

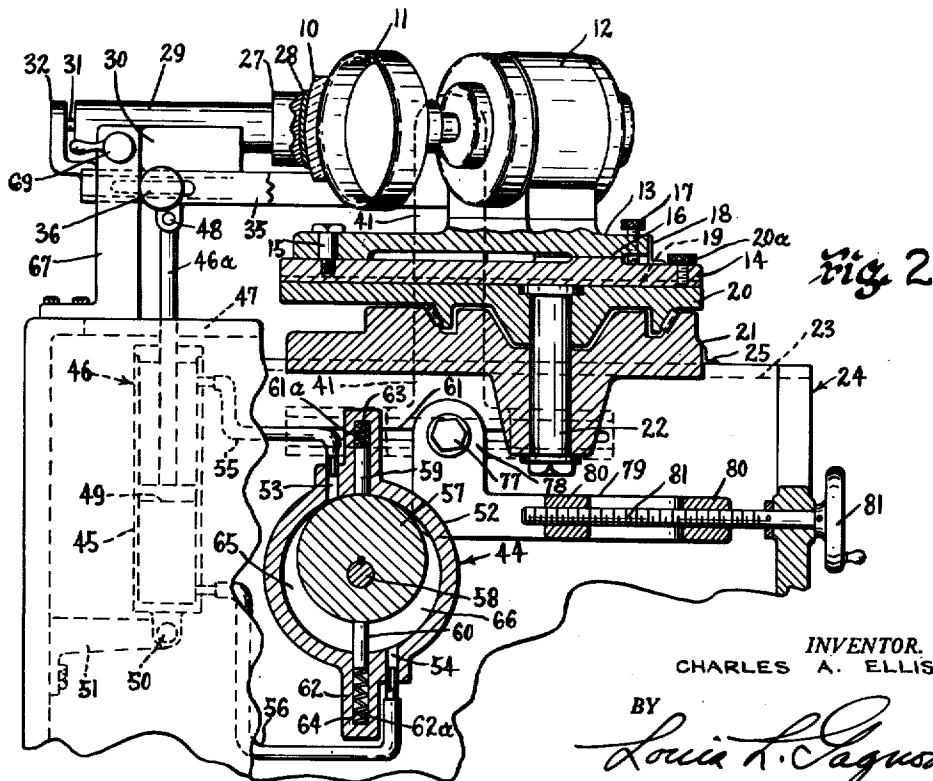
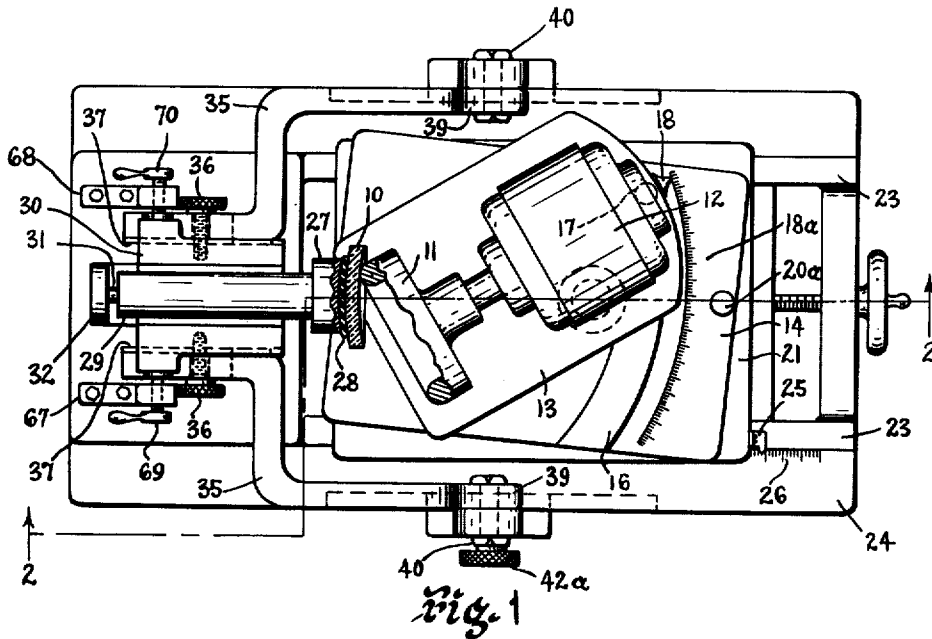
April 7, 1953

