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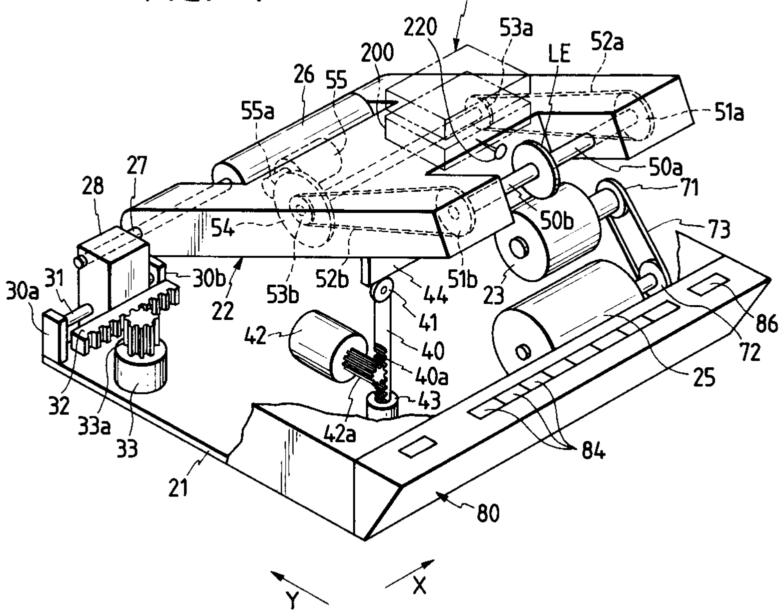
(54) **Lens chamfering machine.**

(57) A lens chamfering machine for chamfering a corner defined by a lens plane and a peripheral ground plane of a lens to be ground comprises a chamfering grindstone for chamfering the corner, a drive mechanism for driving at least one of the lens and the chamfering grindstone to change a relative positional relationship therebetween, and a control unit for determining a relative positional relationship required to attain a desired chamfer shape based on data on the shape of the lens, causing the periphery of the lens to be ground and controlling the drive mechanism based on the determination.

FIG. 1



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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a lens chamfering method for chamfering a corner defined by a lens plane and a peripheral ground plane of a lens to be ground, and a lens chamfering machine by implementing the same.

Related Background Art

A lens grinding machine as shown in Figs. 17 and 18 (Japanese Laid-Open Patent Application No. 56-15984) has been known as a prior art machine.

In the disclosed lens grinding machine, a lens 4 to be ground is held between lens shafts 2 and 3 of a main body 1 and the lens shafts 2 and 3 are rotated at a low speed while a cutting knife 6 driven by a motor 5 is moved toward the lens 4. The press-contact of the cutting knife 6 to a peripheral surface of the lens 4 is controlled to coarsely grind the lens 4 into a shape of a lens frame of an eyeglasses frame on which the lens 4 is to be mounted.

A beveling grindstone 7 is abutted against the coarsely ground lens 4 and driven by a motor 8 so that the beveling grindstone 7 lightly contacts to the periphery of the lens 4 by its weight to form a bevel 4a in the periphery of the lens 4 as shown in Fig. 18. Since the lens 4 is rotated by the lens shafts 2 and 3, a distance from a center of the shaft to the contact area of the lens 4 to the beveling grindstone 7, that is, a dynamic radius varies with the rotation, but the beveling grindstone 7 is vertically swung by a pivotable arm 9 as the dynamic radius varies.

After such beveling, the lens 4 has corners a and b on the opposite sides of the bevel 4a.

In order to chamfer the corners a and b, the disclosed lens grinding machine uses a chamfering grindstone 10 having a smaller V-groove angle than that of the beveling grindstone 7, as shown in Fig. 18.

The chamfering grindstone 10 is attached to an output shaft of a motor 11 and a support plate 12 which supports the motor 11 is rotatably and axially movably mounted on a shaft 13.

In chamfering, an operator manually presses the support plate 12 to press the chamfering grindstone 10 to the bevel 4a of the lens 4 to chamfer the corners a and b. The angles of inclination of the chamfering planes 10a and 10b of the chamfering grindstone are fixed.

Similar machines are disclosed in Japanese Laid-Open Patent Applications 1-271156 and 2-15960. In those machines, the angle of inclination of the chamfering plane of the chamfering grindstone is fixed to any shape of lens.

In the prior art machines, since the angle of the chamfering grindstone to the corner is fixed to any shape of lens, the corner cannot be chamfered with a proper angle.

For example, the angle between the lens plane and the chamfered plane may be acute even after the chamfering. In this case, the chamfering makes no sense.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a lens chamfering machine, a lens chamfering method and a lens grinding machine which assure the chamfering of a proper shape to a corner defined by a lens plane and a peripheral plane of a lens to be ground.

In order to achieve the above object, the lens chamfering machine of the present invention is characterized by the provision of a chamfering grindstone for chamfering a corner defined by a lens plane and a peripheral plane of a lens to be ground, a drive mechanism for driving at least one of the lens and the chamfering grindstone to change a relative positional relationship therebetween, and control means for calculating the relative positional relationship required to attain a desired shape of chamfer based on known data and/or measurement data on a shape of the lens to be ground and controlling the drive mechanism in accordance with the calculation. Preferably, the control means calculates a direction which bisects the corner based on the known or measured angle of the corner, calculates a relative displacement along a direction containing that directional component, and controls the drive mechanism in accordance with the calculation. Angle measurement means for measuring the angle of the corner may be provided in the lens chamfering machine.

In order to achieve the above object, the lens grinding machine of the present invention is characterized by the provision of the lens chamfering machine, a periphery grindstone for grinding a periphery of the lens to be ground, a drive mechanism for driving at least one of the lens and the periphery grindstone to change a relative positional relationship therebetween, and control means for activating the lens chamfering machine when the grinding by the periphery grindstone is completed.

In order to achieve the above object, the lens chamfering method of the present invention is characterized by the steps of determining a direction to bisect a corner defined by a lens plane and a peripheral ground plane of a lens to be ground based on known and/or measured data on a shape of the lens, and grinding the corner by relatively moving the chamfering grindstone to the lens along a direction containing the above directional component.

The control means calculates the relative positional relationship required to attain a desired shape of chamfer based on the known or measured data on the shape of the lens.

Specifically, it calculates the direction which bisects the corner based on the known or measured angle of the corner, and calculates the relative displacement along the direction containing the calculated directional component, which is required to attain the desired shape of chamfer.

The drive mechanism drives at least one of the lens and the chamfering grindstone in accordance with the calculation to attain the desired shape of chamfer.

In this manner, the corner defined by the lens plane and the peripheral ground plane of the lens is ground to the desired shape by the chamfering grindstone.

In accordance with the lens grinding machine of the present invention, a series of processes from the lens periphery grinding to the chamfering are automated and a burden of an operator is significantly reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an overall perspective view of one embodiment of a lens grinding machine of the present invention,
Fig. 2 shows an overall perspective view of one embodiment of a lens shape measurement apparatus of the present invention,
Fig. 3 shows a III-III sectional view of Fig. 2,
Fig. 4 shows an overall perspective view of one embodiment of a lens chamfering machine of the present invention,
Fig. 5 shows a V-V sectional view of Fig. 4,
Fig. 6 shows a block diagram of a control unit in one embodiment of the present invention,
Figs. 7 to 10 show flow charts for explaining operations of the embodiment of the lens grinding machine of the present invention,
Figs. 11A to 11C illustrate position measurement in an optical axis direction of a lens plane,
Fig. 12 illustrates a reference position in the optical axis direction of the lens plane,
Fig. 13 illustrates amount of chamfer,
Figs. 14 and 15 illustrate setting of coordinates of a lens to be ground and a chamfering grindstone to attain optimum chamfering,
Figs. 16A and 16B illustrate chamfering and grinding operations,
Fig. 17 shows an overall perspective view of a prior art lens grinding machine, and
Fig. 18 shows a relationship between a chamfering grindstone and a lens to be ground in the prior art lens grinding machine.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the lens grinding machine of the present invention are now explained with reference to Figs. 1 to 16.

Fig. 1 shows an overall perspective view, partially developed, of the lens grinding machine in accordance with the present invention. A support shaft 27 is axially movably fitted to a support bearing 26 which is secured to a main frame 21. A base end of a head frame 22 is rotatably fitted to the support shaft 27 with a restriction in a thrust direction. An end of the support shaft 27 is integrally engaged with a member 28 for laterally driving the head frame 22. The laterally driving member 28 is supported by a shaft 31 so that it is slidable along an axis of the support shaft 27, and a rack 32 is fixed thereto. The opposite ends of the shaft 31 are supported in parallel to the support shaft 27 by support members 30a and 30b secured to the main frame 21. The rack 32 fixed to a side of the lateral driving member 28 engages with a pinion 33a coupled to a rotation shaft of a head frame lateral driving motor 33. When the lateral driving motor 33 is energized, the lateral driving member 28 is driven axially of the shaft 31 to drive the support shaft 27 which is integral with the lateral driving member 28 along its own axis. The head frame 22 is driven axially of the support shaft 27 in accordance with the rotation of the lateral driving motor 33.

On the other hand, a vertical movement shaft 40 is vertically slidably fitted to a cylinder 43 secured to the main frame 21. A roller 41 is rotatably mounted at an end of the vertical movement shaft 40 and it abuts against a buffer member 44 secured to a bottom of the head frame 22. A rack 40a is formed axially of the vertical movement shaft 40 and it engages with a pinion 42a attached to a rotation shaft of a vertical driving motor 42 which is a pulse motor. As the vertical driving motor 42 rotates, the vertical movement shaft 40 is vertically driven and the head frame 22 is swung around the support shaft 27 by the roller 41 and the buffer member 44.

