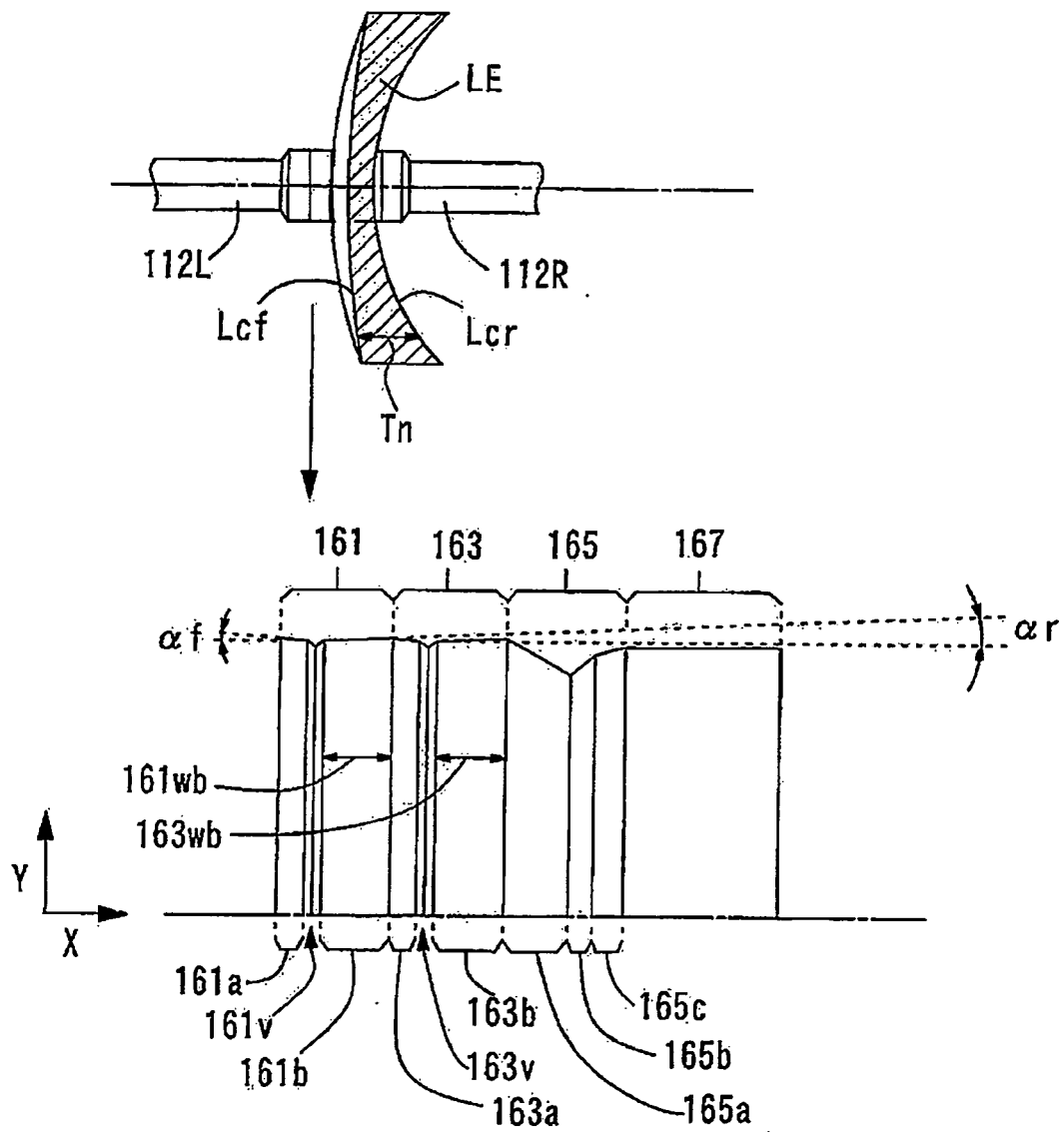


FIG. 4

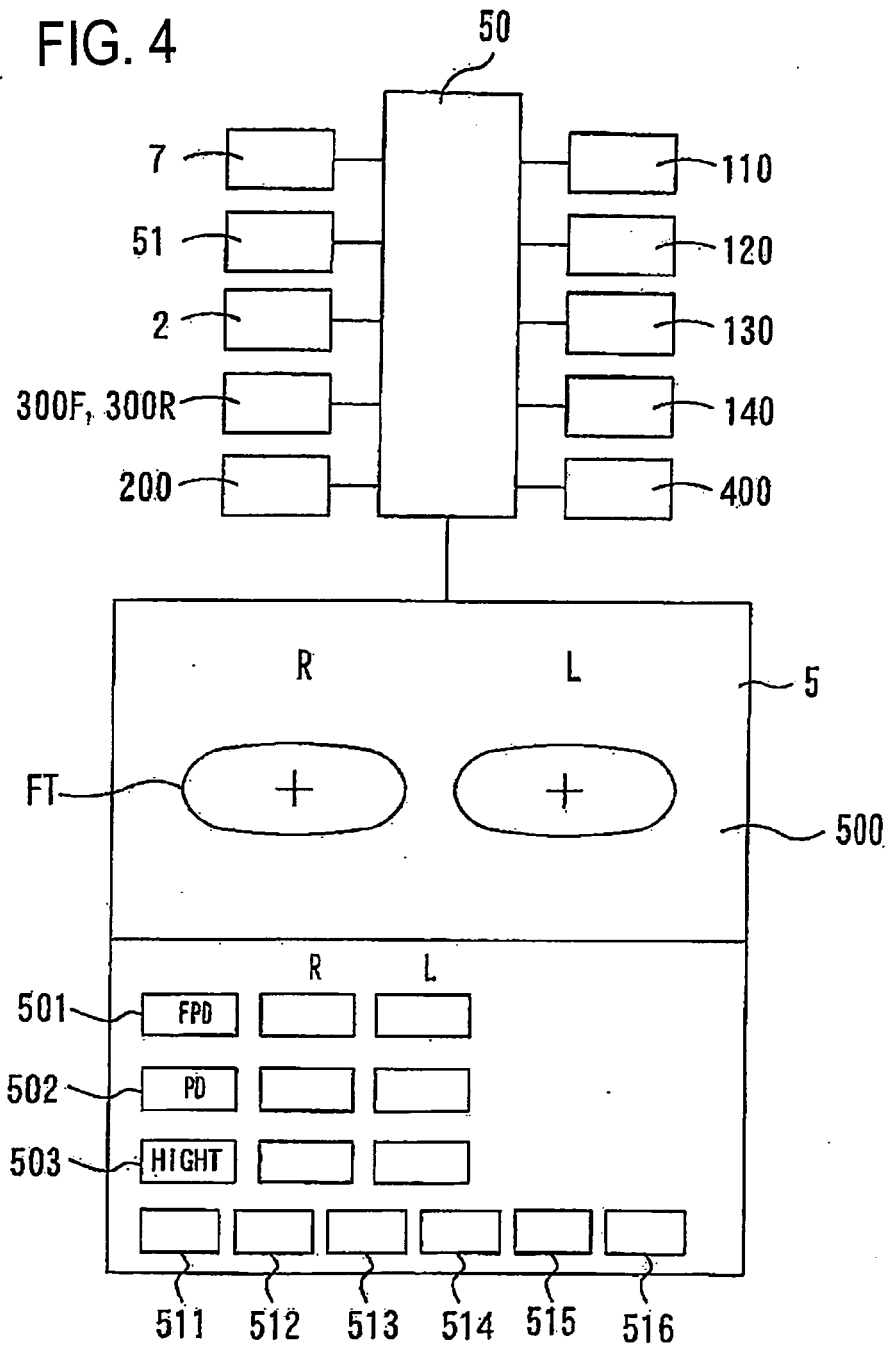


FIG. 5

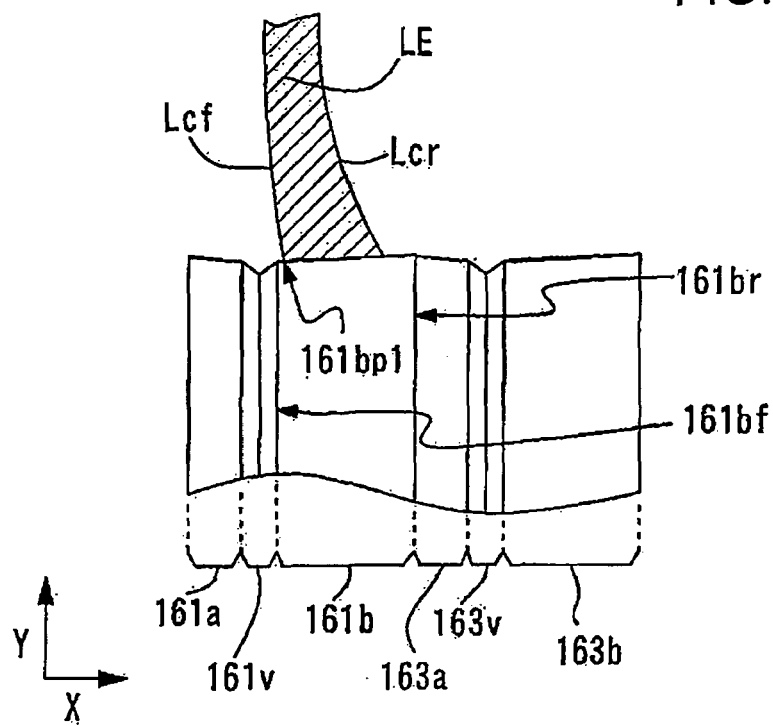


