(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 433 114 A1**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **90403223.2**

(51) Int. Cl.[5]: **B24B 9/14**

(22) Date of filing: **14.11.90**

(30) Priority: **15.11.89 JP 296956/89**

(43) Date of publication of application:
19.06.91 Bulletin 91/25

(84) Designated Contracting States:
DE FR GB IT NL

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(54) **Method and apparatus for measuring the edge thickness of a spectacle lens.**

(57) The V-edge depth of the grinder for grinding the lens and the with of the grinding base are taken into account in the calculation of the all round vector information and the edge thickness of the spectacle lens.

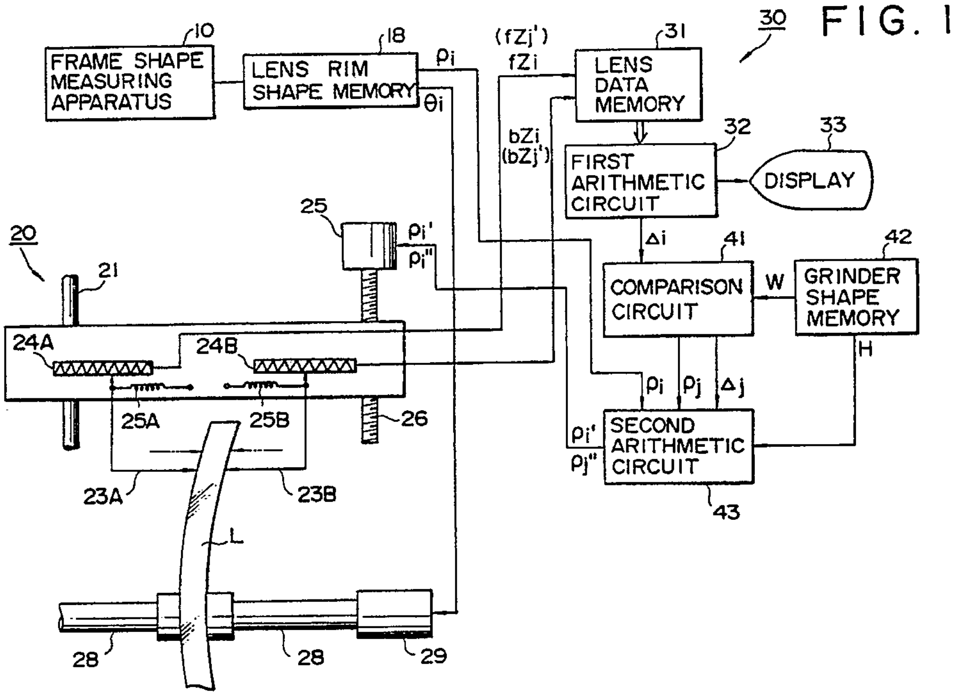

FIG. 1

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METHOD AND APPARATUS FOR MEASURING THE EDGE THICKNESS OF A SPECTACLE LENS

BACKGROUND OF THE INVENTION:

Field of the Invention

This invention relates to a method and an apparatus for measuring the edge thickness of a spectacle lens.

Description of the Prior Art:

An example of a conventional method and apparatus for measuring the edge thickness of a lens is in detail described in Japanese Patent Application No. SHO 60-115079 as a component of a lens grinding apparatus disclosed by the same applicant as in the present application.

This conventional apparatus for measuring the edge thickness is constituted such that the thickness can be measured based on the lens rim shape of the spectacle frame measured by the frame shape measuring device 10 as shown schematically in Fig. 6. The edge thickness measuring apparatus is shown as a block diagram in Fig. 7.

The frame shape measuring apparatus 10 has a symmetric rotator with hexagon-sectional shapes shaped feeler 11 mounted rotatably in the tip. The feeler 11 is connected with a feeler arm 12, which is rotatable about the axis of the perpendicular line As through the edge of contact 11a of the feeler 11, supported by a feeler supporting base 13. And the base 13 is mounted on the rail 14 turned round by a pulse motor 16 and movable by elasticity of a spring 15 fixed to another edge (not shown) of the rail 14. The pulse motor 16 can work by the pulse from a pulse generator 17.

When the edge of contact 11a of the feeler 11 is abutted on the V-edge groove Vf, the moving amount ρ_1 of the feeler 11 is detected by a detector 19 constituted of either an encoder or a position sensor. The detected moving amount ρ_1 is memorized in a lens rim shape memory 18 together with a supply pulse θ_1 to the pulse motor 16.

The moving amount ρ_i of the feeler and the rotational amount of the arm, i.e. the radius vector angle θ_i are memorized as a radius vector information (ρ_i, θ_i) (i = 0,1,2,3...N) of the lens rim F in the lens rim shape memory 18. The moving amount ρ_1 of the feeler is measured over the V-edge groove all around of the lens rim F.

As shown in Fig. 7, the edge thickness measuring apparatus comprises an edge thickness sensor portion 20 and an electric circuit portion 30. The sensor portion 20 includes a lens feeler supporting member 22, which is moved on the guide rail 21 by the driving of a feed screw 26. The screw 26 is rotated by the pulse motor 25. A material lens L is held between lens rotating shafts 28,28 and then the lens L is rotated by the rotation of the shafts 28,28 caused by the driving of the pulse motor 29. The lens feeler supporting member 22 includes lens feelers 23A,23B and detectors 24A,24B. The detectors 24A,24B are constituted of springs 25A,25B for pulling the lens feelers 23A,24B, and encoders or position sensors for detecting the moving amount of the feelers 23A,23B.

The pulse based on the length ρ_i of the radius vector of the radius vector information (ρ_i, θ_i) of the lens rim F is supplied into the pulse motor 25, and the feelers 23A,23B moves inside the lens feeler supporting member 22. This movement determines the position of the lens feelers 23A,23B at the point having the length ρ_i of the radius vector from the axis of rotation of the lens rotating shafts. The length ρ_i of the radius vector is memorized in the lens rim shape memory 18. On the other hand, the pulse based on the rotary angle (radius vector angle) θ_i is supplied to the pulse motor 29 and then the lens rotating shafts 28,28 are rotated. This rotation of the shafts 28,28 produces the rotation of the material lens L by the rotary angle θ_i from the reference position. The lens feeler 23A is moved by the elasticity of the spring 25A and then abutted on the front side refraction surface LF of the material lens L. The moving amount ${}_fZ_i$ is detected by the detector 24A and memorized in a lens data memory 31. In the same way, the lens feeler 23B is moved by the elasticity of the spring 25B and then abutted on the back side refraction surface LB and the moving amount ${}_bZ_i$ is detected by the detector 24B and memorized in a lens data memory 31. This detection is carried out as to all the radius vector informations (ρ_i, θ_i) (i = 0,1,2,3,...N), and the front side refraction surface position information (${}_fZ_i$, θ_i) and the back side refraction surface position information (${}_bZ_i$, θ_i) (i = 0,1,2,3,...N) on the radius vector shaped locus (ρ_i, θ_i) of the lens rim are memorized in the lens data memory 31.

A first arithmetic circuit 32 of an electric circuit portion 30 mounted in the edge thickness sensor portion

20 calculates the edge thickness information (Δ_i, θ_i) (i=0,1,2,3,...N) of the lens L on the radius vector shaped locus (ρ_i, θ_i) based on the front side refraction position information (${}_fZ_i$, θ_i) and the back side refraction position information (${}_bZ_i$, θ_i). Furthermore, the maximum edge thickness Δ_{max} and the minimum edge thickness Δ_{min} are counted up from the edge thickness information (Δ_i, θ_i), and a beveled V-edge (groove) apex position information (${}_kZ_i$, ρ_i, θ_i) (i=0,1,2,3,...N) to form a V-edge in the edge surface of the lens is automatically calculated based on the two values Δ_{max} and Δ_{min}. In the above mentioned way, the lens L is automatically ground. And formed is a configuration that the sectional shape of the lens L is graphically displayed on a display 33.

As shown in Fig. 7, the positions of the contact of the lens feelers 23A,23B with the lens L is taken on the tangent line Q through the V-edge apex Y formed in the V-edge grinding of the lens. And the edge thickness Δ_i on the tangent line Q is calculated by the first arithmetic circuit 32.

The radius of curvature R of the front surface of the lens L is different from that of the back(rear)-surface, and the edge thickness of the base B of the edge surface of the lens L to form a V-edge is exactly Δ_i'. Therefore the calculation of the treated V-edge apex position information (${}_kZ_i$, ρ_i, θ_i) not based on the edge thickness Δ_i' of the base B is inaccurate.

And thus, the positions of the lens feelers 23A,23B are moved to those of 23A′,23B′ when the edge thickness is measured, as shown in Fig. 8. More detailedly, the positions of the lens feelers 23A,23B on the radius vector locus (ρ_i, θ_i) is moved to the positions $\rho_i' = \rho_i - H_H$ where ρ_i is the length of the radius vector and H is the depth (or height) of the peripheral ridge, because the V-edge groove bottom YG and the base YB of the V-edge grinder G of a lens grinding apparatus are a ready known. By this movement, measured is the edge thickness of the base B of the edge surface formed in the lens L at the time when the lens L is ground with the V-edge grinder G. And V-edge apex position information (${}_kZ_i$, ρ_i, θ_i) is calculated based on the edge thickness Δ_i' when the lens is ground with the grinder G. As shown in Fig. 9, however, there is a problem that the V-edge (V-ridge) formed actually on the lens L is an inadequate V-edge in case the edge thickness is smaller than the width (W) of V-edge groove of the grinder G, because the edge surface K of the lens L to grind actually is displaced from the position of the measured edge surface KM owing to the difference between the radius of curvature R_f of the front surface of the lens L and the radius of curvature R_b of the back surface, in case even if the V-edge apex position information (${}_kZ_i$, ρ_i, θ_i) is obtained based on the edge thickness Δ_i' measured by the above method such that the V-edge apex Y is formed at the point where the edge thickness is divided in the ratio of one to one, for example.

SUMMARY OF THE INVENTION

The first means of the present invention is characterized in the following six steps for resolving the above mentioned problem.