The head frame 22 is formed with a recess in which a member for holding a lens LE to be ground is mounted. A lens press shaft 50b and a lens receive shaft 50a are coaxially and rotatably supported by the recess. The lens press shaft 50b has a known holding mechanism (not shown) which holds the lens LE by the shafts 50b and 50a. Pulleys 51a and 51b are mounted on the lens press shaft 50b and the lens receive shaft 50a, respectively, and a rotary shaft 56 having pulleys 53a and 53b at the opposite ends thereof is mounted on the head frame 22. A gear 54 is attached to one end of the rotary shaft 56 and it engages with a pinion 55a mounted on a rotary shaft of a lens drive motor 55 which is a pulse motor. Belts 52a and 52b are spanned between the pulleys 51a and 51b, and the pulleys 53a and 53b, respectively. As the lens driving motor 55 rotates, the lens LE is rotated.

A grindstone 23 and a grindstone driving motor 25 are arranged on the main frame 21. Pulleys 71 and 72 are mounted thereon and they are coupled by a belt 73.

A lens shape measurement apparatus 100 and a lens chamfering machine 200 are arranged at predetermined positions on the main frame 21.

The lens shape measurement apparatus 100 is now explained. It detects various data on the lens shape. It is explained with reference to Figs. 2 and 3. Fig. 2 shows a perspective view of an external view of the lens shape measurement apparatus and Fig. 3 is a III-III sectional view of Fig. 2.

Two guide rails 102a and 102b extend parallely along a Y direction on a base frame 101 and the opposite ends thereof are secured to the base frame. A Y drive table 103 is slidably arranged on the guide rails 102a and 102b. Two support members 110 and 111 are secured to the Y drive table 103, and parallel rails 113a and 113b having the opposite ends thereof secured to the support members 110 and 111 are spanned between the support members 110 and 111. An X drive table 112 is slidably arranged on the parallel rails 113a and 113b. A measurement shaft 121 extending along the Y axis is rotatably fitted to the X drive table 112, and the axial movement thereof is limited by rings 123 and 127 mounted on the measurement shaft 121. A wave washer 128 is held between the ring 127 and the drive table 111, and a switch 129 is mounted at the bottom of the X drive table 112. As the measurement shaft 121 is moved along the (-) Y direction, the ring 127 abuts against the switch 129 to turn it on. The switch 129 is normally off because it receives a force of the wave washer 128 in the direction away from the switch 129.

A measurement device 120 is fixed to an end of the measurement shaft 121. The measurement device 120 comprises a lens outer diameter measuring unit 120a, a lens plane optical axis position measuring unit 120b and a bevel measuring unit 120c. A tension spring 104 for biasing the Y drive table 103 along the (-) Y direction is spanned between the Y direction drive table 103 and the base frame 101. A rack 107 is formed at an end of the Y drive table 103 along the X direction and it is coupled with the Y drive motor 105 which is a pulse motor through a clutch 106. A gear 106a is mounted on one rotary shaft of the clutch 106 and it engages with a pinion 105a mounted on the rotary shaft of the Y drive motor 105. A pinion 106b mounted on the other rotary shaft of the clutch 106 engages with the rack 107. As a result, the Y drive table 103 is pulled leftward in the drawing by the force of the tension spring 104 when the clutch 106 is disengaged. When the clutch 106 is engaged, the Y drive table 103 is moved along the Y direction as the Y drive motor 105 rotates. A rack 108 is mounted at the other end of the Y drive table 103 along the X direction and it engages with a pinion 108a mounted on a rotary shaft of the encoder 109. A displacement of the Y drive table 103 is detected by the decoder 109. Four compression springs 114a, 114b, 114c and 114d are spanned between the X drive table 112 and the support members 110 and 111, and the X drive table 112 is nomally biased toward a neutral position in the X direction. A rack 115 having the opposite ends thereof fixed to the support members 110 and 111 is arranged between the support members 110 and 111 and it engages with a pinion 116a mounted on a rotary shaft of an encoder 116 mounted on the X drive table 112. Thus, a displacement of the X drive table 112 is detected by the encoder 116.

A gear 126 is mounted on a base end of the measurement shaft 121 and it engages with a gear 125a mounted on a rotary shaft of a measurement shaft drive motor 125 which is a pulse motor. Thus, the measurement shaft 121 is rotated by the rotation of the measurement shaft drive motor 125. A solenoid 124 is secured to the Y drive table 103 to face the base end of the measurement shaft 121. When the solenoid 124 is energized, it engages with the base end of the measurement shaft 121. Namely, when the solenoid

124 is energized, the measurement shaft 121 is secured.

A construction of the lens chamfering machine 200 is now explained with reference to Figs. 4 and 5. Fig. 4 shows a perspective view of an external view of the lens chamfering machine 200, and Fig. 5 shows a V-V sectional view of Fig. 4.

Two guide rails 202a and 202b are parallelly spanned on a base frame 201 and the opposite ends thereof are secured to the base frame. A Y drive table 203 is slidably arranged on the guide rails 202a and 202b.

A rack 205 is secured to one end of the Y drive table 203 parallelly to the guide rails 202a and 202b and it engages with a pinion gear 206 secured to a shaft of a chamfering grindstone drive motor 207 secured to the base frame 201.

A shaft 204 is embedded near the center of the Y drive table 203 perpendicularly to the guide rails 202a and 202b and a swingable table 210 is pivotably engaged with the shaft 204. Two springs 217a and 217b are mounted at the opposite ends of the swingable table 210 along the X direction, and the other ends of springs 217a and 217b are secured to the drive table 203.

A block member 211 is secured to the swingable table 210 and a spindle cylinder 216 is secured to the block member 211 along the Y direction. Bearings 215a and 215b are built in the spindle cylinder 216 and a spindle shaft 214 is rotatably built in inner rings of the bearings 215a and 215b. One end of the spindle shaft 214 is coupled to a shaft 212a of a grindstone drive motor 212 secured to the swingable table 210, through a shaft joint 213. A chamfering grindstone 220 is secured to the other end of the spindle shaft 214. The chamfering grindstone 220 is semi-spherical.

A control unit of the lens grinding machine 80 is provided on a front side of the machine as shown in Fig. 1.

As shown in Fig. 6, the control unit 80 comprises a CPU 81 for various arithmetic operations, a program memory 82 which stores a program used for the arithmetic operations by the CPU 81, a data memory 83 which stores various data, input keys 84 for entering various data and commands such as start of operation, an interface circuit 85, a buzzer for informing the end of grinding, and a control circuit 87 for controlling the various motors.

The program memory 82 stores a program for operating the lens shape measuring apparatus 100 and a program for driving the various motors in accordance with data from the lens shape measuring apparatus 100.

The interface circuit 85 is connected to the lens shape measurement apparatus 100 and an end of grinding sensor 29 provided in the roller 21.

An operation of the present embodiment is now explained in accordance with flow charts shown in Figs. 7 to 10.

Positions along the optical axis of points in the vicinity of the periphery of the lens plane are measured based on known or measured frame shape data (ρn, θn) (n = 0, 1, 2, ..., n). As shown in Figs. 11A to 11C, the lens frame shape data is two-dimensional coordinate data on the plane normal to the lens optical axis, ρn is a distance from the center of the lens LE to a desired peripheral point, that is, a radius of the lens, and θn is an angle between a base line passing through the center of the lens LE and the desired peripheral point. The frame shape data is pre-stored in the data memory 83 of the control unit 80.

The clutch 106 of the lens shape measuring apparatus 100 is engaged to drive the Y drive table 103 by the Y drive motor 105 such that the measurement device 120b is brought to a position corresponding to a position $S_{10}(\rho_0\text{-h}, \theta_0)$ which is shorter by a bevel height h in a radial direction of the lens LE for first frame shape data (ρ_0, θ_0) of an R1 plane of the lens. Then, as shown in Figs. 11A and 11B, the motors 33, 43 and 55 are driven to drive the lens LE such that the predetermined point $S_{10}(\rho_0\text{-h}, \theta_0)$ of the R1 plane of the lens abuts against the measurement device 120b.

The encoder 116 reads the displacement X_{10} of the X drive table 112 at $S_{10}(\rho_0\text{-h}, \theta_0)$.

Then, the lens drive motor is driven by an angle θ_1 to rotate the lens LE, and the Y drive motor 105 is driven to the position corresponding to (ρ_1-h) to drive the measurement device 120b so that the measuring element 120b abuts against S_{11} (ρ_1-h, θ_1) of the R1 plane of the lens.

A displacement X_{11} of the X drive table 112 at $S_{11}(\rho_1\text{-h}, \theta_1)$ is read by the encoder 116.

The above process is repeated until $S_{1n}(\rho_n\text{-h } \theta_n)$ is reached, that is, until the displacements X_{10}, X_{11}, ... X_{1n} of the X drive table 112 over the entire periphery of the lens LE are measured.

Similarly, displacements X'_{10}, X'_{11}, ..., X'_{1n} of the X drive table 112 are measured for S'_{10} (ρ_0-h-Δr, θ_0), ..., S'_{1n} (ρ_n-h-Δr, θ_n) which are shorter by a small distance Δr along the radial direction of the lens LE from S_{10}, S_{11}, ..., S_{1n}.