C. A. ELLIS
SURFACING MACHINE

2,633,675

Filed June 10, 1950

2 SHEETS—SHEET 1



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2 SHEETS—SHEET 2

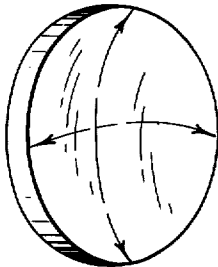


Fig. 3

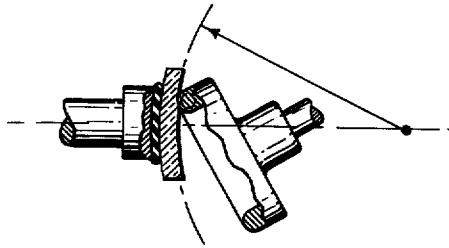


Fig. 4

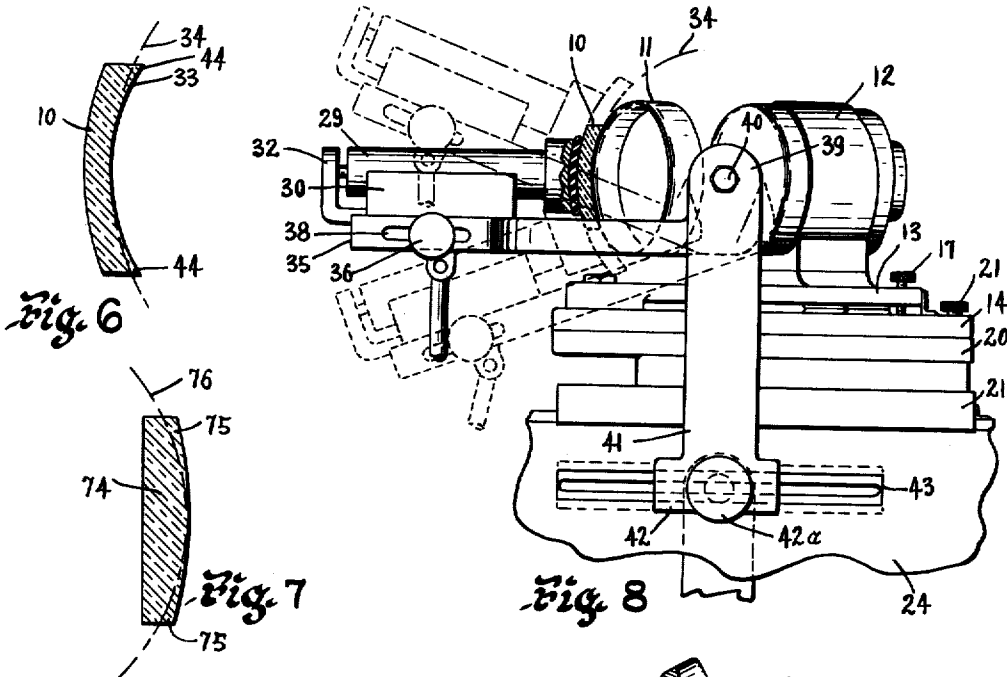


Fig. 6

Fig. 7

Fig. 8

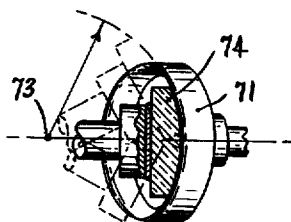


Fig. 9

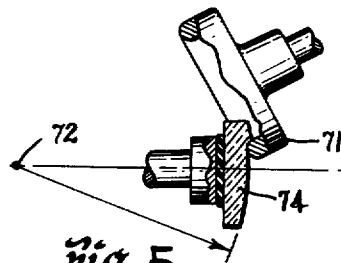


Fig. 5

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2,633,675

SURFACING MACHINE

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Application June 10, 1950, Serial No. 167,420

13 Claims. (Cl. 51—33)

1

This invention relates to improvements in surfacing machines and has particular reference to improved apparatus for producing single or compound curved surfaces on lenses or similar articles, and to an improved process for producing said curved surfaces.

One of the principal objects of this invention is to provide an improved device for forming substantially accurately shaped surfaces of single or compound curvature on articles such as lenses and a novel method of making same.

Another object is to provide an improved device for forming a single or compound curved surface on an article such as a lens and of the type embodying means for feeding a cup-type abrading tool transversely of the article whereby the plane of sweep of the tool produces a surface curvature in one major meridian having a radius substantially equal to the radius of curvature about which the tool is moved and a surface curvature in the opposed major meridian dependent upon the angle at which the tool is disposed relative to the article during said sweep and further embodying means for altering the related position of the tool and article in a direction substantially normal to the plane of the sweep of the tool during said sweep.