The first step is an input of the all round radius vector information (ρ_i, θ_i) of the spectacle frame lens rim for framing the lens to grind. The second step is the obtainment of the all round measuring vector radius information (ρ_i', θ_i) by subtracting the V-edge depth (H) of the grinder for grinding the above lens from the length (ρ_i) of the radius vector of the all round radius vector information (ρ_i, θ_i) in the first step. The third step is the measurement of the edge thickness (Δ_i) of the lens over the all round of the radius vector locus of the lens rim based on the all round measuring radius vector information (ρ_j', θ_j) (j≦i) for measuring narrower edge thickness (Δ_j) than the width (W) of the grinding base by comparing the width (W) of the grinding base of the grinder with the edge thickness measured in the third step. The fifth step is the obtaining of the length (ρ_j'') of the re-measuring radius vector of the partial re-measuring radius vector information (ρ_j'', θ_j) (with j≦i) by the following formula:

$$\rho_J'' = \rho_J' + d_J$$

$$d_J = \left(1 - \frac{\Delta_J}{W}\right) \cdot H$$

$$(\text{with } j \leqq i)$$

And the sixth step is the partial re-measurement of the edge thickness of the lens based on the part re-measuring radius vector information (ρ_j'', θ_j).

The second means of the present invention is characterized in the following five steps.

The first step is the input of the radius vector information (ρ_i, θ_i) of the spectacle frame lens rim for framing the lens. The second step is the obtaining of the measuring radius vector information (ρ_i', θ_i) by subtracting the V-edge depth (H) of the grinder for grinding the lens in the first step from the length (ρ_i) of the radius vector of the radius vector information (ρ_i, θ_i) in the first step. The third step is the successive measurement of the edge thickness of the lens based on the measuring radius vector information (ρ_i', θ_i). The fourth step is the obtaining of the edge thickness of the lens by comparing the width (W) of the grinding base of the grinder with the edge thickness (Δ_i) measured in the third step. In case the measured edge thickness (Δ_j) of the j-th (in the order of) measuring radius vector information (ρ_i', θ_i) is narrower than the width (W) of the grinding base, the edge thickness (Δ_{j+1}) of the lens is measured by the compensated measuring radius vector information (τ_{j+1}, θ_{j+1}) obtained by the following formulas:

$$\tau_{j+1} = \rho_{j+1}' + t_1$$

$$t_1 = \left(1 - \frac{\Delta_j}{W}\right) \cdot H$$

where τ_{j+1} is the compensated radius vector length and ρ_{j+1} is the measured radius vector length (j+1)th in order from the grinding depth (II) of the grinder. An the fifth step is the sequent measurement of the edge thickness (Δ_{j+m}) (with m=2,3,4,...M, M<N) in case of the narrower measured edge thickness (Δ_{j+1}) than the preceding measured edge thickness (Δ_j). That is, if it has proved that the measured edge thickness (Δ_{j+1}) is narrower than the measured edge thickness (Δ_j) measured immediately before the thickness (Δ_{j+1}), the compensated measuring radius vector information (τ_{j+m}, θ_{j+m}) is first obtained by the following formulas:

$$\tau_{j+m} = \rho_{j+m}' + t_m$$

$$t_m = \Sigma\left(1 - \frac{\Delta_{j+m}}{\Delta_{j+m-1}}\right) \cdot H$$

where (τ_{j+m}) is the compensated radius vector length, (ρ_{j+m}') is the measured radius vector length for the succeeding measuring radius vector information (ρ_{j+m}', θ_{j+m}) (with m=2,3,4,...M,M < N), and H is the V-edge depth of the grinder. And then the edge thickness (Δ_{j+m}) of the lens is successively measured based on the measuring radius vector information (τ_{j+m}, θ_{j+m}) until the measured edge thickness (Δ_{j+m-1}) just before the thickness (Δ_{j+m}) has a wider width than the width (W) of the grinding base.

The third means of the present invention is characterized in the following means. A first means is an input means for inputting the all round radius vector information (ρ_i, θ_i) of the spectacle frame lens rim for framing the lens. A second means is an arithmetic means for obtaining the all round measuring radius vector information (ρ_i', θ_i) by subtracting the V-edge depth (H) of the grinder for grinding the lens from the length (ρ_i) of the radius vector of the all round radius vector information (ρ_i, θ_i). This arithmetic means is constituted such that the length (ρ_j'') of re-measuring radius vector of the partial re-measuring radius vector information (ρ_j'', θ_j) (with j≦i) is obtained by the following formula:

$$\rho_j'' = \rho_j' + d_j$$

$$d_j = \left(1 - \frac{\Delta_j}{W}\right) \cdot H$$

$$(\text{with } j \leqq i)$$

A third means is an edge thickness measuring means for measuring the edge thickness (Δ_i) of the lens over the all round of the radius vector locus of the lens rim based on the all round measuring radius vector information (ρ_i', θ_i). This edge thickness measuring means is constituted such that the edge thickness of the lens is measured again and partly based on the partial re-measuring radius vector information (ρ_j'', θ_j). A fourth means is a memory means for memorizing the width (W) of the grinding base of the grinder beforehand. A fifth means is a comparison means for comparing the width (W) of the grinding base with the measured edge thickness (Δ_i) and obtaining the partial measuring radius vector information (ρ_j', θ_j) (with j≦i) for the edge thickness (Δ_j) narrower than the width (W) of the grinding base.

The fourth means of the present invention is characterized in the following means and constitutions. A first means is an input means for inputting the radius information (ρ_i, θ_i) of the spectacle frame lens rim for framing the lens. A second means is an arithmetic means for obtaining the measuring radius vector information (ρ_i', θ_i) by subtracting the V-edge height (H) of the grinder for grinding the lens from the radius vector length (ρ_i) of the radius vector information. A third means is an edge thickness measuring means for successively measuring the edge thickness of the lens over the radius vector locus of the lens based on the measuring radius vector information (ρ_i', θ_i). A fourth means is a memory means for memorizing the width (W) of the V-edge of the grinder beforehand. A fifth means is a comparison means for in order comparing the measured edge thickness (Δ_i) with the width (W) of the grinding base. If the comparison means judges that the measured edge thickness (Δ_j) of the j-th (in the order of) measuring radius vector information (ρ_j', θ_j) is narrower than the width (W) of the grinding base, the arithmetic means if constituted such that the compensated measuring radius vector is obtained by the following formulas:

$$\tau_{j+1} = \rho_{j+1}' + t_1$$

$$t_1 = \left(1 - \frac{\Delta_j}{W}\right) \cdot H$$

where (τ_{j+1}) is the compensated radius vector length, and (ρ_{j+1}) is the (Δ_{j+1}) th measuring radius vector length. The edge thickness measuring means measures the edge thickness (Δ_{j+1}) of the lens based on the compensated measuring radius vector information (τ_{j+1}, θ_{j+1}). And if the comparison means has judged that the measured edge thickness (Δ_{j+1}) is narrower than the thickness (Δ_j) measured immediately before the thickness (Δ_{j+1}), the arithmetic means obtains the compensated measuring radius vector information (τ_{j+m}, $_{j+m}$) by the following formulas:

$$\tau_{j+m} = \rho_{j+m}' + t_m$$

$$t_m = \Sigma \left(1 - \frac{\Delta_{j+m}}{\Delta_{j+m}}\right) \cdot H$$

where (τ_{j+m}) is the compensated radius vector length (ρ_{j+m}') is the measured radius vector length of the succeeding radius vector information (ρ_{j+m}', θ_{j+m}) (with m = 2,3,4,...M, M<N), and H is the V-edge height of the grinder. And the edge thickness measuring means measures the edge thickness (Δ_{j+m}) of the lens based on the compensated measuring radius vector information (τ_{j+m}, θ_{j+m}) until the measured edge thickness (Δ_{j+m-1}) immediately before the thickness (Δ_{j+m}) is wider than the width (W) of the grinding base.

These and other objects, features and advantages of the present invention will be well appreciated upon reading of the following description of the invention when taken in conjunction with the attached drawings with understanding that some modifications, variations and changes of the same could be made by the skilled person in the art to which the invention pertains without departing from the spirit of the invention or the scope of claims appended hereto.

BRIEF DESCRIPTION OF THE ATTACHED DRAWINGS

Fig. 1 is a block diagram showing an embodiment of an edge thickness measuring apparatus according to the present invention;

Fig. 2 is a partly diagrammatic sectional view showing a measuring radius vector, a partial re-measuring radius vector, a lens feeler, and a relation between a measured edge thickness and a grinder's shape, each for describing a first embodiment of an edge measuring method according to the present invention;

Figs. 3A and 3B are schematic illustrations showing a measuring radius vector, and a relation among the partial re-measuring radius vector and the measured radius vector locus and the partial re-measured radius vector locus, each for explaining the first embodiment of a edge thickness measuring method;

Fig. 4 is a schematic illustration showing the measuring radius vector, and a relation among the compensated measuring radius vector and the measured radius vector locus and the compensated measured radius vector locus, each for explaining the second embodiment of an edge thickness measuring method;

Fig. 5 is a schematic illustration showing the compensated measured points and the lens feeler at the points, and a relation between the measured edge thickness and the shape of the grinder, each for explaining the second embodiment of an edge thickness measuring method;

Fig. 6 is a block diagram showing a constitution of a conventional frame shape measuring apparatus;

Fig. 7 is a block diagram showing a constitution of a conventional edge thickness measuring apparatus;

Fig. 8 is a schematic illustration showing the measuring radius vector and the lens feeler, and a relation between the measured edge thickness and the shape of the grinder for explaining a conventional edge thickness measuring method;

Fig. 9 is a schematic diagram showing a relation between the measured edge thickness and the edge shape ground by the grinder according to a conventional edge thickness measuring method.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the present invention will be described hereinafter with reference to the accompanying drawings.