When all data on the lens plan R1 have been measured, the head frame lateral drive motor 33 and the vertical drive motor 43 are activated to drive the head frame 22 so that the lens LE is moved away from the measurement device 120. Then, the Y drive motor 105 is activated to drive the Y drive table 103 in the direction to retract the measurement device 120. The measurement shaft drive motor 125 is then activated to invert the measurement device 120 by 180 degrees. Then, the head frame lateral drive motor 33 is activated to drive the head frame 22 so that the lens LE approaches the measurement unit 120b and thereafter the motor 105 is activated so that the drive table 103 is driven to bring the measurement unit 102b to the position corresponding to S_{20} (ρ_0-h, θ_0) of the lens plane R2, as shown in Fig. 11C. Then, the head frame 2 is driven to a predetermined position of the plane R2 as it is done in the measurement of the plane R1. Similarly, the displacements X_{20}, ..., X_{2n} and X'_{20}, ..., X'_{2n} of the X drive table 112 are measured as it is done for the plane R1. The displacements X_{10}, ..., X'_{2n} of the X drive table 112 are distances from an initial position sensor (not shown) of the X drive table 112.

The measured displacements X_{10}, ..., X'_{2n} are converted to the distances x_{10}, ..., x'_{2n} from the spindle shaft 214 of the lens chamfering machine 200 by the CPU 81 as shown in Fig. 12. Three dimensional coordinate data of the measured points S_{10}, ..., S_{1n}; S'_{10}, ..., S'_{1n}; S_{20}, ..., S_{2n} and S'_{20}, ..., S'_{2n} are calculated (steps 1 and 2).

Specifically, the three-dimensional coordinate data are expressed by S_{1n} (ρ_n-h θ_n, x_{1n}), S'_{10} (ρ_n-h-Δr, θ_n, x'_{1n}), S_{2n} (ρ_n-h, θ_n, x_{2n}), S'_{2n} (ρ_n-h-Δr, θ'_n, x'_{2n}) and they are stored in the data memory 83 of the control unit 80.

The motors 33, 43 and 25 are activated by an instruction from the CPU 81 to coarsely grind and bevel the lens periphery. The grindstone 23 comprises a coarse grindstone and a bevel grindstone which are integral so that the coarse grinding and the bevel grinding are effected by the grindstone 23 (step 3).

When the bevel grinding is completed, the CPU 81 perfomrs various arithmetic operations based on the three-dimensional coordinate data (step 4). The arithmetic operations are explained with reference to flow charts shown in Figs. 8 to 10. In the following description, only the arithmetic operations for the plane R2 is explained to avoid duplicate.

As shown in Fig. 14, an angle α_1 between a straight line L_2 connecting S_{2n} (ρ_n-h θ_n, x_{2n}) and S_{2n} (ρ_n-h-Δr, θ'_n, x'_{2n}) and a straight line L_2 passing through S_{2n} (ρ_n-h, θ_n, x_{2n}) on the grinding plane of the lens periphery is calculated from a formula (1) (step 42). The direction of the line L_1 is parallel to the lens optical axis and known.

$$\alpha_1 = \tan^{-1}\left|\frac{(\rho_n-h)-(\rho_n-h-\Delta r)}{x'_{2n}-x_{2n}}\right|$$

$$= \tan^{-1}\left|\frac{\Delta r}{x'_{2n}-x_{2n}}\right| \qquad \ldots (1)$$

Then, an angle α_2 between a straight line L_3 bisecting the angle α_1 and the straight line L_1 is calculated from a formula (2) (step 43).

$$\alpha_2 = \frac{\alpha_1}{2.} = \frac{1}{2}\tan^{-1}\left|\frac{\Delta r}{x'_{2n}-x_{2n}}\right| \qquad \ldots (2)$$

When the angle α_2 is determined, the coordinates of the point S_{2n} when the lens LE is driven in the X direction and the coordinates of the center point P_{2n} of the chamfering grindstone 220 when the chamfering grindstone 220 is driven in the Y direction so that the S_{2n} (ρ_n-h, θ_n, x_{2n}) which is the crosspoint of the lens plane R2 and the grinding plane of the lens periphery contacts to the semi-spherical chamfering grindstone 220 and calculated (step 45).

The point S_{2n} and the center point P_{2n} are represented by

S_{2n} ($^{\rho}{}_n$-h, θ_n, e_{2n}) (e_{2n} = ℓ cosα_2)
P_{2n} (ρ_n-h + f_{2n}, θ_n, 0) (f_{2n} = ℓ sinα_2)

where ℓ is a radius of the chamfering grindstone 220.

Then, the coordinates of the point S_{2n} when the desired chamfering is effected by driving the lens LE in the X direction are calculated. since the point S_{2n} disappears by the chamfering, the coordinates of the points S_{2n} are calculated on the assumption that the point S_{2n} is present (step 45).

As shown in Fig. 13, the point S_{2n} is represented by

S_{2n} (ρ_n-h, θ_n, e_{2n}-g_2)

where g_2 is a chamber.

Since the chamfering grindstone 220 is not driven now, the coordinates of the center point P_{2n} of the chamfering grindstone 220 do not change.

The above arithmetic operations are done for the entire periphery of the lens plane R2.

Similarly, the arithmetic operations are done for the entire periphery of the lens plane R1 (step 44).

The coordinates of the point S and the center point P are given as follows.

Immediately before the start of the chamfering (that is, when the lens LE contacts to the chamfering grindstone 220):

S_{1n} (ρ_n-h, θ_n, e_{2n}), P_{1n} (ρ_n-h + f_{1n}, θ_n, 0)
S_{2n} (ρ_n-h, θn, e_{2n}), P_{2n} (ρ_n-h + f_{2n}, θ_n, 0)

Immediately after the chamfering:

S_{1n} (ρ_n-h, θ_n, e_{1n}-g_1), P_{1n} (ρ_n-h + f_{1n}, θ_n, 0)
S_{2n} (ρ_n-h, θ_n, e_{2n}-g_2), P_{2n} (ρ_n-h + f_{2n}, θ_n, 0)

In the arithmetic operations of the steps 42 to 45, it is assumed that the periphery of the lens at the end of the periphery grinding is selectively thick and there are a bevel as well as planes parallel to the optical axis on the opposite sides of the bevel. However, where the lens periphery is relatively thin and only the bevel is formed on the periphery ground plane, the arithmetic operations are done as shown in flow charts of Figs. 8 to 10.

As shown in Fig. 15, whether there are planes parallel to the optical axis on the opposite sides of the bevel on the periphery ground plane or not is determined.

In the determination, the periphery thickness t = S_{1n} - S_{2n} is calculated.

From S_{1n} (ρ_n-h, θ_n, x_{1n}) and S_{2n} (ρ_n-h, θ_n, x_{2n}), the periphery thickness is given by $t = |x_{1n} - x_{2n}|$.

Since a bevel with Y of the beveling grindstone is known, t and Y are compared step 41 and if $t \leqq Y$, a decision is made that only the bevel is present on the periphery ground plane, and the process proceeds to a step 50. If t > Y, the process proceeds to the step 42. An actual bevel height m is then calculated (step 50).

As shown in Fig. 15, a bevel top J is generally at the center of the periphery thickness t when the edge thickness is thin. An angle of the bevel, that is, an angle between a line JS''_{1n} and a line JS''_{2n} is represented by 2 x β , there S''_{1n} and S''_{2n} are crosspoints of the planes R1 and R2 and the periphery ground plane and β is an angle made to the radial direction of the lens LE.

The actual bevel height m is a distance between the line L_1 passing through S''_{1n} and S''_{2n} and the bevel top J. Since

$$t/2m = \tan\beta$$

the actual bevel height m is calculated by

$$m = t/(2 \cdot \tan\beta) \qquad (3)$$

The coordinates of S''_{1n} and S''_{2n} which are the crosspoints of the planes R1 and R2 and the periphery ground plane are calculated (step 51).

Since S_{1n} and S''_{1n} are very close to each other, a difference between the positions of S_{1n} and S''_{1n} in the optical axis direction is almost zero. Similarly, a difference between the positions of S_{2n} and S''_{2n} in the optical axis direction is almost zero.

Accordingly, the coordinates of the points S''_{1n} and S''_{2n} are represented by

S''_{1n} (ρ_n-m, θ_n, x_{1n})
S''_{2n} (ρ_n-m, θ_n, x_{2n})

Then, the angle α_1 between the planes R1 and R2 and the optical axis is calculated (step 52). The angle between the line L_2 passing through the points S''_{2n} and S'_{2n} on the plane R1 and the line L_2 passing through the point S''_{2n} and parallel to the optical axis is used.

Since the coordinates of the points S'_{2n} and S''_{2n} are given by S'_{2n} (ρ_n-h-Δr, θ_n, x'_{2n}) and S''_{2n} (ρ_n-m, θ_n, x'_{2n}), respectively, the angle α_1 between the lines L_2 and L_1 is calculated by

$$\alpha_1 = \tan^{-1}\left|\frac{(\rho_n-h-\Delta r)-(\rho_n-m)}{x'_{2n}-x_{2n}}\right|$$

$$= \tan^{-1}\left|\frac{m-h-\Delta r}{x'_{2n}-x_{2n}}\right| \quad \ldots (4)$$

The angle α_3 between the optical axis and the periphery ground plane is calculated (step 53).

Since the angle α_3 is the angle between the line L_4 passing through the point S''_{2n} and the top J and the line L_1, the angle α_3 is calculated by

$\alpha_3 = 90° - \beta$ (5)

The angle α_4 between the line L_2 and the line L_4 is calculated (step 54) by

$\alpha_4 = \alpha_1 + \alpha_3$ (6)

The angle α_2 between the line L_3 and the line L_2 which is a bisecting line to the angle α_4 is calculated (step 55)

$$\alpha_2 = \frac{1}{2}\alpha_4 = \frac{1}{2}(\alpha_1+\alpha_3) = \frac{1}{2}(\alpha_1+90°-\beta)$$

$$= \frac{1}{2}\left[\tan^{-1}\left|\frac{m-h-\Delta r}{x'_{2n}-x_{2n}}\right| + 90° - \beta\right] \ldots (7)$$

The coordinates of the point S'' and the center point P immediately before and after the chamfering are determined in the same manner as that for the relatively thick periphery by assuming $e_{2n} = \ell\cos\alpha_2$ and $f_{2n} = \ell\sin\alpha_2$ (steps 56 and 57). Those points are given as follows.