FIG. 6A

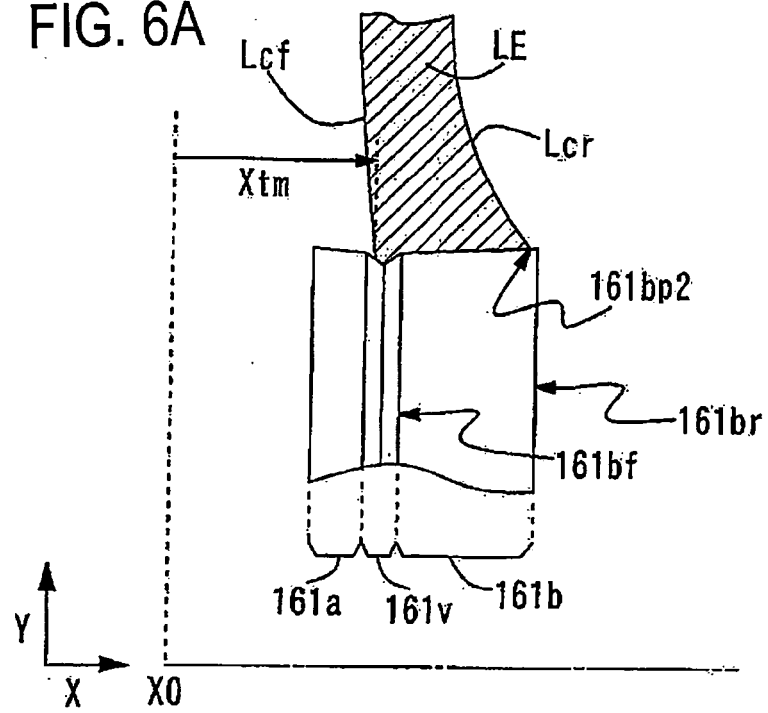


FIG. 6B

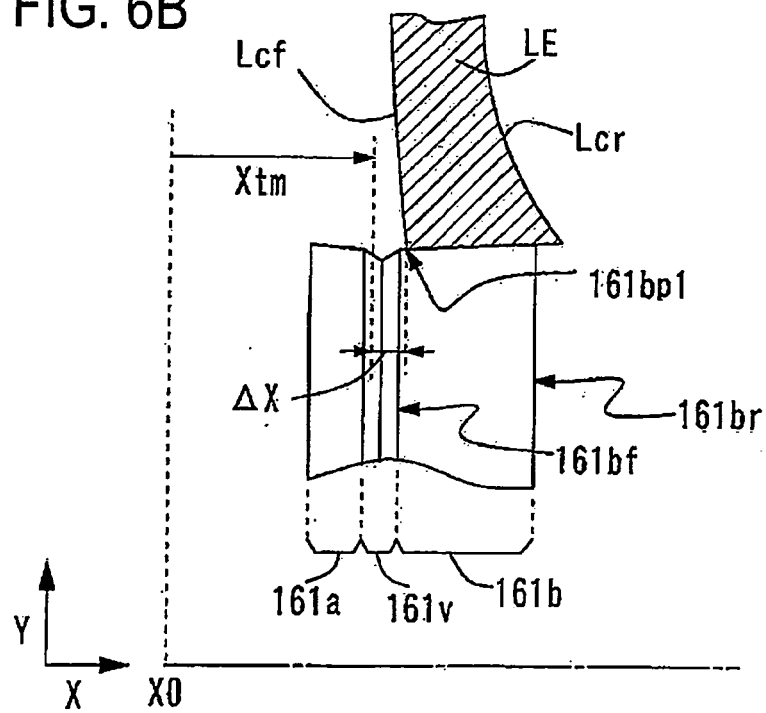


FIG. 7