Fig. 1 is a block diagram showing a constitution of the embodiment of the edge thickness measuring apparatus according to the present invention. In this embodiment, employed are the identical characters to the same of similar components as the components in the conventional edge thickness measuring apparatus (mentioned above) disclosed in Japanese Patent Application No. SHO 60-115079, in order to avoid duplication of the explanation. A first arithmetic circuit 32 in Fig. 1 calculates an edge thickness information (Δ_i, θ_i) from a front and back surface position informations ($_fZ_i$, θ_i), ($_bZ_i$, θ_i) of a material lens L as a lens to grind which is detected by detectors 24A,24B. This first arithmetic circuit 32 also connects with a comparison circuit 41. The comparison circuit 41 connects with a grinder shape memory 42 which keeps memorizing an already-known V-edge base width W and a V-edge height H.

The second arithmetic circuit 43 connects with a lens rim shape memory 18 of a frame shape measuring apparatus 10, the comparison circuit 41, and the grinder shape memory 42. The lens rim shape memory 18 memorizes the all round radius vector information (hereinafter referred to as radius vector information, for brevity) (ρ_i, θ_i) (with i - 0,1,2,3,...N) can be identical with a value measured by the frame shape measuring apparatus 10 such as the conventional apparatus disclosed in Japanese Patent Publication No. SHO 60-115079, or with data memorized in a memory means such as a floppy disk or an IC card, or with data from a framemaker or the agent by the on-line information processing system.

The length ρ_i of the radius vector of the radius vector information (ρ_i, θ_i) (with i = 0,1,2,3,...N) of the lens rim from the lens rim shape memory 18 is input in a second arithmetic circuit 43, which subtracts the V-edge height H memorized in the grinder shape memory 42 from the length ρ_i and obtains, as shown in Fig. 2, the length ρ_i' of the measuring radius vector of the all round measuring radius vector information (hereinafter referred to as measuring radius vector information) (ρ_i', θ_i) by the following formula:

$\rho_i' = \rho_i - H$ (1)

The memory 18 and the second arithmetic circuit 43 act as an input means and an arithmetic means, respectively.

The length (ρ_i') obtained is input in a pulse motor 29. The pulse motors 25,29 are driven and controlled by the second arithmetic circuit 43, corresponding to the measuring radius vector information (ρ_i', θ_i). The driving of the pulse motors 25,29 makes the lens feelers 23A,23B move to position them (23A,23B) at the measuring point ρ_i (as shown in Figs. 3A,3B). The feelers 23A,23B positioned there abut on the lens L by elasticity of the springs 25A,25B.

The moving amount of the lens feelers 23A,23B is detected in terms of the front and back surface position informations ($_fZ_i$, θ_i), ($_bZ_i$, θ_i) of the lens L by the detectors 24A,24B. And then, as shown in Figs. 3A,3B, the first arithmetic circuit 32 calculates the Δ_i of the edge thickness information (Δ_i, θ_i) of the lens L at the measuring point i on the basis of the information ($_fZ_i$, θ_i), ($_bZ_i$, θ_i) as follows:

$\Delta_i = {_bZ_i} - {_fZ_i}$ (2)

The measurement of the edge thickness is carried out over the all round of the radius vector locus S to be measured, that is, all of the measuring points from the 0-th measuring point to the N-th measuring point. The first arithmetic circuit 32 acts as an edge thickness measuring means.

The edge thickness information (Δ_i, θ_i) (with i = 0,1,2,3,...N) calculated by the first arithmetic circuit 32 is compared with the width (W) of the V-edge base of the V-edge grinder G memorized in the grinder shape memory 42 by the comparison circuit 41. And selected is a measuring radius vector having an edge thickness narrower than the width W. The grinder shape memory 42 acts as a memorizing means and the comparison circuit 41 acts as a comparing means.

Fig. 3A shows the lens L as a minus lens. In this case, selected are a partial measuring radius vector information (Δ_j', θ_j) (with j= a,a+1,a+2,...b-1,b) which defines the partial measuring locus S_1 of measuring points P_a and P_b, and a partial measuring radius vector information (ρ_j', θ_j) (with j=c,c+1,c+2,...d-1,d) which defines the partial measuring locus S_2 of a measuring points P_c and P_d.

Fig. 3B shows the lens L as a plus lens. In this case, selected are a partial measuring radius vector information (ρ_j', θ_j) (with j=c,c+1,c+2,...d-1,d) which defines a partial measuring locus S_2 of measuring points P_c and P_d, and a partial measuring radius vector information (ρ_j', θ_j) (with j=g,g+1,g+2,...h-1,h) which defines a partial measuring locus S_4 of measuring points P_s and P_h. And these measuring radius vector lengths ρ_j' and edge thicknesses Δ_j are input into the second arithmetic circuit 43.

Referring to Fig. 2, if the edge thickness Δ_j is approximately equal to the edge thicknesses Δ_j', the proportion of H to W is:

$H : W = (H-d_j) : \Delta_j$ (3)

where H is a V-edge height and W is a V-edge base width of a V-edge grinder G and d_j is a compensated amount. And therefore, the amount d_j is:

$$d_J = \left(1 - \frac{\Delta_J}{W}\right) \cdot H \quad \cdots\cdots (4)$$

The second arithmetic circuit 43 obtains the length ρ_j'' of a re-measuring radius vector of the partial re-measuring radius vector information (ρ_j'', θ_j) by employing the length ρ_j' and the above amount d_j as follows:

$\rho_j'' = \rho_j' + d_j$ (5)

And then the second circuit 43 inputs the re-measuring radius vector length ρ_j'' to the pulse motor 25 and the re-measuring radius vector angle θ_j to the pulse motor 29. The pulse motors 25,29 driven and controlled based on these inputs move the lens feelers 23A and 23B to the positions 23A', 23B' as shown in Fig. 2. By this movement, the lens feelers 23A and 23B measure the front and back surface position informations ($_fZ_j'$, θ_j), ($_bZ_j'$, θ_j) of the lens L on the partial re-measuring loci S_1' through S_4' as shown in Figs. 3A and 3B.

After the measurement of the informations, the calculation of the V-edge apex position, the display of the image, the determination of the radius vector for grinding, and the grinding are each carried out in the circuit (not shown), as disclosed in the above mentioned Japanese Patent Application No. SHO 60-115079.

Figs. 4 and 5 are schematic illustration showing another edge thickness measuring method with the above mentioned edge thickness measuring apparatus.

First, all kinds of the length of the radius vector of the radius vector information (ρ_i, θ_i) (with i=0,1,2,...N) from the lens rim shape memory 18 are input to the second arithmetic circuit 43. The second circuit 43 obtains the measuring radius vector information (ρ_i', θ_i) (with i=0,1,2,...N) by the formula (1), that is, by subtracting the V-edge height memorized in the grinder shape memory from all (ρ_i) s.

Second, the second arithmetic circuit 43 inputs the 0-th measuring radius vector ($\rho_\emptyset'$) in the pulse motor 25 and the 0-th radius vector angle ($\theta_\emptyset$). The driving of the pulse motors 25,29 makes the lens feelers 23A,23B move to the measuring point $P_\emptyset$ (see Figs. 3A and 3B). The lens feelers 23A,23B at the point P abut on the lens L by elasticity of the springs 25A,25B. The moving amount of the lens feelers 23A,23B are detected as the 0-th front surface position information ($_fZ_\emptyset$, $\theta_\emptyset$) and the 0-th back surface position information ($_bZ_\emptyset$, $\theta_\emptyset$) of the lens L by the detectors 24A,24B. The first arithmetic circuit 32 calculates the $\Delta_\emptyset$ of the 0-th edge thickness information ($\Delta_\emptyset$, $\theta_\emptyset$) at the 0-th measuring point $P_\emptyset$ from the informations ($_fZ_\emptyset$, $\theta_\emptyset$), ($_bZ_\emptyset$, $\theta_\emptyset$). The calculation is performed by the following formula similar to the (2) :

$\Delta_\emptyset = {}_bZ_\emptyset - {}_fZ_\emptyset$ (2')

And then, the 0-th edge thickness information ($\Delta_\emptyset$, $\theta_\emptyset$) calculated by the first circuit 32 is compared with the V-edge base width W of the V-edge grinder G memorized in the grinder shape memory 42.

The 0-th edge thickness $\Delta_\emptyset$ is broader than the V-edge base width W in the example of Fig. 4. Therefore, the second arithmetic circuit 43 inputs the length ρ_i' of the 1st measuring radius, vectorwhich follows the 0-th thickness into the pulse motor 25 and the first radius vector angle θ_1, into the pulse motor 29. And the lens feelers 23A,23B are moved to and placed at the first measuring position P1.

The moving amounts of the lens feelers 23A,23B are detected in terms of the first front surface position information ($_fZ_1$, θ_1) and the first back surface position information ($_bZ_1$, θ_1) of the lens L by the detectors 24A,24B. And the first arithmetic circuit 32 calculates the Δ_1 of the first edge thickness information (Δ_1, θ_1)

at the first measuring point P_1 from the information $({}_fZ_1, \theta_1)$, $({}_bZ_1, \theta_1)$ the same as (2').

Next, the first edge thickness information (Δ_1, θ_1) calculated by the first arithmetic circuit 32 is compared with the V-edge base width W of the V-edge grinder G memorized in the grinder shape memory 42 by the comparison circuit 41. The first edge thickness Δ_1 is broader than the V-edge base width W in the example of Fig. 4. The same procedures are in order followed to the j-th measuring radius vector information (ρ_j', θ_j) judged that the edge thickness Δ_j is narrower than the V-edge base width W. If the comparison circuit 41 judges that the j-th edge thickness Δ_j in the j-th measuring radius vector information (ρ_j', θ_j) is narrower than the V-edge base width W as shown in Fig. 5(a), the second arithmetic circuit 43 changes the length ρ_{j+1}' of the (j+1)th measuring radius vector of the (j+1)th measuring radius vector information $(\rho_{j+1}, \theta_{j+1})$ into the first compensated radius vector length τ_{j+1} as shown in Fig. 4.