Immediately before the chamfering:

S''_{1n} (ρ_n-m, θ_n, e_{1n}), P_{1n} (ρ_n-m + f_{1n}, θ_n, 0)
S''_{2n} (ρ_n-m, θ_n, e_{2n}), P_{2n} (ρ_n-m + f_{2n}, θ_n, 0)

Immediately after the chamfering:

S''_{1n} (ρ_n-m, θ_n, e_{1n}-g_1), P_{1n} (ρ_n-m + f_{1n}, θ_n, 0)
S''_{2n} (ρ_n-m, θ_n, e_{2n}-g_2), P_{2n} (ρ_n-m + f_{2n}, θ_n, 0)

When the coordinates are calculated by the steps 41 to 45 and the steps 50 to 57, they are stored in the data memory 83 of the control unit 80.

When the above steps are carried out for the entire peripheries of the planes R1 and R2 (step 47), the chamfering calculation is over. In the present embodiment, the chamfering calculation (step 4) is carried out after the bevel grinding (step 3) although it may be carried out after the steps 1 and 2 or during the grinding of the lens periphery (step 3).

When the chamfering calculation is over, the chamfering is started (steps 6 and 7).

When the plane R2 is to be beveled, the height of the lens center O is matched to the height of the axial center Q of the spindle shaft 214 of the lens chamfering machine 200 as shown in Fig. 16B, and the lens LE is spaced from the chamfering grindstone 220 by x_{2n} along the optical axis.

The lens LE is then rotated so that the point θ_0 of the lens LE is on an extension of the line Q.

The grindstone drive motor 212 is activated to rotate the chamfering grindstone 220 while the chamfering grindstone 220 is driven along the Y direction so that the Y coordinate of the center P of the chamfering grindstone 220 matches to the calculated value (ρ_0-h + f_{20}) and the lens LE is driven along the X direction so that the X coordinate of the point S_{20} of the lens LE matches to the calculated value (X_{20} = e_{20} - g_2).

The desired chamfer g is attained by the movement of the lens LE. When the corner of the lens LE is ground, it may be cracked when a strong impact is applied thereto. Accordingly, springs 217a and 217b are provided on the chamfering grindstone 220 as the buffer member to relieve the impact.

The lens LE is most preferably driven along the line L_3 which bisects the angle between the lens plane and the lens periphery ground plane, but since the chamfering grindstone 220 is semispherical, the chamfering of desired chamfer and angle may be attained even if it is driven along the X direction.

The chamfering of the point S_{20} is thus completed.

The above steps are applied to the entire periphery of the plane R2 while the lens LE is rotated to chamfer the plane R2. Similarly, the plane R1 is chamfered.

When the planes R1 and R2 have been chamfered; the end of grinding sensor 29 detects it and sound an end buzzer 86 (step 7).

In the present embodiment, since the steps from the coarse grinding of the lens periphery to the chamfering are fully automatically carried out, the manpower is significantly saved.

Since the planes R1 and R2 are chamfered in accordance with the angles between the planes R1 and R2 and the lens periphery ground plane, the chamfering of proper angle is attained.

Further, since the end buzzer 86 is sounded, a time from the end of the lens grinding to the next step such as exchange of a machined product and an unmachined product can be shortened.

In the present embodiment, the lens is moved in the periphery grinding step and the chamfering step although the grindstone may be moved to change the relative distance between the lens and the grindstone.

In accordance with the present invention, the relative positional relationship between the grindstone and the lens to be ground which is required to attain the desired chamfer shape is calculated based on the data on the shape of the lens to be ground, and the relative positional relationship is changed in accordance with the calculation result. Accordingly, the chamfering with proper angle and amount can be attained.

Claims

1. A lens chamfering machine for chamfering a corner defined by a lens plane and a peripheral ground plane of a lens to be ground, comprising:

a chamfering grindstone for chamfering the corner;

a drive mechanism for driving at least one of the lens to be ground and said chamfering grindstone to change a relative positional relationship therebetween; and

control means for determining a relative positional relationship required to attain a desired chamfer shape based on data on the shape of the lens to be ground, causing a periphery of the lens to be ground, and controlling said drive mechanism in accordance with the determination.

2. A lens chamfering machine for chamfering a corner defined by a lens plane and a peripheral ground plane of a lens to be ground, comprising:

a chamfering grindstone for chamfering the corner;

a drive mechanism for driving at least one of the lens to be ground and said chamfering grindstone to change a relative positional relationship therebetween; and

control means for determining a bisecting direction of the corner based on data including an angle of the corner, determining a relative displacement required to attain a desired amount of chamber along a direction containing the bisecting direction, causing a periphery of the lens to be ground and controlling said drive mechanism in accordance with the determination.

3. A lens chamfering machine according to claim 2 further comprising angle measurement means for measuring the angle of the corner.

4. A lens chamfering machine according to claim 2 wherein the periphery of the lens after the grinding has at least a portion parallel to an optical axis, said control means receives positional coordinates of the corner which are grinding data of the periphery of the lens, said lens chamfering machine further comprises measurement means for measuring positional coordinates in the vicinity of the periphery of the lens, and said control means determines the angle of the corner based on the received positional coordinates of the corner and the positional coordinates of the vicinity of the periphery of the lens measured by said measurement means.

5. A lens chamfering machine according to claim 2 wherein the periphery of the lens after the grinding includes only a bevel having a triangular section, said control means receives an apex angle of the bevel and positional coordinates of the apex which are grinding data of the lens, said lens chamfering machine further comprises measurement means for measuring positional coordinates of the lens plane, and said control means determines the angle of the corner based on the received apex angle of the bevel and the received apex positional coordinates and the positional coordinates of the lens plane measured by said measurement means.

6. A lens chamfering machine according to claim 5 further comprising measurement means for measuring the positional coordinates of the lens plane, wherein said control means receives a width of the bevel which is the grinding data of the periphery of the lens, and compares the received width of the bevel with the positional coordinates of the lens plane measured by said measurement means to determine whether the periphery of the ground lens comprises only the bevel having the triangular section.

7. A lens chamfering machine according to claim 2 for a lens to be ground to have at least a peripheral portion parallel to an optical axis wherein said lens chamfering machine includes measurement means for measuring the coordinates of the lens plane, said control means receives two-dimensional coordinates of the position of the corner which are the grinding data of the periphery of the lens and determines a point on the lens plane which is closer to the center point than said corner by a small distance based on the two-dimensional coordinates of the corner, said measurement means measures the center points of the lens and the three-dimensional coordinates to the optical axis for the corner and said point, and said control means determines a straight line passing through said corner and said point based on the three-dimensional coordinates of said corner and said point and selects the angle between said line and the peripheral plane of the lens as the angle of the corner.

8. A lens chamfering machine according to claim 2 for a lens to be ground to have a periphery thereof comprising only a bevel having a triangular section, wherein said lens chamfering machine further comprises measurement means for measuring the coordinates of the lens plane, said control means receives an apex angle of the bevel and the two-dimensional coordinates of the apex which are grinding data of the periphery of the lens, said measurement means measures the thickness of the periphery of the lens plane, and said control means determines a height of the bevel based on the measured thickness of the periphery, the apex angle of the bevel and the two-dimensional coordinates of the apex, and determines the two-dimensional coordinates of the position of the corner based on the height of the bevel and the two-dimensional coordinates of the apex of the bevel, and further determines a point on the lens plane closer to the center point than the corner by a small distance based on the two-dimensional coordinates of the corner, said measurement means measures the center points of the lens and the three-dimensional coordinates to the optical axis for the corner and said point, and said control means determines a first angle between a first straight line passing through the corner and said point and a second straight line passing through said point in parallel to the optical axis, determines a second angle between an inclined plane of the bevel adjacent to the corner to be chamfered and said line and determines the angle of the corner by adding the first angle and the second angle.

9. A lens chamfering machine according to claim 2 wherein said chamfering grindstone is generally semi-spherical.

10. A lens chamfering machine according to claim 2 wherein said chamfering grindstone is supported by a resilient member.

11. A lens chamfering machine according to claim 2 wherein said drive mechanism drives at least one of the lens to be ground and said chamfering grindstone in at least one of the optical axis direction and perpendicularly thereto.

12. A lens chamfering machine according to claim 2 further comprising output means for generating a signal when the chamfering of the lens is over.

13. A lens grinding machine including a lens chamfering machine according to claim 2 comprising:
a periphery grinding grindstone for grinding a periphery of the lens;
a periphery grinding grindstone drive mechanism for driving at least one of the lens and said periphery grinding grindstone; and
drive means responsive to the end of grinding by said periphery grinding grindstone for activating said lens chamfering machine.

14. A lens chamfering method for chamfering a corner defined by a lens plane and a peripheral ground plane of a lens to be ground by a chamfering grindstone, comprising:
a first step of determining an angle of the corner and a bisecting direction of the corner; and
a second step of relatively driving said chamfering grindstone to the lens along a direction containing the bisecting direction after the grinding of the periphery of the lens to grind the corner.