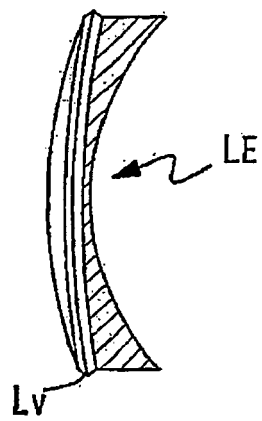


FIG. 8

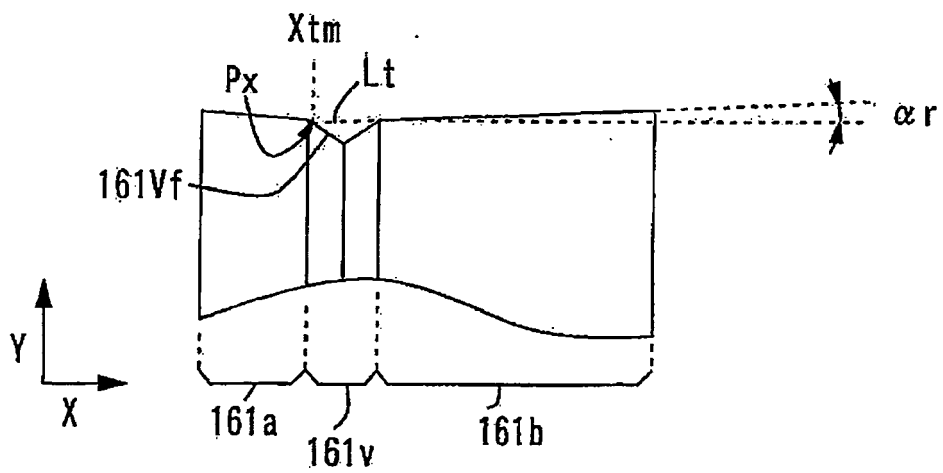


FIG. 9A

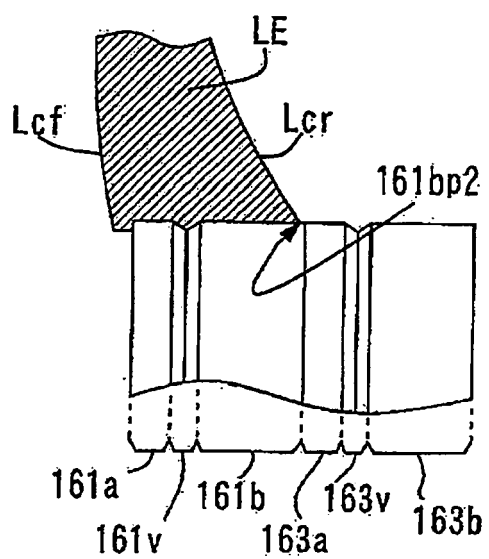
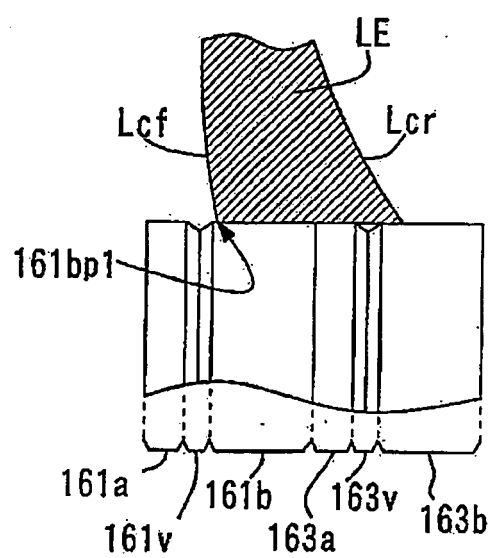


FIG. 9B



REFERENCES CITED IN THE DESCRIPTION

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