The first compensated amount t_1 is obtained the same as the formula (4):

$$t_1 = \left(1 - \frac{\Delta_j}{W}\right) \cdot H \; .... (6)$$

where W is the width of the V-edge base of the V-edge grinder G and H is the V-edge height. And the first compensated radius vector length τ_{j+1} is :

$\tau_{j+1} = \rho_{j+1}' + t_1$ (7)

The second arithmetic circuit 43 inputs the first compensated radius vector length τ_{j+1} into the pulse motor 25 and the first compensated radius vector angle θ_{j+1} (equivalent to the (j+i)th measuring radius vector angle θ_{j+1}) into the pulse motor 29. And the lens feelers 23A and 23B are moved to the position of the first compensated measuring point T_{j+1} in Figs. 4 and 5(b) based on these inputs.

And then the first arithmetic circuit 32 obtains the j+1 edge thickness Δ_{j+1} from the front and back surface position informations of the lens L at the first compensated measuring point T_{j+1}. The comparison circuit 41 compares the (j+1)th edge thickness Δ_{j+1} with the j-th edge thickness Δ_j preceding to Δ_{j+1}.

If the (j+1)th edge thickness Δ_{j+1} is narrower than the j-th edge thickness Δ_j just before the Δ_{j+1} as shown in Fig. 5(b), the second arithmetic circuit 43 changes the following (j+2)th measuring radius vector length ρ_{j+2}' of the (j+2)th measuring radius vector information $(\rho_{j+2}', \theta_{j+2})$ into the second compensated radius vector length τ_{j+2} as shown in Fig. 4.

Therefore, the second compensated amount t_2 is obtained the same as the formula (6). That is :

$$t_2 = \left(1 - \frac{\Delta_{j+1}}{\Delta_j}\right) \cdot H \; ...... (8)$$

and the second compensated radius vector length τ_{j+2} is:

$\tau_{j+2} = \rho_{j+2}' + (t_1 + t_2)$ (9)

The second arithmetic circuit 43 inputs the second compensated radius vector length τ_{j+2} into the pulse motor 25 and the second compensated radius vector angle θ_{j+2} (equivalent to the (j+2)th measuring radius vector angle θ_{j+2}) into the pulse motor29, respectively. The lens feelers 23A,23B move to the second compensated measuring point T_{j+2} shown in Fig. 4 and Fig. 5(c) based on these inputs.

After the measurement of the front and back surface position informations of the lens L at the second compensated measuring point T_{j+2}, the first arithmetic circuit 32 obtains the (j+2)th edge thickness Δ_{j+2}. The comparison circuit 41 compares the (j+2)th edge thickness Δ_{j+2} with the (j+1)th edge thickness preceding to the (j+2)th thickness.

If the (j+2)th edge thickness Δ_{j+2} is narrower than the preceding (j+1)th edge thickness as shown in Fig. 5(c), the second arithmetic circuit 43 changes the following (j+3)th measuring radius vector length ρ_{j+3}' of the (j+3)th measuring radius vector information $(\rho_{j+3}', \theta_{j+3})$ into the third compensated radius vector length τ_{j+3}.

And the third compensated amount t_3 is obtained the same as in the formula (6). That is :

$$t_3 = \left(1 - \frac{\Delta_{j+2}}{\Delta_{j+1}}\right) \cdot H \; .... (10)$$

where H is the V-edge height of the V-edge grinder G and the Δ_{j+2}, Δ_{j+1} are the edge thicknesses. And the third compensated radius vector length τ_{h+3} is :

$\tau_{j+3} = \rho_{j+3}' + (t_1 + t_2 + t_3)$ (11)

The second arithmetic circuit 43 inputs the third compensated radius vector length τ_{j+3} into the pulse motor 25 and the third compensated radius vector angle θ_{j+3} (equivalent to the (j+3)th measuring radius vector angle θ_{j+3}) into the pulse motor29, respectively. And then the lens feelers 23A,23B are moved to the third compensated measuring point T_{j+3} as shown in Figs. 4 and 5(d). And then the lens feelers 23A,23B are moved to the third compensated measuring point T_{j+3} as shown in Figs. 4 and 5(d).

The front and back surface position information s of the lens L as the third compensated measuring point T_{j+3} are measured, and then the first arithmetic circuit 32 calculates the (j+3)th edge thickness Δ_{j+3}. And the comparison circuit 41 compares the (j+3)th edge thickness Δ_{j+3} with the preceding (j+2)th edge thickness Δ_{j+2}.

If the (j+3)th edge thickness Δ_{j+3} is broader than the preceding (j+2)th edge thickness and narrower than the V-edge base width W of the V-edge grinder as shown in Fig. 5(d), the second arithmetic circuit 43 changes the following (j+4)th measuring radius vector length ρ_{j+4}' of the (j+4) measuring radius vector information (ρ_{j+4}', θ_{j+4}) into the fourth compensated radius vector length τ_{j+4} as shown in Fig. 4.

And the fourth compensated amount t_4 is obtained the same as in the formula (6). That is :

$$t_4 = \left(1 - \frac{\Delta_{j+3}}{\Delta_{j+2}}\right) \cdot H \quad \ldots\ldots\ (12)$$

where H is the V-edge height of the V-edge grinder G and the Δ_{j+3}, Δ_{j+3} are the edge thicknesses. And the fourth compensated radius vector length τ_{j+4} is :

$\tau_{j+4} = \rho_{j+4}' + (t_1 + t_2 + t_3 + t_4)$ (13)

where t_4 is the negative number.

The second arithmetic circuit 43 inputs the fourth compensated radius vector length τ_{j+4} into the pulse motor 25 and the fourth compensated radius vector angle θ_{j+4} (equivalent to the (j+4)th measuring radius vector angle θ_{j+4}) into the pulse motor29, respectively. And then the lens feelers 23A,23B are moved to the fourth compensated measuring point T_{j+4} as shown in Figs. 4 and 5(e).

The front and back surface position information s of the lens L as the fourth compensated measuring point T_{j+4} are measured,and then the first arithmetic circuit 32 calculates the (j+4)th edge thickness Δ_{j+4}.

And the comparison circuit 41 compares the (j+4)th edge thickness Δ_{j+4} with the preceding (j+3)th edge thickness Δ_{j+3}.

If the (j+4)th edge thickness Δ_{j+4} is equal to or broader than the V-edge base width W of the V-edge grinder G as shown in Fig. 5(e), the following (j+5)th measuring radius vector information (ρ_{j+5}', θ_{j+5}) does not need to be changed,and the measuring of the edge thickness at the measuring point T_{j+5} on the measuring radius vector locus S as shown in Fig. 5(f) is carried out.

As mentioned above, in case the measuring edge thickness Δ_j first turns narrower than the V-edge base width W, the following first compensated measuring radius vector length τ_{j+1} for the (j+1)th measuring radius vector ρ_{j+1}' is changed from the first compensated amount t_1 of the formula (6) to the formula (7):

$$t_1 = \left(1 - \frac{\Delta_j}{W}\right) \cdot H \quad \ldots\ldots\ldots\ (6)$$

$$\tau_{j+1} = \rho_{j+1}' + t_1 \quad \ldots\ldots\ldots\ (7)$$

And the (j+1)th edge thickness is measured at the (j+1)th measuring point T_{j+1} as a changed position.

Referring to the measurement following to the (j+1)th, the second compensated measuring radius vector length τ_{j+2} and the measuring edge thickness Δ_{j+m-1} preceding to the τ_{j+2} is changed into the (m)th compensated measuring radius vector length τ_{j+m} broader than the V-edge base width W.

The (m)th compensated amount tm in a generalized formula of the formulas (8) through (13) is expressed as follows :

$$t_m = \Sigma (1 - \frac{\Delta_{j+m}}{\Delta_{j+m-1}}) \cdot H \text{ .... } (14)$$

And the (m)th compensated measuring radius vector length τ_{j+m} is:

$\tau_{j+m} = \rho_{j+m}' + t_m$ (15)

(with m=2,3,4,...M. M<N, in both (14) and (15))

In case the measured edge thickness is narrower than the width W of the V-edge base of the V-edge grinder G as mentioned above, the measurement of the thickness is carried out at the compensated measuring point on the compensated locus S' shown with the stitch line in Fig. 4.

And thus,the present invention can provide a method and an apparatus for measuring the edge thickness of a spectacle lens, which has an advantage to measure more accurately the edge thickness of the lens narrower than the width of the V-edge base of the V-edge grinder in comparison with the prior art.

Claims

(1) A method for measuring the edge thickness of a spectacle lens comprising:

a first step for inputting an all round radius vector information (ρ_i, θ_i) of the spectacle frame lens rim for framing a lens grind ;

a second step for obtaining an all round measuring vector radius information (ρ_i', θ_i) by subtracting the V-edge depth (H) of the grinder for grinding said lens from the length (ρ_i) of the radius vector of said all round radius vector information (ρ_i, θ_i);

a third step for measuring the edge thickness (Δ_i) of the lens over the all round of the radius vector locus of the lens rim based on said all round measuring radius vector information (ρ_j', θ_j);

a fourth step for obtaining the partial measuring radius vector information (ρ_j', θ_j) (j≦i) for a narrower edge thickness (Δ_j) than the width (W) of the grinding base by comparing the width (W) of the grinding base of the grinder with said edge thickness (Δ_i);

a fifth step for obtaining the length (ρ_j'') of the re-measuring radius vector of the partial re-measuring radius vector information (ρ_j'', θ_j) (j≦i) as follows:

$$\rho_j'' = \rho_j' + d_j$$

$$d_j = (1 - \frac{\Delta_j}{W}) \cdot H$$

(with j≦i); and

a sixth step for again and partially measuring the edge thickness of said lens based on said partial re-measuring radius vector information (ρ_j'', θ_j).