15. A lens chamfering method according to claim 14 for a lens to be ground to have at least a peripheral portion parallel to an optical axis, wherein said first step includes the steps of:
receiving two-dimensional coordinates of the position of the corner which are grinding data of the periphery of the lens;
determining a point on the lens plane which is closer to a center point than the corner based on the two-dimensional coordinates of the corner;
measuring the center point of the lens and three-dimensional coordinates to the optical axis for the corner and said point; and
determining a straight line passing through the corner and said point based on the three-dimensional coordinates of the corner and said point and selecting the angle between said straight line and the peripheral plane of the lens as the angle of the corner.

16. A lens chamfering method according to claim 14 for a lens to be ground to have a periphery constructed only by a bevel having a triangular section, wherein said first step includes the steps of:
receiving an apex angle of the bevel and two-dimensional coordinates of the apex which are grinding data of the periphery of the lens;
measuring a thickness of the periphery of the lens plane;
determining a height of the bevel based on the meausred peripheral thickness, the apex angle of the bevel and the two-dimensional coordinates of the apex and determining two-dimensional coordinates of the position of the corner based on the height of the bevel and the two-dimensional coordinates of the apex of the bevel;
determining a point on the lens plane closer to a center point than the corner by a small distance based on the two-dimensional coordinates of the corner;
measuring the center points of the lens and three-dimensional coordinates to the optical axis for the corner and said point;
determining a first angle between a first straight line passing through the corner and said point and a second straight line passing through said point in parallel to the optical axis;
determining a second line between an inclined plane of the bevel adjacent to the corner to be chamfered and said straight line; and
determining the angle of the corner by adding the first angle and the second angle.

FIG. 1

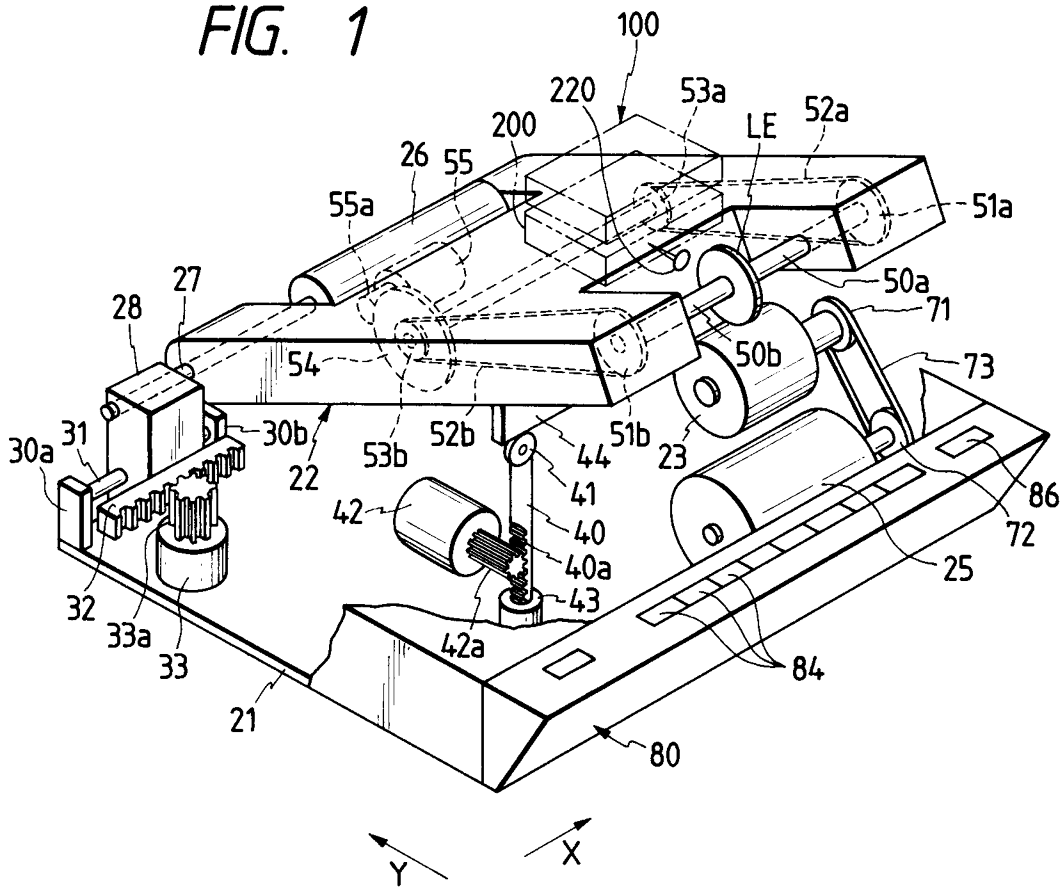

100
220
53a
LE
52a
200
26
55
55a
51a
50a
71
27
28
54
50b
73
30a
31
30b
53b
52b
22
44
51b
23
86
41
42
40
40a
72
25
32
33a
33
43
42a
84
21
80
Y
X

FIG. 2

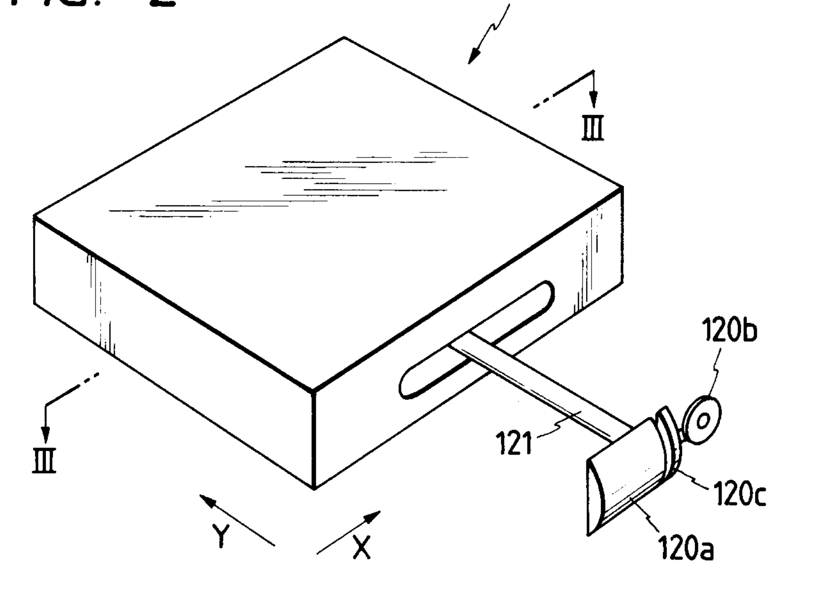

100
III
120b
121
III
120c
120a
Y
X

FIG. 3

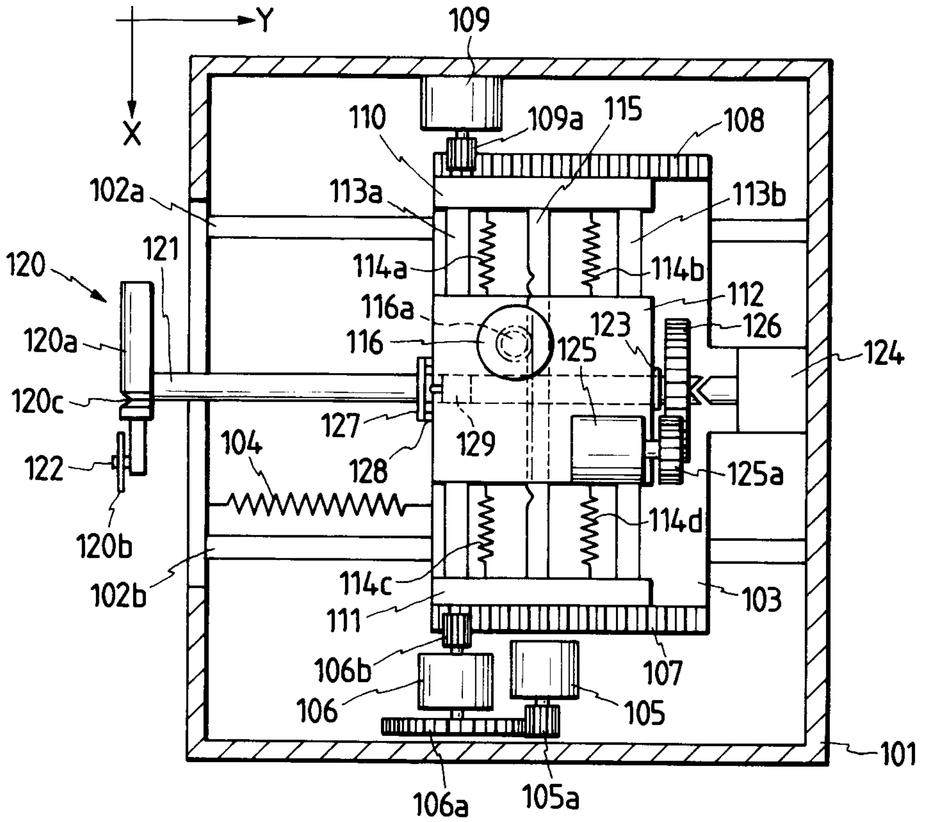

Y
X
109
110
109a
115
108
102a
113a
113b
121
120
114a
114b
116a
112
116
123
126
120a
125
124
120c
127
129
104
122
128
125a
114d
120b
102b
114c
103
111
106b
107
106
105
101
106a
105a