Another object is to provide a surfacing machine of the above character wherein the means for altering the related position of the tool and article in said normal direction causes movement about an axis which is located in the plane of sweep of the abrading tool and at a distance from the surface being abraded substantially equal to the radius desired of the surface curvature in said opposed major meridian.

Another object is to provide a surfacing machine of the above character which will generate either concave or convex surface shapes on articles such as lenses.

Another object is to provide a surfacing machine of the above character embodying means for feeding a cup-shaped abrading tool transversely of an article being abraded with the tool being angled to present a rim portion thereof toward the article, which rim portion performs the abrading, and means for supporting the article for movement along an arcuate path substantially normal to the plane of sweep of the tool and further about an axis parallel to and lying in the plane of sweep of the tool whereby inaccuracies resulting from ellipticity of the effective abrading surface of the tool will be eliminated.

Another object is to provide a machine of the above character with simple and efficient means

2

for adjusting the tool and article for proper positionment and for movement with respect to one another for generating the desired surface shape on the article.

Another object is to provide an improved hydraulic system for controlling the moving of the article to be abraded and its supporting means about a predetermined axis.

Further objects are to provide in a manner as hereinafter set forth a surfacing machine which is comparatively simple in its construction, durable, thoroughly efficient in its use, and readily set up and adjusted for providing articles such as lenses with various single or compound surface curvatures.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a top plan view of a machine embodying the invention;

Fig. 2 is a fragmentary sectional view taken approximately on line 2—2 of Fig. 1;

Fig. 3 is a perspective view of a lens of a type suitable for shaping in accordance with the invention;

Fig. 4 is a fragmentary sectional top plan view illustrating diagrammatically the respective positions of the abrading tool and article during the forming of a concave surface on the article;

Fig. 5 is a view similar to Fig. 4 illustrating the forming of a convex surface on the article;

Figs. 6 and 7 are sectional views of lenses having concave and convex surfaces respectively thereon;

Fig. 8 is a fragmentary side elevational view illustrating the movement of a lens and supporting means therefor when forming a concave surface thereon, and

Fig. 9 is a fragmentary side elevation illustrating diagrammatically the engagement of a lens with an abrading tool when forming a convex surface on the lens.

Prior mechanical devices for generating a curved surface on an article such as a lens have sometimes proven to be inefficient because of the somewhat complicated nature of the means used to adjustably position an article in abrading position in an abrading machine and to adjust the abrading tool for proper engagement with the article. The use of cupped-type abrading tools which are angled to present a rim portion to the article for abrading the surface thereof have proven to be most satisfactory with respect to simplicity and speed in generating surface curva-

3

tures particularly on articles such as ophthalmic lenses. However, such devices generally employ means for moving the angled tool in an arcuate path transversely of the article, which, due to the ellipticity of the effective surface of the tool, produces an inaccurate curvature in the major meridian at right angles to the plane of sweep of the tool.

The present invention overcomes the above undesirable feature by providing means for moving the article while in engagement with the abrading tool along an arcuate path substantially normal to the plane of sweep of the tool as it moves transversely, whereby the surface of the article will be abraded accurately and simply to substantially the curvature desired.

In following the teachings of the invention, it has been previously stated that due to the ellipticity of the tool at different angular positions of adjustment, there is an error in the curve generated in the major meridian of the lens formed by the angle of the tool.

In generating minus curves, it has been found that the curvature as it moves outwardly from the axis of the lens in that meridian of the lens formed by the angle of the tool deviates from the desired true curvature in that the curve is generated to stronger curvatures which are of a shorter radius than that desired. In accordance with the present invention, an accurate curve in this direction is generated by oscillating the work or lens about a radius of curvature equal to that desired of the lens in said meridian during the movement of the tool about the radius of curvature desired in the other major meridian of the lens. This oscillation is so controlled that the resultant curvature in the meridian generated by the angle of the tool will be a substantially true curve.

The true curve may be arrived at either by setting the tool to the proper angle required for theoretically producing this curve and compensating for the error by oscillation as described above or by offsetting the angle of the tool from that required for the true theoretical curvature slight amounts, and cooperatively arranging the oscillatory movement so as to arrive at said curve.