(2) A method for measuring the edge thickness of a spectacle lens comprising:

a first step for inputting a radius vector information (ρ_i, θ_i) of the spectacle frame lens rim for framing the lens;

a second step for obtaining an all round measuring radius vector information (ρ_i', θ_i) by subtracting the V-edge depth (H) of the grinder for grinding said lens from the length (ρ_i) of the radius vector of said radius vector information (ρ_i, θ_i);

a third step for successively measuring the edge thickness (Δ_i) of the lens based on said measuring radius vector information (ρ_i', θ_i);

a fourth step for obtaining the edge thickness of the lens by in order comparing the width (W) of the grinding base of the grinder with said edge thickness (Δ_i), and for measuring the edge thickness (Δ_{j+1}) of said lens based on the compensated measuring radius vector information (τ_{j+1}, θ_{j+1}) obtained by the following formulas:

$$\tau_{j+1} = \rho_{j+1}' + t_1$$

$$t_1 = (1 - \frac{\Delta_j}{W}) \cdot H$$

where τ_{j+1} is the compensated radius vector length and ρ_{j+1}' is the $(j+1)$th measuring radius vestor length, in case the measured edge thickness (Δ_j) of the j-th measuring radius vector information (ρ_j', θ_j) is narrower than the width (W) of the grinding base; and

a fifth step for the sequent measurement of the edge thickness (Δ_{j+m}) (with m = 2,3,4,...M,M < N) in the following way, in case of the narrower measured edge thickness (Δ_{j+1}) than the preceding measured edge thickness (Δ_j), the compensated measuring radius vector information $(\tau_{j+m}, \theta_{j+m})$ is first obtained by the following formulas:

$$\tau_{j+m} = \rho_{j+m}' + t_m$$

$$t_m = \Sigma (1 - \frac{\Delta_{j+m}}{\Delta_{j+m-1}}) \cdot H$$

where (τ_{j+m}) is the compensated radius vector length, (ρ_{j+m}') is the measured radius vector length for the succeeding measuring radius vector information $(\rho_{j+m}', \theta_{j+m})$ (with m = 2,3,4,...M, M<N), and H is the V-edge depth of the grinder, and then the edge thickness (Δ_{j+m}) of the lens is successively measured based on the measuring radius vector information $(\tau_{j+m}, \theta_{j+m})$ until the measured edge thickness (Δ_{j+m-1}) just before the thickness (Δ_{j+m}) gets wider than the width (W) of the grinding base.

(3) An apparatus for measuring the edge thickness of a spectacle lens comprising:

a first means, which is an input means for inputting the all round radius vector information (ρ_i, θ_i) of the spectacle frame lens rim for framing the lens;

a second means,which is an arithmetic means for obtaining the all round measuring radius vector information (ρ_i', θ_i) by subtracting the V-edge depth (H) of the grinder for grinding the lens from the length (ρ_i) of the radius vector of the all round radius vector information (ρ_i, θ_i),

a third means,which is an edge thickness measuring means for measuring the edge thickness (Δ_i) of the lens over the all round of the radius vector locus of the lens rim based on the all round measuring radius vector information (ρ_i', θ_i),

a fourth means, which is a memory means for beforehand memorizing the width (W) of the grinding base of the grinder; and

a fifth means, which is a comparison means for comparing the width (W) of the grinding base with the measured edge thickness (Δ_i) and obtaining the partial measuring radius vector information (ρ_j', θ_j) (with $j \leqq i$) as the edge thickness (Δ_j) narrower than the width (W) of the grinding base.

said arithmetic means being constituted such that the length (ρ_j'') of re-measuring radius vector of the partial re-measuring radius vector information (ρ_j'', θ_j) (with $j \leqq i$) is obtained by the following formulas:

$$\rho_j'' = \rho_j' + d_j$$

$$d_j = (1 - \frac{\Delta_j}{W}) \cdot H$$

$$(\text{with } j \leqq i);$$

said edge thickness measuring means being constituted such that the edge thickness of the lens is measured again and partly based on the partial re-measuring radius vector information (ρ_j'', θ_j);

(4) An apparatus for measuring the edge thickness of a spectacle lens comprising:

a first means, which is an input means for inputting the radius information (ρ_i, θ_i) of the spectacle frame lens rim for framing the lens;

a second means, which is an arithmetic means for obtaining the measuring radius vector information (ρ_i', θ_i) by subtracting the V-edge groove depth (H) of the grinder for grinding the lens from the radius vector length (ρ_i) of the radius vector information;

a third means, which is an edge thickness measuring means for successively measuring the edge thickness Δ_i of the lens over the radius vector locus of the lens based on the measuring radius vector information (ρ_i', θ_i);

a fourth means, which is a memory means for beforehand memorizing the width (W) of the V-edge of the grinder ;

a fifth means,which is a comparison means for in order comparing the measured edge thickness (Δ_i) with the width (W) of the grinding base, if said comparison means judges that the measured edge thickness (Δ_j) of the j-th measuring radius vector information (ρ_j', θ_j) is narrower than the width (W) of the grinding base, said arithmetic means is constituted such that the compensated measuring radius vector is obtained by the following formulas:

$$\tau_{j+1} = \rho_{j+1}' + t_1$$

$$t_1 = \left(1 - \frac{\Delta_j}{W}\right) \cdot H$$

where (τ_{j+1}) is the compensated radius vector length,and (ρ_{j+1}) is the (Δ_{j+1})th measuring radius vector length,and the edge thickness measuring means measures the edge thickness (Δ_{j+1}) of the lens based on the compensated measuring radius vector information (τ_{j+1}, θ_{j+1}), and if the comparison means has judged that the measured edge thickness (Δ_{j+1}) is narrower than the thickness (Δ_j) measured immediately before the thickness (Δ_{j+1}), the arithmetic means obtains the compensated measuring radius vector information (τ_{j+m}, θ_{j+m}) by the following formulas:

$$\tau_{j+m} = \rho_{j+m}' + t_m$$

$$t_m = \Sigma \left(1 - \frac{\Delta_{j+m}}{\Delta_{j+m-1}}\right) \cdot H$$

where (τ_{j+m}) is the compensated radius vector length, (ρ_{j+m}') is the measured radius vector length of the succeeding radius vector information (ρ_{j+m}', θ_{j+m}) with m=2,3,4,...M, M<N), and H is the V-edge depth of the grinder, and then the edge thickness measuring means measures the edge thickness (Δ_{j+m}) of the lens based on the compensated measuring radius vector information (τ_{j+m}, θ_{j+m}) until the measured edge thickness (Δ_{j+m-1}) immediately before the thickness (Δ_{j+m}) is wider than the width (W) of the grinding base.

FIG. 1

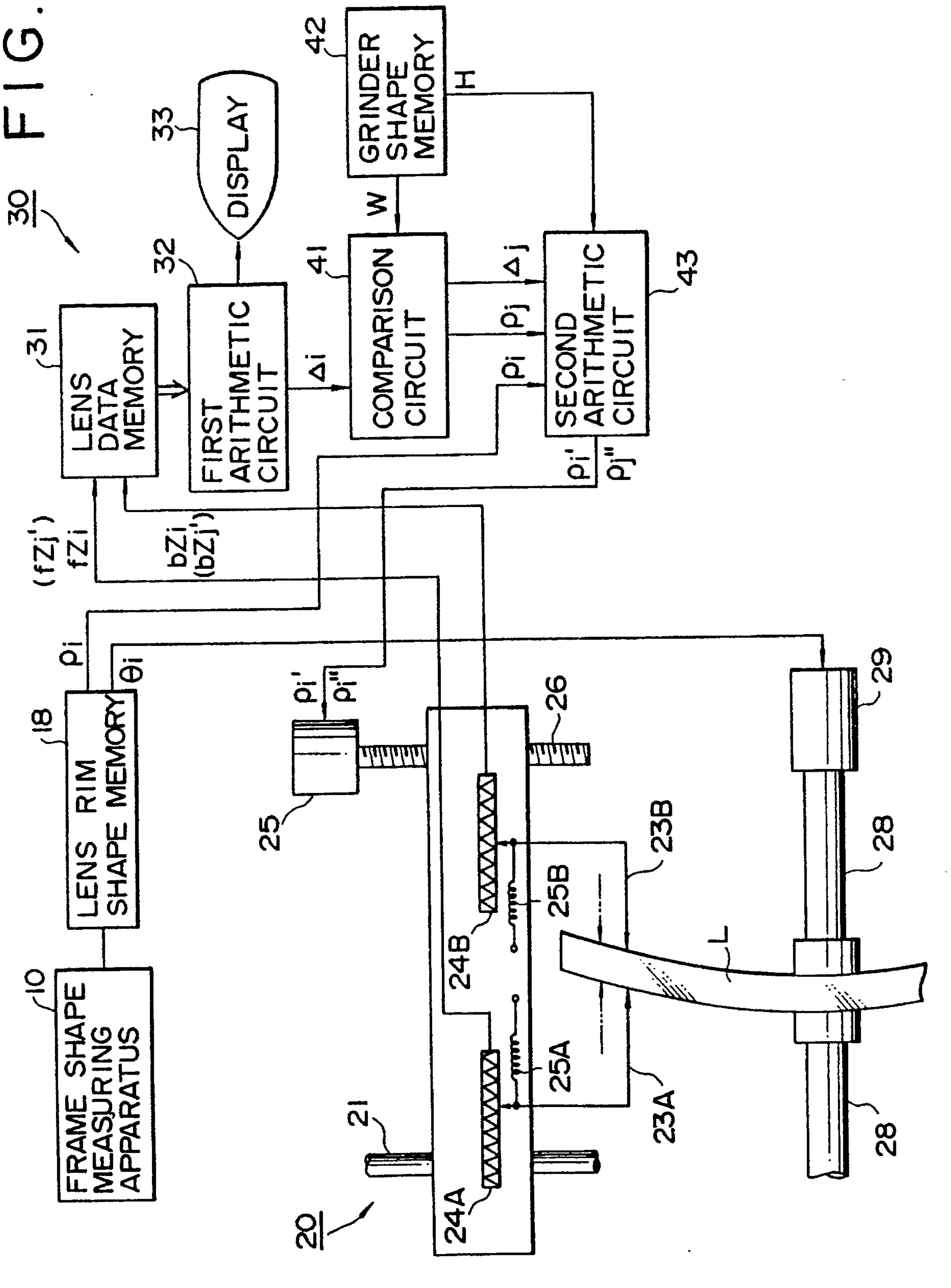

30
LENS DATA MEMORY
31
FIRST ARITHMETIC CIRCUIT
32
DISPLAY
33
COMPARISON CIRCUIT
41
GRINDER SHAPE MEMORY
42
SECOND ARITHMETIC CIRCUIT
43
W
H
Δi
Δj
ρj
ρi
ρi'
ρj''
(fZj')
fZi
bZi
(bZj')
FRAME SHAPE MEASURING APPARATUS
10
LENS RIM SHAPE MEMORY
18
ρi
θi
ρi'
ρi''
25
26
21
24A
24B
25A
25B
23A
23B
L
28
29
20