FIG. 4

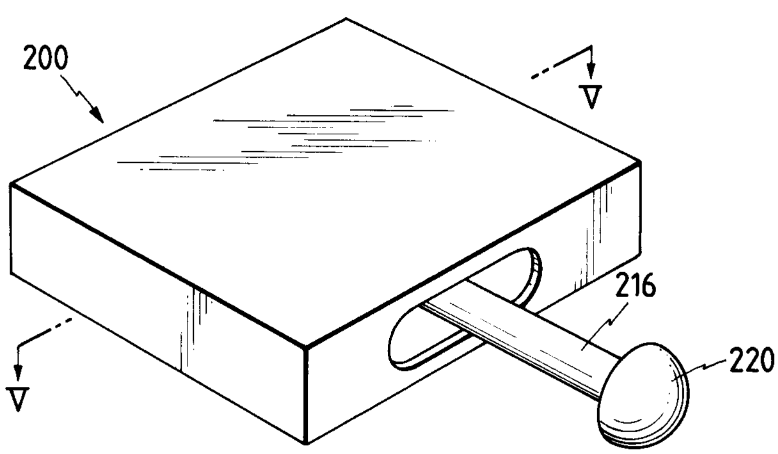

200
V
216
220
V

FIG. 5

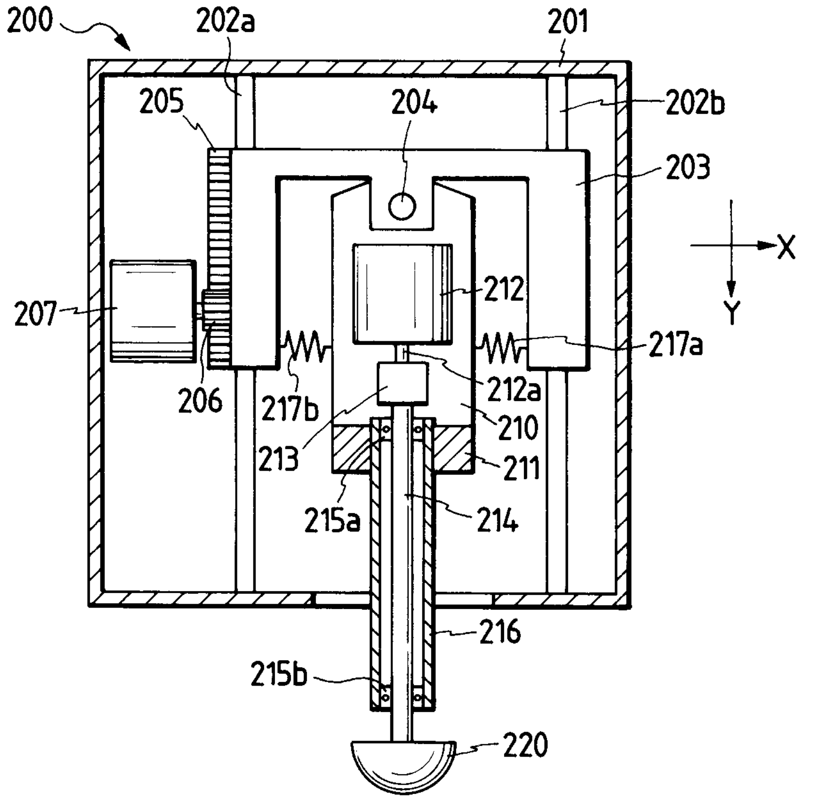

200
202a
201
205
204
202b
203
X
Y
207
212
217a
212a
206
217b
210
213
211
215a
214
216
215b
220

FIG. 6

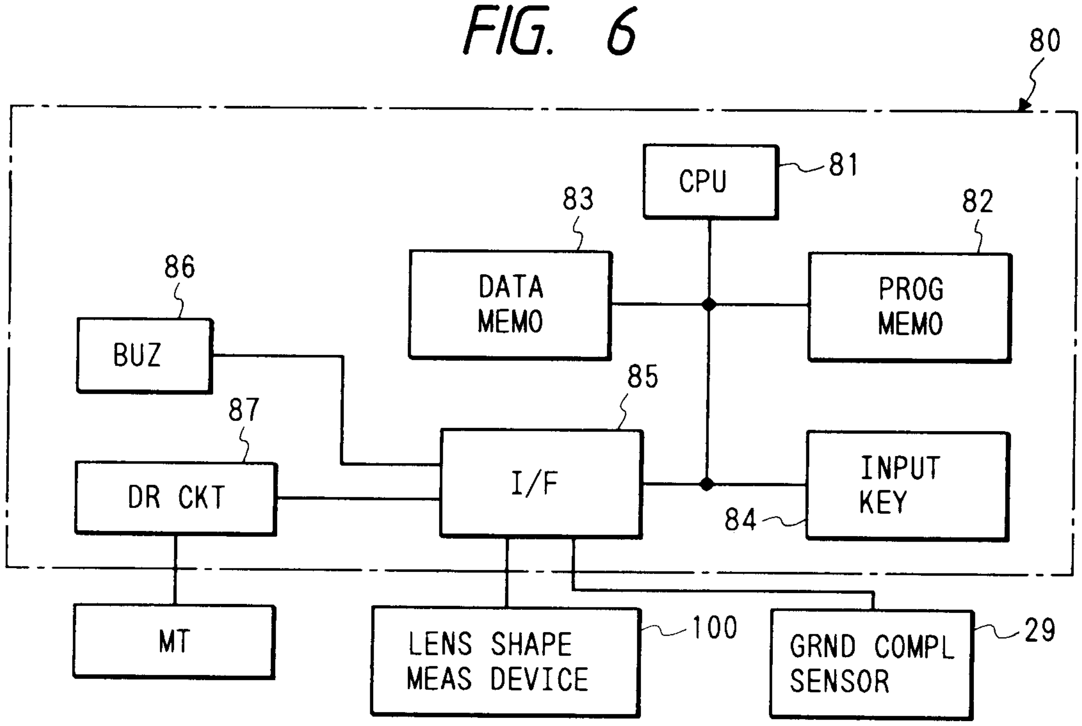

80
CPU
81
83
82
DATA MEMO
PROG MEMO
86
BUZ
85
87
DR CKT
I/F
INPUT KEY
84
MT
LENS SHAPE MEAS DEVICE
100
GRND COMPL SENSOR
29

FIG. 7

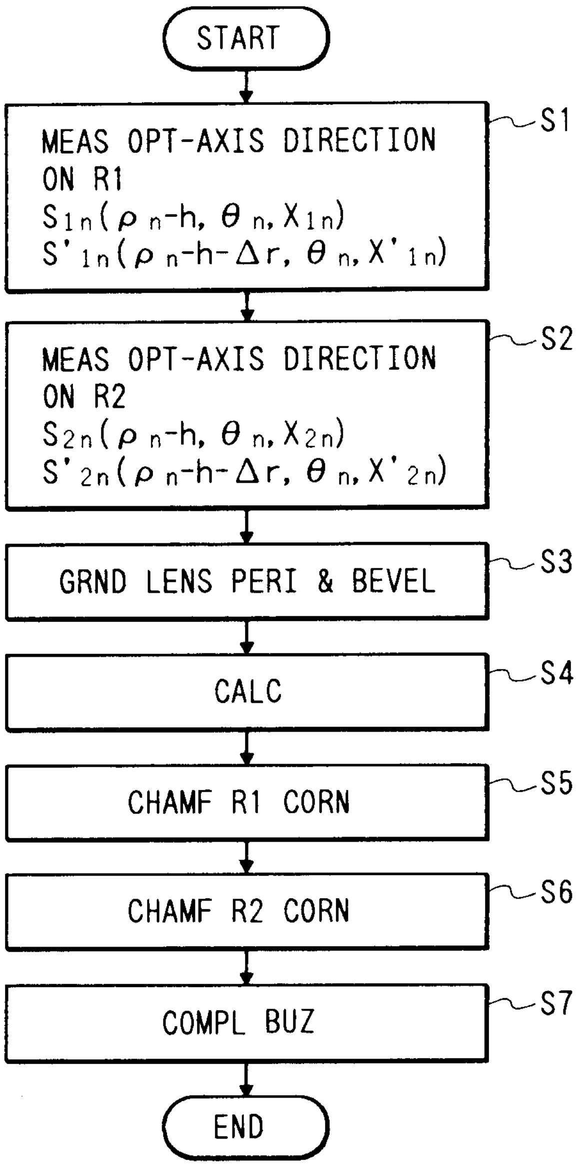

START
MEAS OPT-AXIS DIRECTION ON R1
$S_{1n}(\rho_n - h, \theta_n, X_{1n})$
$S'_{1n}(\rho_n - h - \Delta r, \theta_n, X'_{1n})$
S1
MEAS OPT-AXIS DIRECTION ON R2
$S_{2n}(\rho_n - h, \theta_n, X_{2n})$
$S'_{2n}(\rho_n - h - \Delta r, \theta_n, X'_{2n})$
S2
GRND LENS PERI & BEVEL
S3
CALC
S4
CHAMF R1 CORN
S5
CHAMF R2 CORN
S6
COMPL BUZ
S7
END