In generating plus curves on an article such as a lens in the meridian produced by the angling of the tool, it has been found that the curve as it progresses inwardly from the margin of the lens toward the axis in said meridian becomes progressively stronger than the final true curve desired.

In order to compensate for this condition the tool is so angled as to produce a curve of greater radius than that of the final true curve desired with said angle being so controlled that the curve formed in the axial area of the lens is substantially that of the true curve desired in said meridian of the lens and by oscillating the lens as stated above the curve as it progresses outwardly from said axial area toward the margin of the lens may be caused to assume the true curvature whereby the resultant radius of curvature in said meridian will be substantially that of the true curve desired.

Referring more particularly to the drawings wherein like characters of reference designate like parts throughout the several views, the machine illustrated in Figs. 1 and 2 is constructed and adjusted for production of minus or concave surfaces on articles such as ophthalmic lenses and includes means for supporting a lens or lens blank 10 for engagement with a

4

cupped or ring-type abrading tool 11. The tool 11 is preferably of a diamond impregnated or charged type and is rotatably carried in a conventional manner by a motor 12 which is fixedly mounted on a base plate 13. The base plate 13 is attached to a slide member 14 adjacent one end thereof by a pivot 15 and is rotatable about the pivot 15 on a raised machined track 16 provided on the upper surface of the slide member 14, and a lock screw 17 or similar means is provided to frictionally lock the base plate 13 in adjusted position on the slide member 14, as indicated by a pointer 18 on the base plate 13 which is adapted to be aligned with the graduations on a scale 18a provided on the slide member 14. By adjusting the base plate 13 in the desired position on the slide member 14, the abrading tool 11 can be angled to present a rim portion directed toward the lens 10 to be abraded, and this adjustment will determine the approximate curvature to be provided in one major meridian on the lens surface, in this case the vertical meridian.

The slide member 14 is mounted for movement longitudinally of the machine in a guideway 19 provided therefor in the upper surface of a base 20 and adapted to be locked in position thereupon by means such as a lock screw 20a. The base 20 is rotatably secured to an adjustable support 21 by a pivot member 22. The support 21 is adjustable longitudinally of the machine in guideways 23 formed in the upper surface of the machine base 24. This adjustment is for the purpose of positioning the pivot member 22 at the desired distance from the point of engagement between the lens blank 10 and tool 11, and the tool 11 and supporting mechanism therefor is rotatable about the axis of the pivot member 22. Therefore, the radius of curvature to be generated in the opposed or horizontal meridian of the lens will be determined by the spacing of the pivot member 22 from a parallel line through the point of engagement between the lens blank and tool and is indicated by a pointer 25 on the support 21 which is adapted to be aligned with graduations on the scale 26 on the machine base 24.

The preferred method of setting up the machine so as to generate the desired curvatures in both the horizontal and vertical meridians is to first adjust the support 21 on the machine base 24 to position the pivot member 22 as desired to establish the radius of sweep of the tool 11. Then, after angling the tool by adjusting the base plate 13 on slide member 14 to establish the radius of curvature in the vertical meridian, the slide member 14 is adjusted on the base 20 as described to position the effective abrading portion of the tool in engagement with the surface of the lens blank 10 to be abraded. Then, upon operation of the machine, the motor 12 will cause the tool 11 to rotate and the entire head mechanism will be swung about the axis of the pivot member 22 either by manual or conventional automatic power to cause the tool 11 to arcuately traverse the lens surface.

The lens blank 10 which is to be surfaced by the tool 11 is secured to a block 27 by conventional means such as a layer of pitch 28 or other suitable adhesive and the block 27 is suitably attached to the end of a spindle 29 which is positioned in a longitudinal V-groove formed in the upper surface of a chuck 30. The chuck 30 is of any suitable conventional type, preferably magnetic, which will retain the spindle 29 immovable in the V-groove. To position the lens

blank 10 for proper engagement with the abrading portion of the total 11, the spindle 29 is provided with an extension 31 on its outer end. The extension 31 is adjustable longitudinally of the spindle 29 so as to control the distance between the end thereof and the surface of the lens blank 10. By providing such an adjustment the surfaces of lenses to be abraded can be consistently maintained at a controlled distance from a stop arm 32 on the chuck 30 against which the extension is positioned irrespective of variations in the thickness of the lens blanks.

This adjustment can be accomplished in many satisfactory ways. However, the preferred method is clearly shown and described in copending U. S. patent application Serial No. 792,668, filed December 19, 1947, now Patent No. 2,548,418, dated April 10, 1948.