FIG. 2

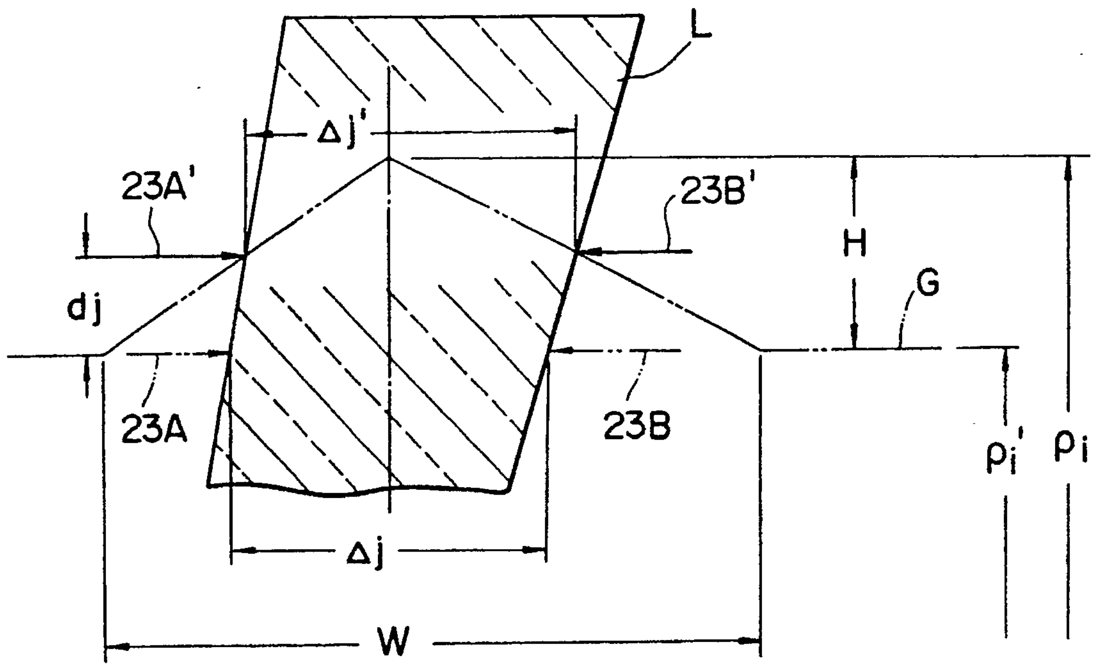


FIG.3A

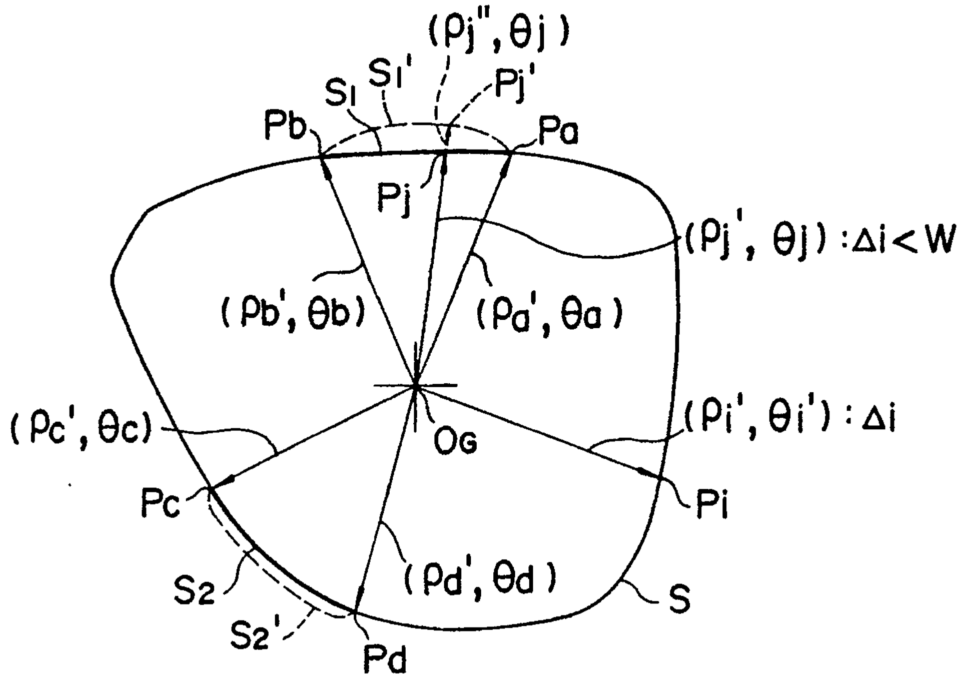
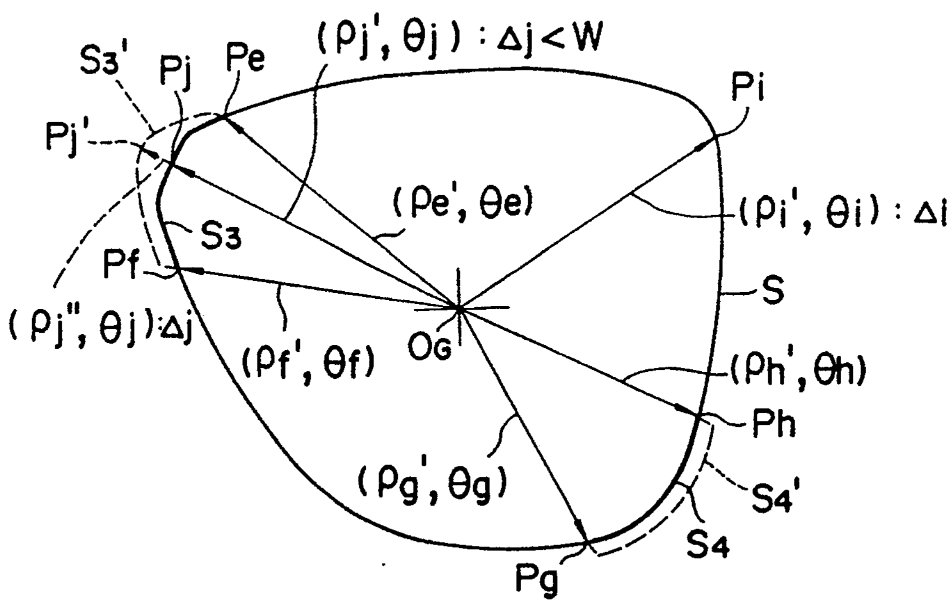

(ρj", θj)
S1'
Pj'
S1
Pb
Pa
Pj
(ρj', θj) :Δi<W
(ρb', θb)
(ρa', θa)
(ρc', θc)
(ρi', θi') : Δi
OG
Pc
Pi
(ρd', θd)
S2
S
S2'
Pd

FIG.3B


S3'
Pj
Pe
(ρj', θj) : Δj<W
Pi
Pj'
(ρe', θe)
(ρi', θi) : Δi
S3
Pf
S
(ρj", θj):Δj
(ρf', θf)
OG
(ρh', θh)
Ph
(ρg', θg)
S4'
S4
Pg