FIG. 8

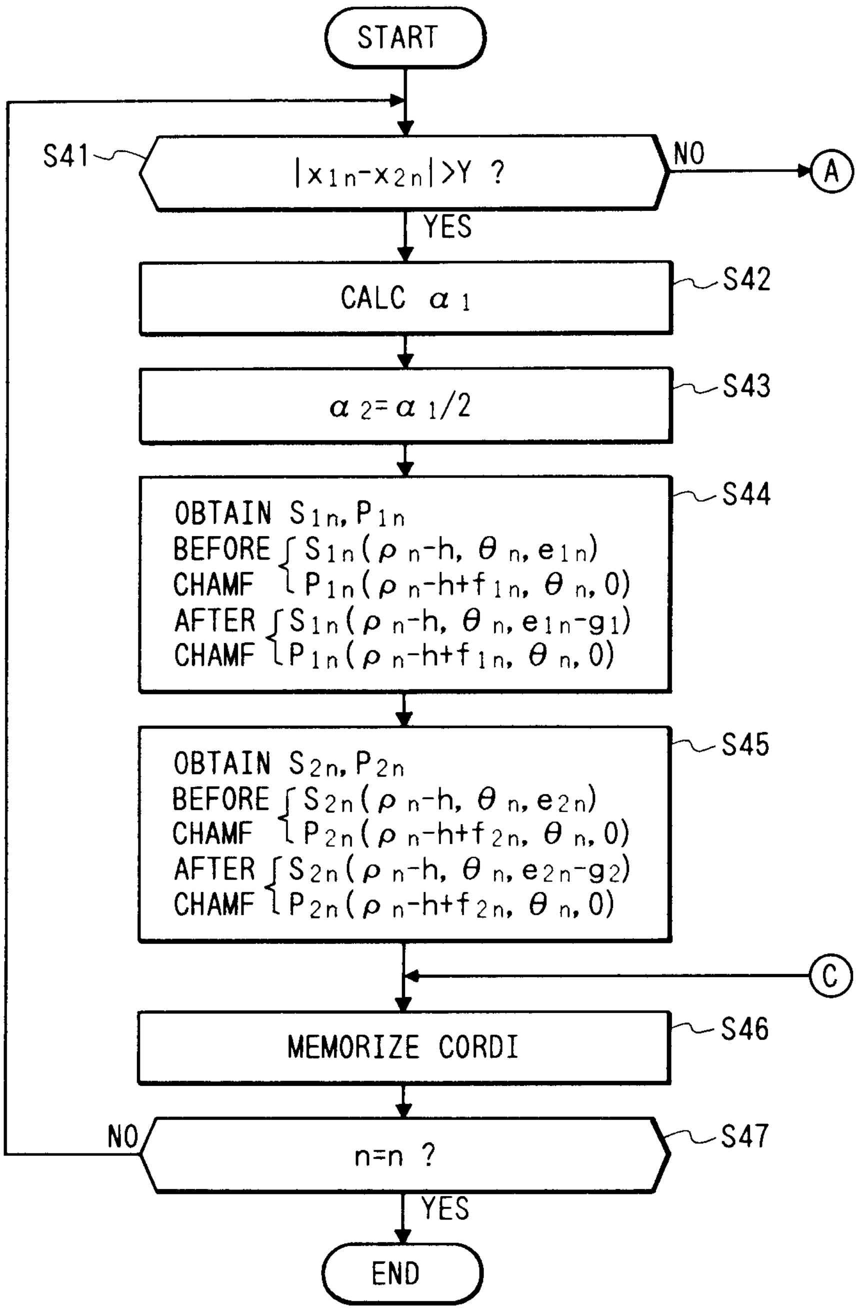

START
S41
|x1n-x2n|>Y ?
NO
A
YES
CALC α1
S42
α2=α1/2
S43
OBTAIN S1n, P1n
BEFORE CHAMF S1n(ρn-h, θn, e1n)
P1n(ρn-h+f1n, θn, 0)
AFTER CHAMF S1n(ρn-h, θn, e1n-g1)
P1n(ρn-h+f1n, θn, 0)
S44
OBTAIN S2n, P2n
BEFORE CHAMF S2n(ρn-h, θn, e2n)
P2n(ρn-h+f2n, θn, 0)
AFTER CHAMF S2n(ρn-h, θn, e2n-g2)
P2n(ρn-h+f2n, θn, 0)
S45
C
MEMORIZE CORDI
S46
NO
n=n ?
S47
YES
END

FIG. 9

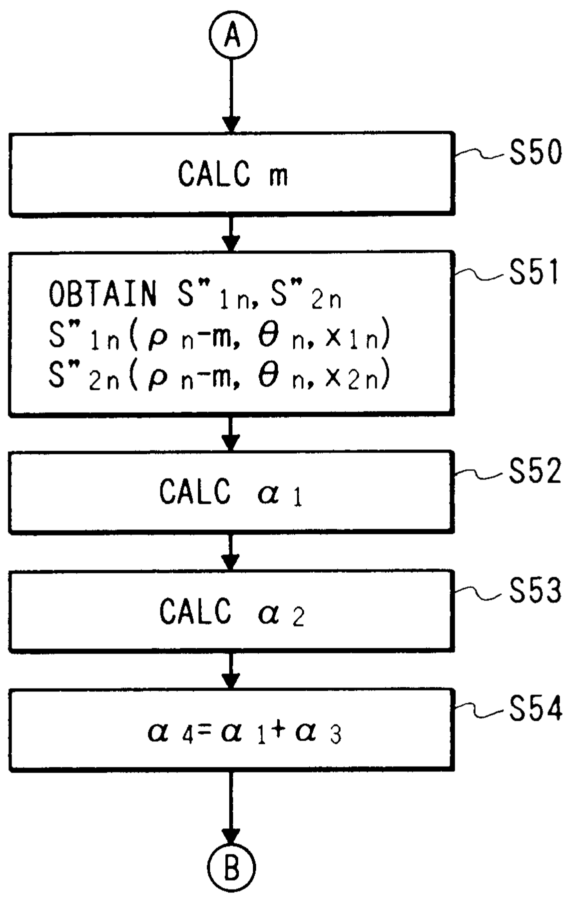

A
CALC m
S50
OBTAIN S"1n, S"2n
S"1n(ρn-m, θn, x1n)
S"2n(ρn-m, θn, x2n)
S51
CALC α1
S52
CALC α2
S53
α4=α1+α3
S54
B

FIG. 10

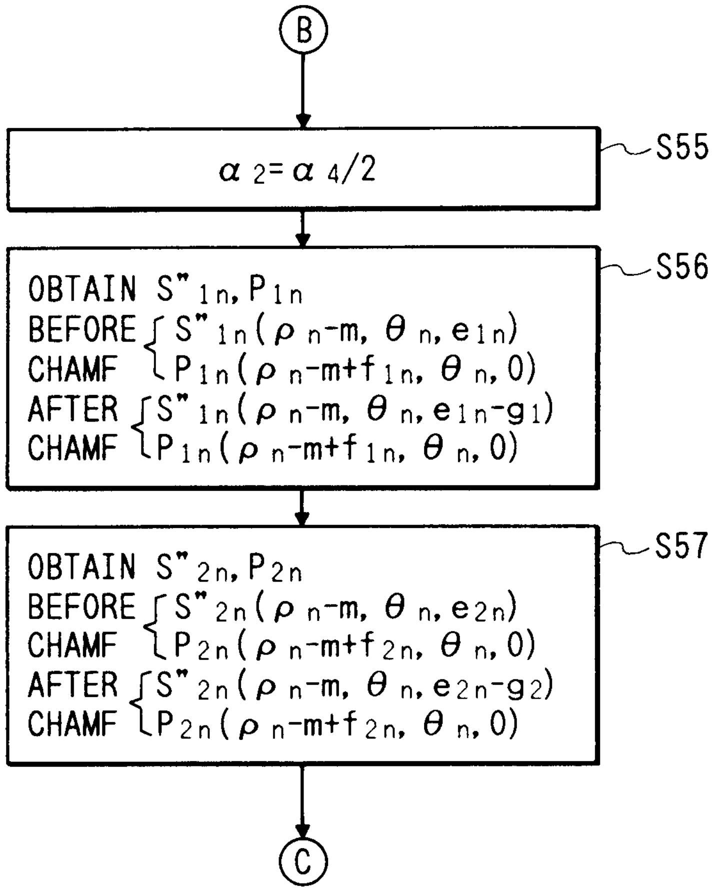

B
α2=α4/2
S55
OBTAIN S"1n, P1n
BEFORE CHAMF S"1n(ρn-m, θn, e1n)
P1n(ρn-m+f1n, θn, 0)
AFTER CHAMF S"1n(ρn-m, θn, e1n-g1)
P1n(ρn-m+f1n, θn, 0)
S56
OBTAIN S"2n, P2n
BEFORE CHAMF S"2n(ρn-m, θn, e2n)
P2n(ρn-m+f2n, θn, 0)
AFTER CHAMF S"2n(ρn-m, θn, e2n-g2)
P2n(ρn-m+f2n, θn, 0)
S57
C