Suitable conventional mechanism (not shown) such as a micrometer adjustment can be used in connection with the spindle 29 or chuck 30 to advance the lens blank 10 toward the tool 11 for removal of controlled amounts of glass from the surface of the blank.

The foregoing description refers to a known type of mechanism used in generating simple or compound curves on the surfaces of articles such as ophthalmic lenses. However, when angling an abrading tool 11 as described, and sweeping it transversely across the surface of a lens blank 10, the ellipticity of the tool will cause the surface of the lens to be generated inaccurately in the vertical meridian, as indicated in Fig. 6 wherein numeral 33 indicates the aspheric curve formed by the tool 19 and numeral 34 indicates the true spherical curve desired.

In accordance with this invention, in order to generate a surface having an accurate curvature in the vertical meridian on a lens blank 10, it has been found that this can be done by oscillating the lens blank along an arcuate path substantially normal to the plane of sweep of the tool and about an axis located in the plane of the sweep of the tool and at a distance from the surface being abraded substantially equal to the radius desired of the curvature in the vertical meridian.

The means for performing this operation embodies a rocker mechanism comprising a pair of spaced arms 35 each having an end portion disposed adjacent the opposed sides of the chuck 30 and adjustably attached thereto by studs 36. The inner surfaces of the arms 35 adjacent the chuck 30 are provided with raised integral track-like portions 37 which are positioned for sliding movement in longitudinal grooves provided therefor in the sides of the chuck 30. The threaded studs 36 are headed and each extends through a longitudinal slot 38 in the respective arms 35 to provide means whereby the chuck 30 can be adjusted longitudinally of the arms 35 and locked in desired position by tightening the studs 36 and clamping the arms between the chuck and the heads of the studs.

The other ends of the arms 35 are provided with upwardly extending portions 39 which are attached for coaxial pivotal movement to the upper ends of stands 41 by pivot members 40. The lower ends of the stands 41 are each provided with enlarged portions 42 which are positioned for sliding movement in aligned slots 43 formed in the sides of the base 24 so that the stands 41 and arms 35 may be adjusted longitudinally of the machine and held in adjusted position by means such as locking screw 42a

(Figs. 1 and 8). A short shaft 77 connects each of the lower ends of the stands 41 to respective upturned end portions 78 of a bifurcated member 79. The bifurcated member 79 is provided with cross bars 80 for threadedly receiving an operating shaft 81 which is rotatably carried in the end of the machine base 24 and adapted to be rotated by means such as crank 81. Thus, upon rotation of the crank 81 the bifurcated member 79 will move longitudinally of the machine and cause simultaneous responsive longitudinal movement of the stands 41, with the member 79 also serving to retain the stands in preadjusted relative positions and consequently the axes of the pivot members 40 in axial alignment. The stands 41 may be locked in adjusted position by means such as knob 42a which is threadedly mounted on one of the shafts 77 and can be turned to clamp the stands 41 against the sides of the base 24 in the conventional manner.

With this construction it is apparent that the lens can be made to oscillate about the axis of the pivot members 40. It is important, however, that the pivot members 40 be located substantially in the plane of sweep of the tool and at a distance from the point of engagement between the lens and tool substantially equal to the radius of curvature desired in the vertical meridian. Thus, upon adjusting the stands 41 in the slots 43 on the base 24 so as to establish the desired distance between the lens surface and the pivot members 40, the lens blank 10 can be made to oscillate about the axes of the pivot members 40 during the initial abrading operation as the tool sweeps transversely of the lens blank or upon the return sweep of the head after completion of the first abrading operation, or during a second traverse of the tool across the lens blank. In this manner, as the lens blank is oscillated about the axes of the pivot members 40, the unwanted portions 44 of material, which are normally left on the lens blank, are removed since these portions are made to engage and be abraded by the effective portions of the abrading tool 11 approximating most closely the exact radius of curvature desired. In this way, an accurate surface can be abraded on a lens blank or similar article.