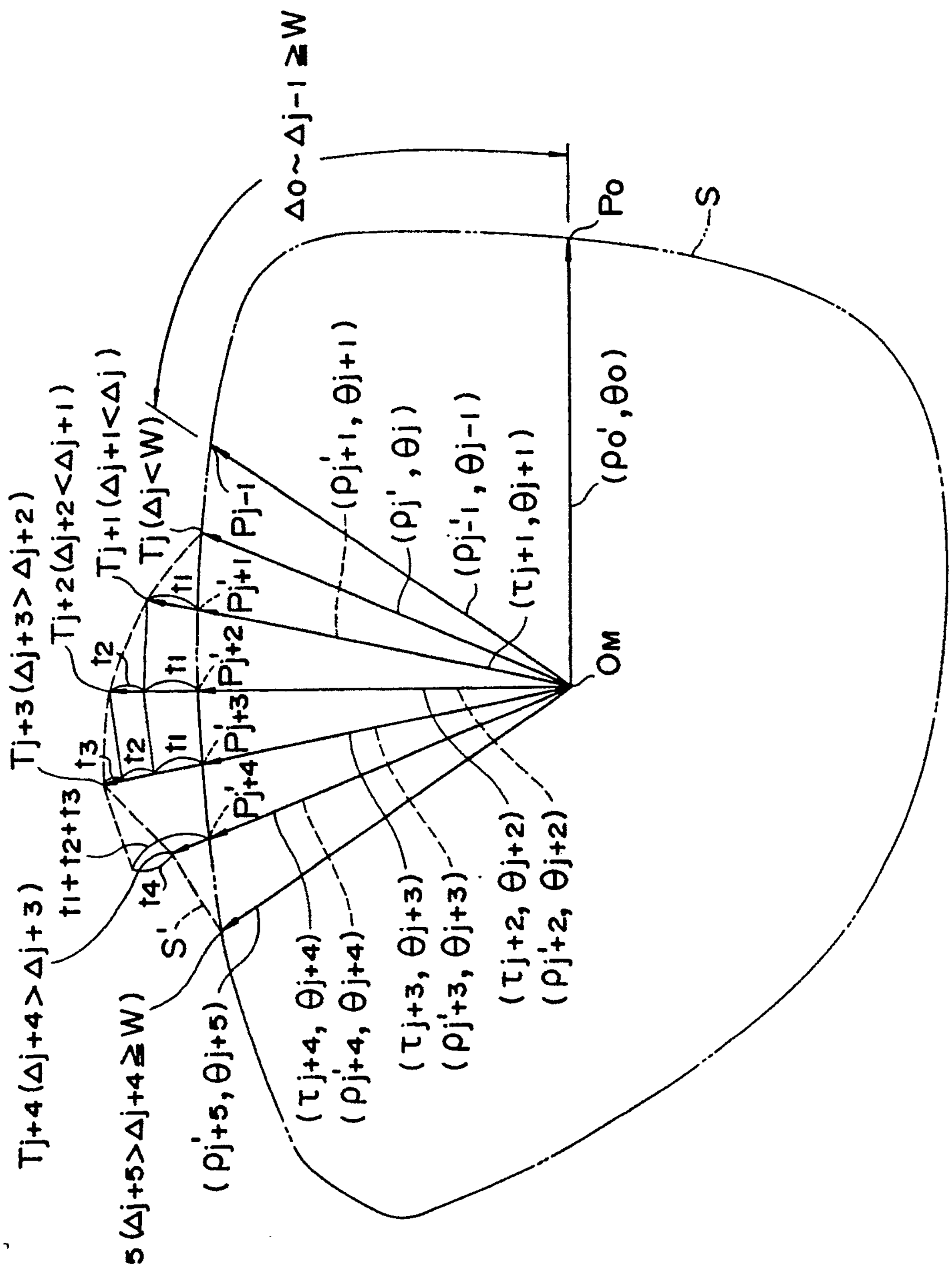

Δo~Δj-1 ≧W
Po
S
OM
(ρo', θo)
(ρj+1', θj+1)
(ρj', θj)
(ρj-1', θj-1)
(τj+1, θj+1)
(τj+2, θj+2)
(ρj+2', θj+2)
(τj+3, θj+3)
(ρj+3', θj+3)
(τj+4, θj+4)
(ρj+4', θj+4)
(ρj+5', θj+5)
Pj-1
Pj+1'
Pj+2'
Pj+3'
Pj+4'
S'
Tj (Δj<W)
Tj+1 (Δj+1<Δj)
Tj+2 (Δj+2<Δj+1)
Tj+3 (Δj+3>Δj+2)
Tj+4 (Δj+4>Δj+3)
Tj+5 (Δj+5>Δj+4 ≧W)
t1+t2+t3
t1
t2
t3
t4

FIG. 4

F I G. 5

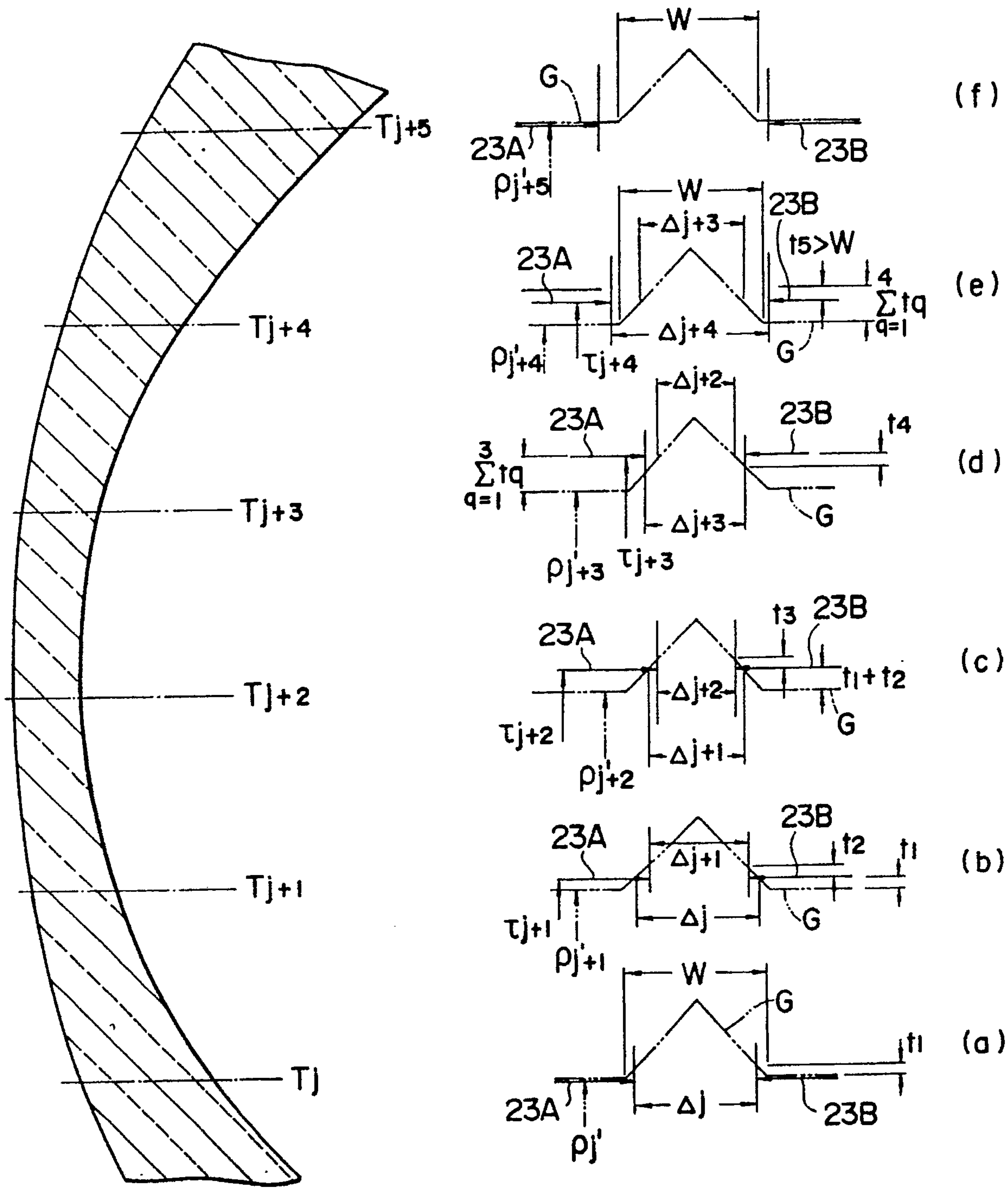

Tj+5
Tj+4
Tj+3
Tj+2
Tj+1
Tj
W
G
23A
23B
ρj'+5
(f)
Δj+3
t5>W
Δj+4
ρj'+4
τj+4
(e)
Δj+2
t4
ρj'+3
τj+3
(d)
t3
t1+t2
Δj+1
τj+2
ρj'+2
(c)
t2
t1
Δj
τj+1
ρj'+1
(b)
ρj'
(a)

FIG. 6

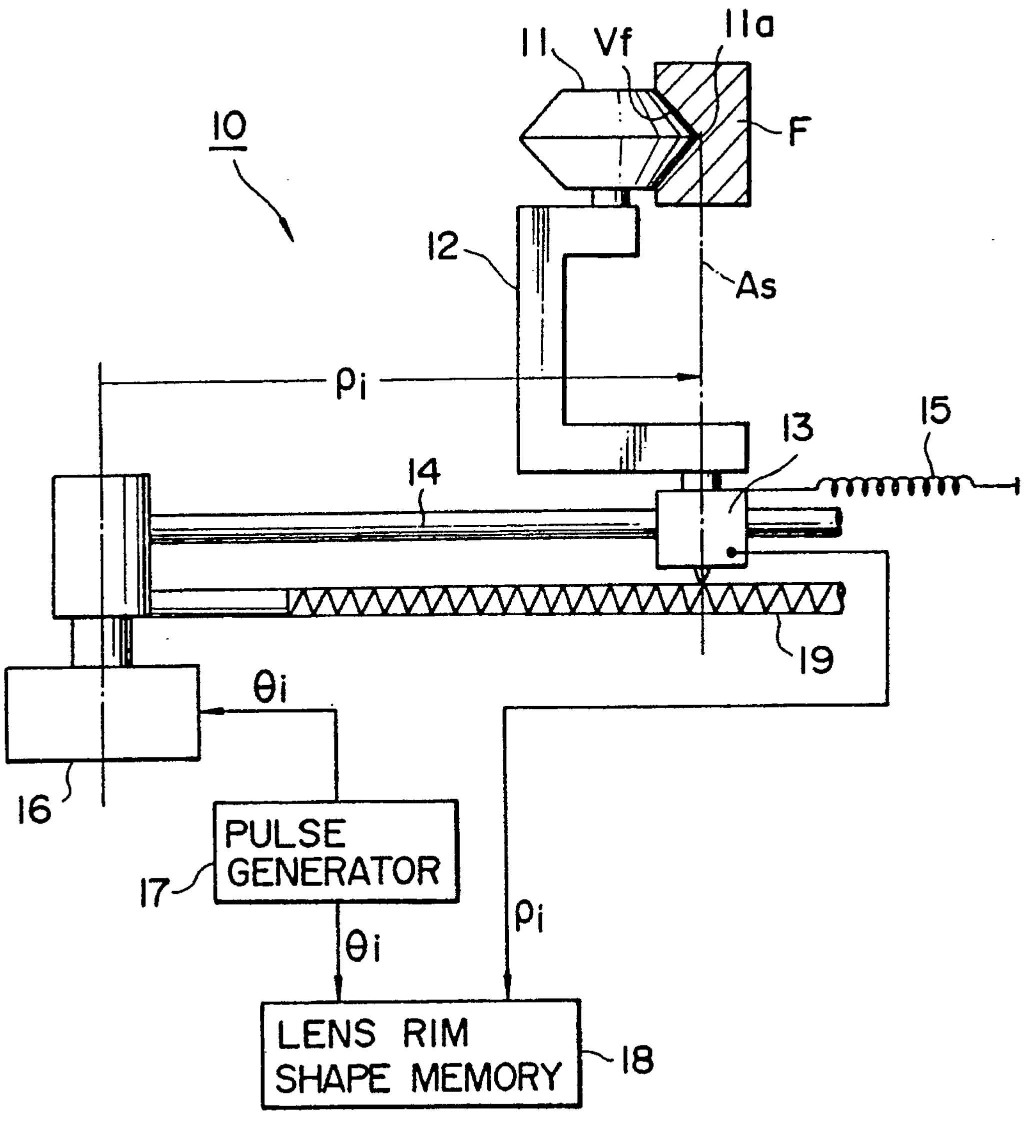
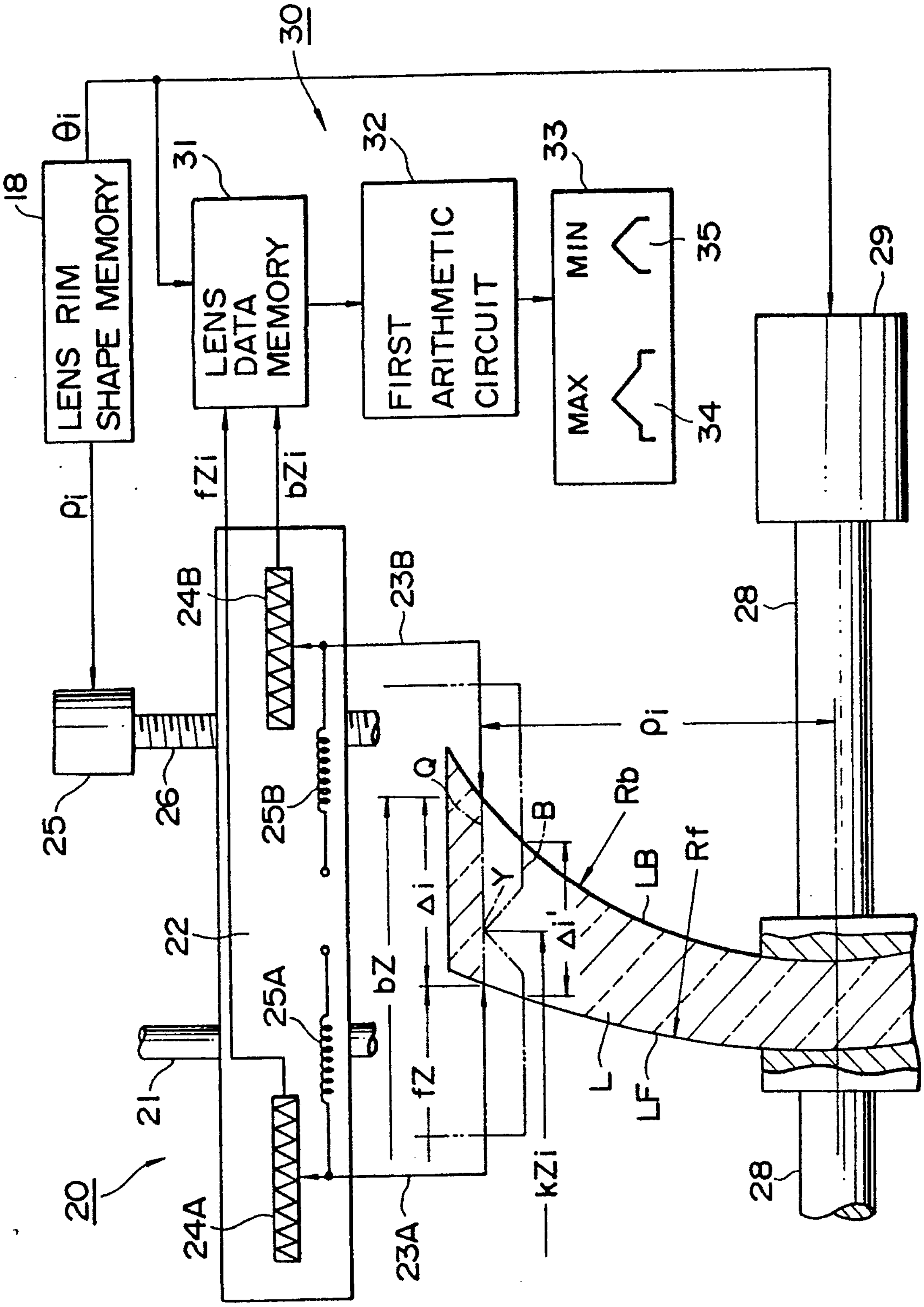