FIG. 11A

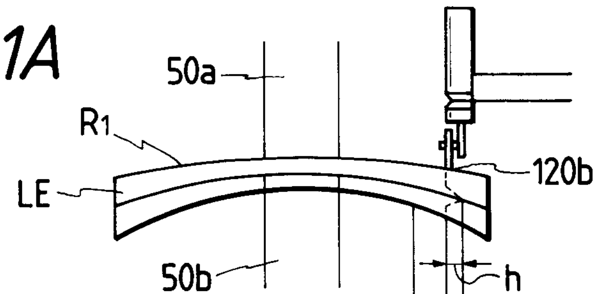


FIG. 11B

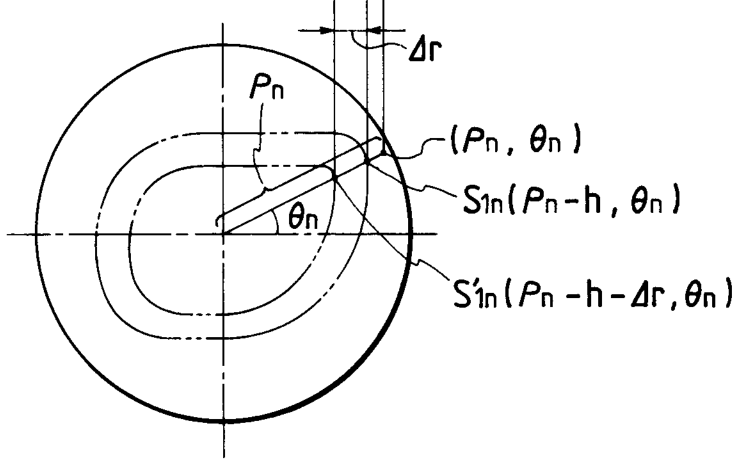


FIG. 11C

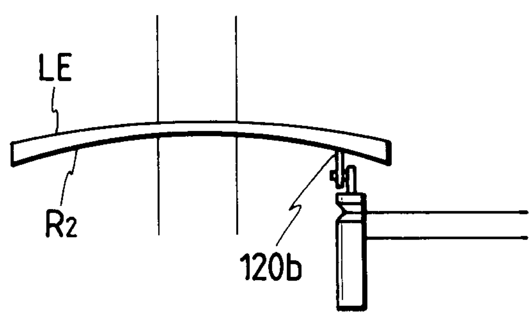


FIG. 12

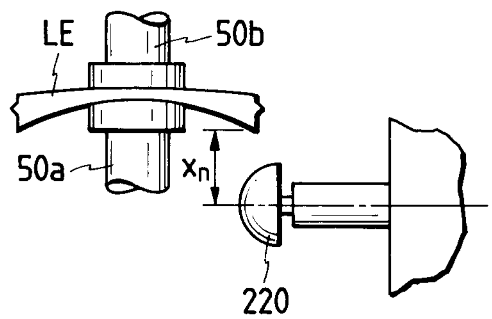


FIG. 13

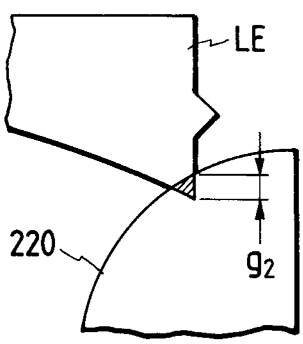


FIG. 14

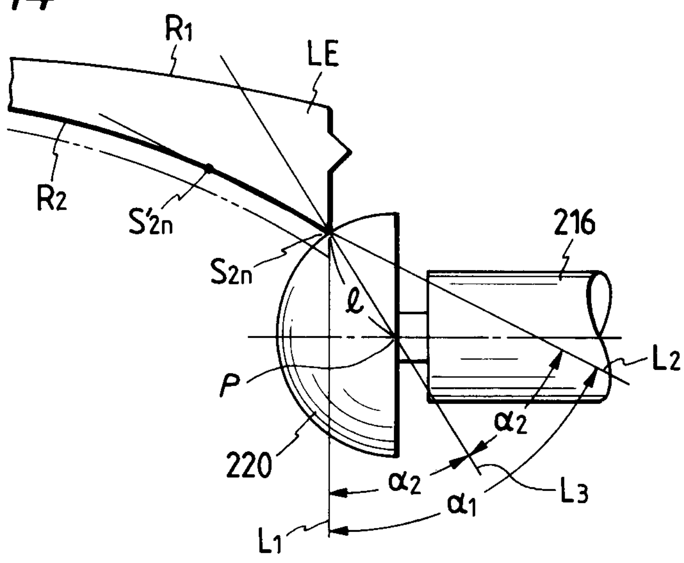


FIG. 15

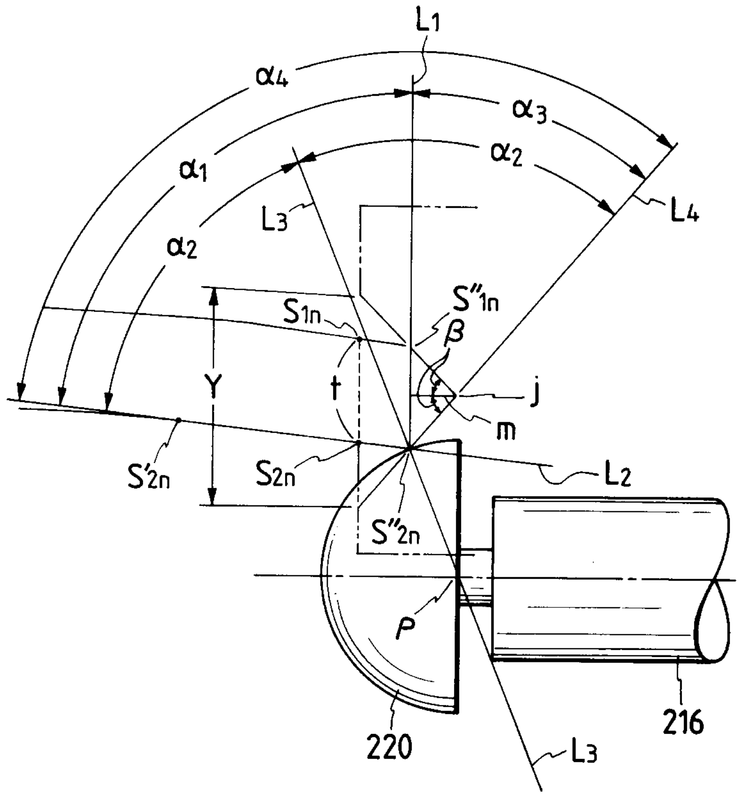


FIG. 16A

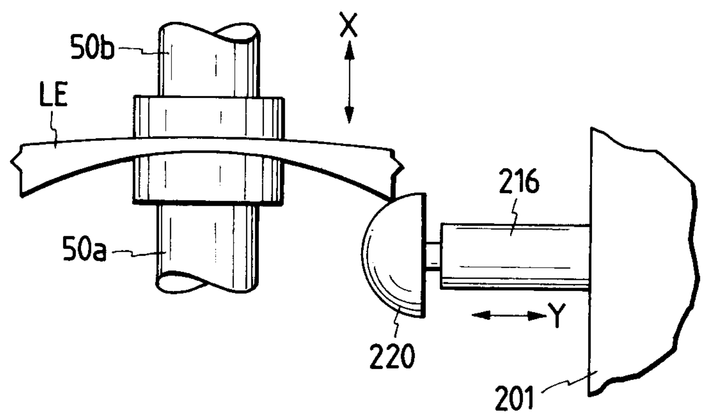


FIG. 16B

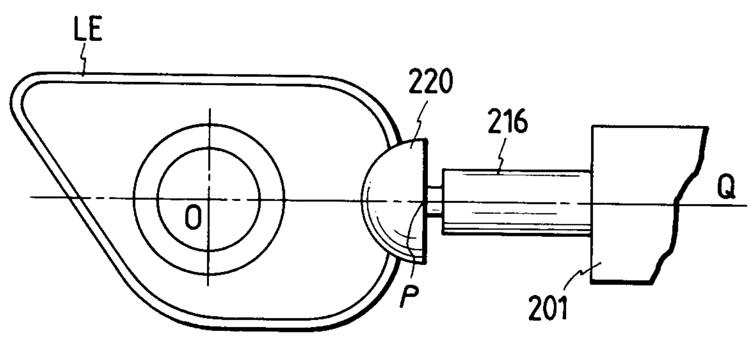


FIG. 17

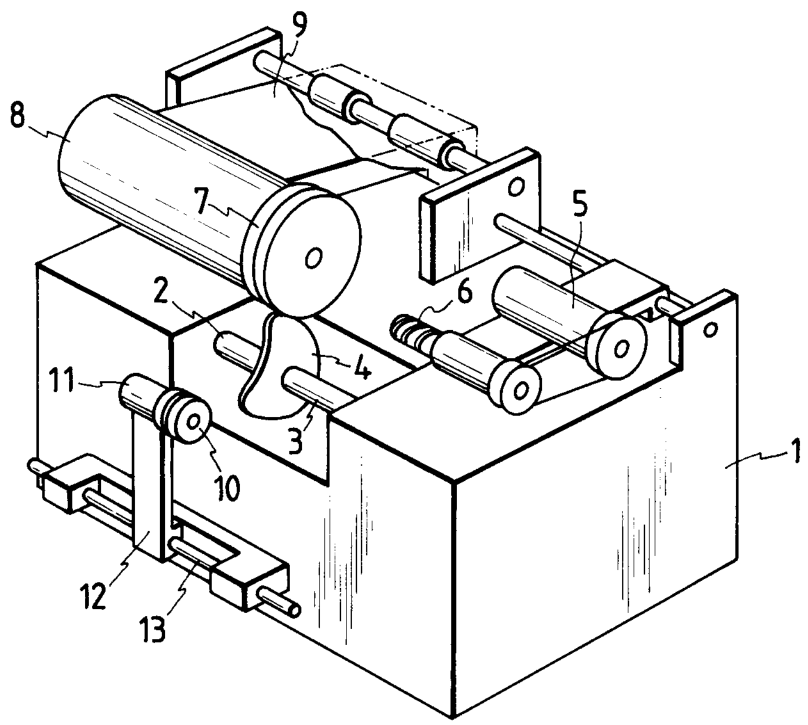
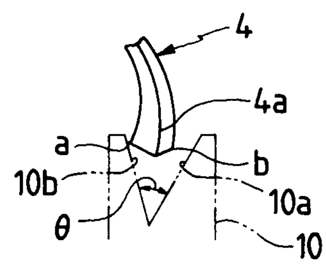


FIG. 18



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 10 6267

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X A	US-A-4 286 415 (LORETO) * column 5, line 43 - column 10, line 53; figures * ---	1 2,14	B24B9/14
A	US-A-4 912 880 (HADDOCK ET AL.) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B24B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07 AUGUST 1992	ESCHBACH D.P.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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