The mechanism for causing the lens to oscillate embodies a pump 44 which is adapted to force a suitable hydraulic fluid into a cylinder 45 for causing operation of a piston 46, the pump and piston both being preferably located inside the machine base 24. The upper end of the piston rod 46a extends through an opening 47 formed in the upper surface of the base 24 and has its upper end pivotally connected at 48 to the chuck 30. The lower end of the piston rod 46a is provided with a conventional piston disc 49 which is shaped to snugly fit within the walls of the cylinder 45, the cylinder 45 being pivotally connected at its lower end as at 50, to a bracket 51 attached to the inner wall of the machine base 24. The pump 44 is comprised of a cylinder 52 having a pair of diametrically opposed openings 53 and 54 therethrough to which are connected one end of flexible conduits 55 and 56 respectively, the other ends of the conduits 55 and 56 being connected to the piston cylinder 45 at points respectively above and below the piston disc 49. An eccentric 57 is disposed within the pump cylinder 52 and is adapted to be rotated by an operating shaft 58. A pair of reciprocating plates 59 and 60 are located in slots 61a and 62a respectively formed in enlarged portions 61 and

7

62 of the cylinder 52 and are adapted to engage opposed sides of the eccentric 57. Coiled tension springs 63 and 64 are also provided in the slots to constantly urge the plates 59 and 60 respectively toward the eccentric 57 and thus maintain them continuously in engagement therewith. In this manner there are formed two chambers 65 and 66 within the cylinder 52, the chamber 65 communicating with conduit 55 and chamber 66 communicating with conduit 56. Thus, upon rotation of the operating shaft 58 and consequently of the eccentric 57 in a clockwise direction hydraulic fluid in the chamber 66 will be forced by the eccentric through the conduit 56 into the lower portion of the piston cylinder 45, urging the piston and consequently the lens and lens holding mechanism upwardly. As the eccentric continues to be rotated in a clockwise direction, fluid in the chamber 65 will be forced through conduit 55 into the upper portion of the cylinder 45 to urge the piston 46 downwardly, and thus cause the lens to be simultaneously moved downwardly. The plates 59 and 60 by their reciprocating movements prevent the fluid from passing between the chambers 65 and 66.

With this construction the lens blank 10 can be easily and efficiently made to oscillate about the axis of the pivot members 40, as diagrammatically shown in dotted outline in Fig. 8, and thus will cause the unwanted portions 44 of material to be removed from the surface of the lens as described.

Mechanism may be provided for restraining the lens supporting means from movement and as shown in Figs. 1 and 2 comprise a pair of spaced brackets 67 and 68 which are provided on the base 24 and are adapted to extend upwardly one on each side of the chuck 30. Screw clamps 69 and 70 are provided in the upper ends of the brackets 67 and 68 respectively and are adapted to engage the sides of the chuck 30 to restrain it from movement when setting up the machine or when it is desired to cause the tool to arcuately traverse the surface of the lens blank without causing simultaneous oscillation of the blank.

It is to be understood also that conventional devices not pertaining directly to the invention can be added to the machine if desired such as by providing the sides of the chuck 30 with cheeks or plates adapted, during oscillating movement of the work supporting head, to slidably engage the screw clamps 69 and 70 to prevent the undesirable condition known as "chattering."

Although the foregoing description refers to a machine set up and operated so as to form minus or concave surfaces on articles such as lenses, it is within the scope of this invention to form plus or convex curved surfaces by modifying the construction of the machine so that the article will engage an inner abrading portion of the angled tool 71. In such a machine the tool 71 and article 74 (Figs. 5 and 9) will both be movable about respective axes 72 and 73, which axes are both located rearwardly of the article 74 rather than forwardly thereof as in the minus curve generating machine.

In adjusting the machine to produce an accurate plus curve, the tool will be located so as to sweep transversely of the lens for producing the desired curvature in the horizontal meridian. Then, to adjust the device for generation of the curvature in the opposed or vertical meridian, the tool is angled to the degree necessary for producing the desired curve in the conventional manner. However, at this point the tool is further

8

angled so as to produce a slightly weaker or flatter curve and upon initially sweeping the tool transversely across the lens, it will be understood that excess material will be retained by the lens adjacent the edges thereof as indicated by numeral 75 in Fig. 7. This excess material 75 will be removed either during the initial sweep of the tool or subsequent thereto by oscillating the lens 74 about an axis located at a distance from the surface being generated corresponding to the radius of curvature desired in the vertical meridian. Thus, a true spherical curve 76 can be accurately formed on a plus lens.

In accordance with the foregoing description, it will be apparent that there is provided an improved device for forming a single or compound curved surface on an article such as a lens blank by providing means for feeding a cup type abrading tool transversely of the article and means for moving said article along an arcuate path substantially normal to the plane of sweep of the tool and thus producing accurate surface curvatures in both the horizontal and vertical meridians.