11
Vf
11a
F
10
12
As
ρi
13
15
14
19
θi
16
PULSE GENERATOR
17
ρi
θi
LENS RIM SHAPE MEMORY
18

FIG. 7



LENS RIM SHAPE MEMORY
LENS DATA MEMORY
FIRST ARITHMETIC CIRCUIT
MAX
MIN
18
30
31
32
33
34
35
θi
ρi
fZi
bZi
20
21
22
23A
23B
24A
24B
25
25A
25B
26
28
29
fZ
bZ
Δi
Δi'
kZi
Q
B
Y
Rb
LB
Rf
L
LF

FIG. 8

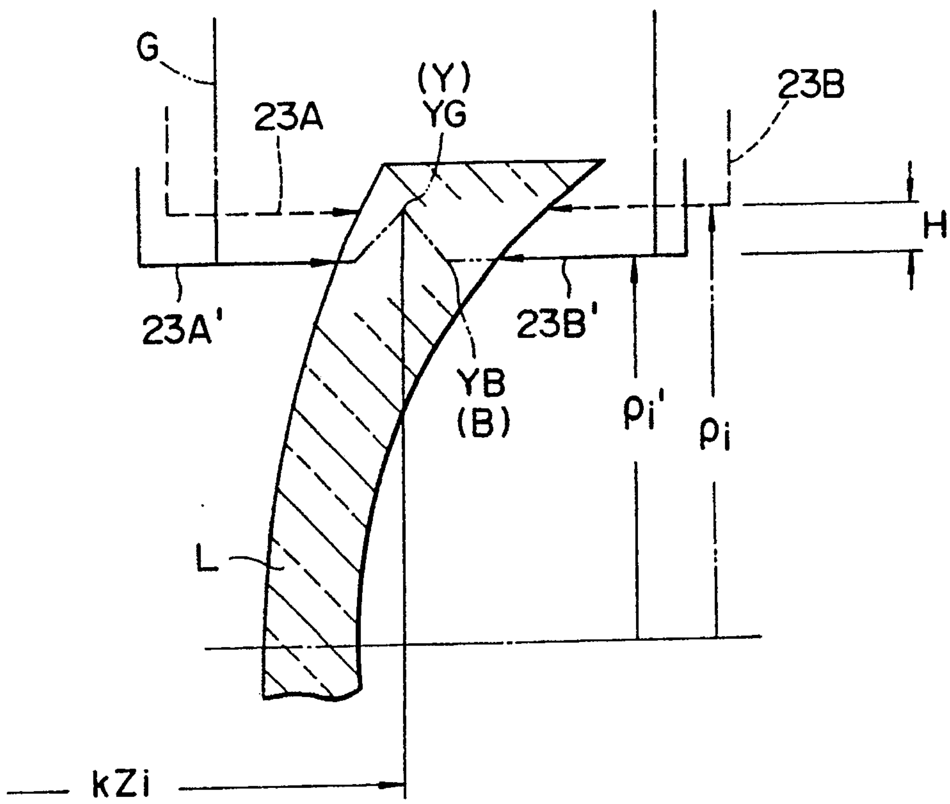
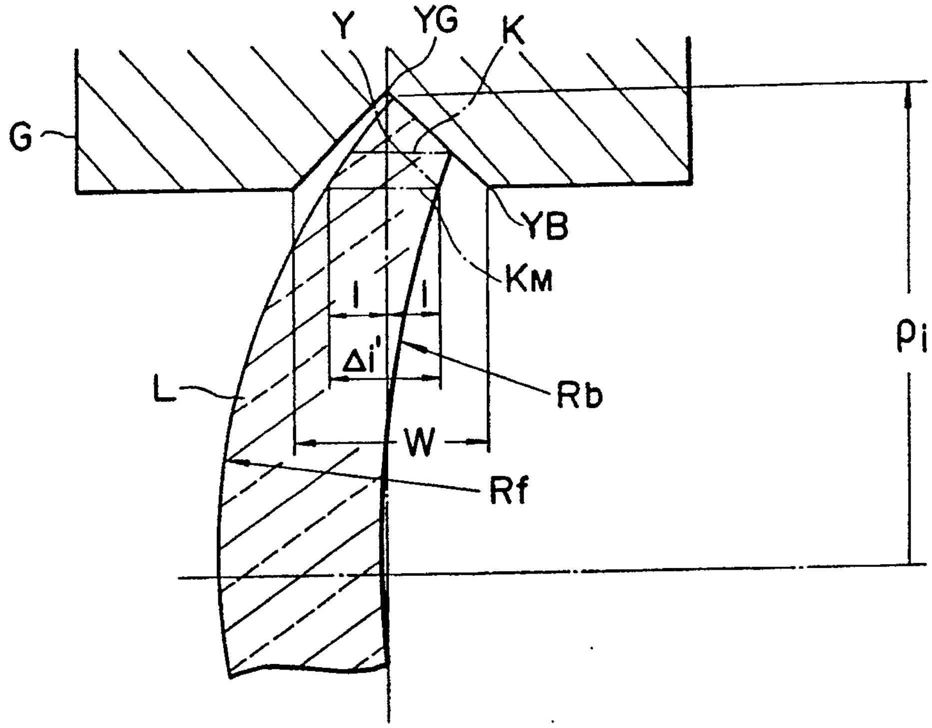


FIG. 9



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 40 3223

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)
A	EP-A-0 196 114 (TOKYO KOGAKU KIKAI K.K.) * claims ; figures * – – –	1,3	B 24 B 9/14
A	FR-A-2 555 929 (NIPPON KOGAKU K.K.) * pages 3 - 4; figures * – – –	1,3	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 300 (M-848)(3648) 11 July 1989, & JP-A-1 92055 (GURANDO SEIKO K.K.) 11 April 1989, * the whole document * – – –	1,3	
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 27 (M-662)(2874) 27 January 1988, & JP-A-62 181864 (TOKYO OPTICAL CO LTD) 10 August 1987, * the whole document * – – –	1,3	
A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 135 (M-585)(2582) 28 April 1987, & JP-A-61 274860 (TOKYO OPTICAL CO LTD) 05 December 1986, * the whole document * – – –	1,3	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)**
D,A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 135 (M-585)(2582) 28 April 1987, & JP-A-61 274859 (TOKYO OPTICAL CO LTD) 05 December 1986, * the whole document * – – – – –	1,3	B 24 B

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	26 February 91	ESCHBACH D.P.M.

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