While certain novel features of the invention have been shown and described and are pointed out in the annexed claims, it will be understood that various omissions, substitutions and changes in the forms and details of the device illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention.

I claim:

1. A surfacing machine for generating a curved surface on an article such as a lens comprising a work supporting head for carrying an article to be surfaced, and a tool supporting head adjacent said work supporting head, an axially rotatable cup-shaped abrading tool mounted on said tool supporting head and angled with respect to the surface of the article to be abraded so that the portion which controls the resultant radius of curvature formed in one major meridian of the article will have line contact therewith, said tool supporting head being mounted for transverse swinging movement about an axis spaced from the effective surface of the tool an amount substantially equal to the radius of curvature to be generated on the article in one major meridian, and said work supporting head being mounted for pivotal movement in a path substantially normal to the plane of sweep of the tool and about an axis located in said plane of sweep of the tool, said axis of the work supporting head being disposed on the side of the article directed toward the tool and at a distance from the surface to be abraded substantially equal to the radius of curvature to be generated on the article in the opposed meridian.

2. A surfacing machine for generating a curved surface on an article such as a lens comprising a base, a tool supporting head on said base, an axially rotating cup-shaped abrading tool mounted on said tool supporting head, and said tool supporting head being swingable about a second axis disposed approximately normal to the axis of the tool and spaced from the effective abrading surface of the tool an amount substantially equal to the radius of curvature to be generated on the article in one major meridian, said tool having its axis offset with respect to the axis about which the tool supporting head is swingable so that the portion of the tool which controls the radius of curvature formed in one major meridian of the article will have line contact therewith dur-

ing the abrading action and supporting means for said article comprising a stand carried by said base, a yoke pivotally connected to said stand, and carrying said article for arcuate movement about the axis of said pivot, the axis of said pivot being located in the plane of sweep of the tool and at a distance from the surface to be abraded substantially equal to the radius of curvature to be generated in the opposed major meridian.

3. A surfacing machine comprising a base, a work supporting head located upon the base for carrying an article to be surfaced, locating mechanism on said base adjacent the work supporting head, a tool supporting head adjustably mounted on said locating mechanism for movement about a first axis, means for supporting the article to be surfaced on said work supporting head, an axially rotatable cup-shaped surfacing tool mounted on said tool supporting head with its axis approximately normal to said first axis and with its effective abrading portion disposed adjacent said first axis, said locating mechanism being rotatable about a second axis parallel to said first axis, means for adjusting said second axis in directions toward and away from said work supporting head whereby the tool may sweep transversely across the article on a radius in accordance with the curvature to be formed on the article in one major meridian, said tool supporting head being adjustable on said locating mechanism about said axis of adjustment thereof to locate the tool in operative position with respect to the article and at an angle thereto in accordance with the general curvature to be formed on the article in the opposed major meridian, and oscillating means operatively connected to said work supporting head for moving said article in an arcuate path substantially normal to the plane of sweep of said tool on a radius substantially equal to the desired radius of curvature to be formed in said opposed major meridian.

4. A surfacing machine comprising a base, a work supporting head located upon the base for carrying an article to be surfaced, locating mechanism on said base adjacent the work supporting head, an axially rotatable cup-shaped abrading tool having an effective abrading portion of arcuate shape in section, a tool supporting head carrying said tool and being pivotally connected to said locating mechanism for adjustment about a first axis disposed approximately normal to the axis of the tool and passing through said effective abrading portion thereof, means for supporting the article to be surfaced on said work supporting head with a surface in position for abrading action by the tool, said locating mechanism being rotatable about a second axis substantially parallel to the pivotal axis of the tool supporting head and adjustable toward and away from said first axis whereby the tool may sweep transversely across the article on a radius in accordance with the curvature to be formed on the article in one major meridian, said tool supporting head being adjustable on said locating mechanism about said first axis to locate the tool in operative position with respect to the surface of the article to be abraded and at an angle thereto in accordance with the general curvature to be formed on said surface in the opposed major meridian, and oscillating means operatively connected to said work supporting head for moving said article in an arcuate path substantially normal to the plane of sweep of said tool on a radius adjustable to substantially equal the desired radius of curvature to be formed in said opposed major meridian.

ian, said arcuate movement of the article being about an axis located in the plane of sweep of the tool and on the side of the article directed toward the tool.

5. A surfacing machine comprising a base, a work supporting head located upon the base for carrying an article to be surfaced, locating mechanism on said base adjacent the work supporting head, an axially rotatable abrading tool of ring shape and having an effective abrading surface of arcuate shape in section a tool supporting head carrying said tool and being pivotally connected to said locating mechanism for adjustment of the tool about a first axis approximately normal to the axis of the tool and intersecting the effective abrading portion thereof, means for supporting the article to be surfaced on said work supporting head with its surface exposed for abrading action thereon, said locating mechanism being rotatable about a second axis approximately parallel to said first axis and adjustable toward and away from said first axis whereby the tool may sweep transversely across the surface of the article to be abraded on a radius in accordance with the curvature to be formed on said surface in one major meridian, said tool supporting head being adjustable on said locating mechanism about said first axis to locate the tool in operative position with respect to said surface of the article and at an angle thereto in accordance with the general curvature to be formed on said surface in the opposed major meridian, and oscillating means operatively connected to said work supporting head and comprising a stand carried by said base and adjustable toward and away said work supporting head and having bearing portions for carrying said work supporting head for oscillating movement about the axes thereof, said axes of the bearing portions being located substantially parallel to and intersecting the plane defined by the sweep of the tool and on the side of the article directed toward the tool.

6. The method of forming a curved surface on an article such as a lens comprising supporting the surface of an article in line engagement with the portion of an axially rotating cupped-type abrading tool which controls the radius of curvature formed therein said tool being angled with respect to the surface of said article in accordance with the general curvature to be formed on said surface in one major meridian, feeding said tool in an arcuate path transversely across the surface of said article about an axis spaced from the effective abrading surface of the tool an amount substantially equal to the radius of curvature to be formed on the surface of said article in the opposed major meridian, and oscillating said article while in engagement with said tool to provide the desired curvature on said surface of the article in the first said major meridian.

7. The method of forming a curved surface on an article such as a lens comprising supporting an article for engagement with a cupped-type abrading tool, rotating said tool while angled with respect to said article in accordance with the general curvature to be formed on the article in one major meridian to cause the portion of the tool which controls the resultant radius of curvature formed in one major meridian of the article to maintain line contact with the surface being abraded, feeding said tool in an arcuate path transversely across said article about an axis spaced from the effective abrading surface of the tool an amount substantially equal to the

radius of curvature to be formed on the article in the opposed major meridian, and oscillating said article while in engagement with said tool about an axis located in the plane of sweep of the tool to cause the article to move in an arcuate path substantially normal to the plane of sweep of the tool on a predetermined radius to provide the desired curvature on the article in the first said major meridian.

8. A surfacing device of the character described comprising a work-support and an axially rotatable ring-type abrading tool having an effective abrading portion of arcuate shape in section, a tool support supporting said abrading tool for sweeping movement across the surface of the work when in abrading relation therewith about an axis disposed substantially normal to the axis of rotation of the tool, said tool being so disposed on said tool support that its effective abrading portion which controls the resultant curvature formed in one major meridian of the work has substantially line contact with the surface of the work during the abrading action, means for adjusting the spacing between said axis of rotation of the tool support and the surface of the work to be abraded to control the radius of sweep of the effective abrading portion of the tool across said surface of the work, said work support being mounted for movement about an axis disposed approximately normal to the axis of rotation of the tool support and lying within the plane defined by said sweep of the abrading portion of the tool across the surface of the work, and means for causing oscillatory movement of the work support about its axis whereby a compound curvature may be formed on the surface of the work supported thereby controlled according to the radii of swing of the tool and the work about the axes of their respective supports while maintaining line contact between the surface of the work being abraded and said portion of the tool.

9. A surfacing device of the character described comprising a work-support and an axially rotatable ring-type abrading tool having an effective abrading portion of arcuate shape in section, a tool support supporting said abrading tool for sweeping movement across the surface of the work when in abrading relation therewith about an axis disposed substantially normal to the axis of rotation of the tool, said tool being pivotally connected to said tool support for adjustment about a second axis disposed substantially parallel with the axis of the tool support and passing through the effective abrading portion of the tool, means for adjusting the spacing between said axis of rotation of the tool support and said axis about which the tool is adjustable to control the radius of sweep of the effective abrading portion of the tool across the surface of the work, said work support being mounted for movement about an axis disposed approximately normal to the axis of rotation of the tool support and lying within the plane defined by said sweep of the abrading portion of the tool across the surface of the work, and means for causing oscillatory movement of the work support about its axis whereby a compound curvature may be formed on the surface of the work supported thereby controlled according to the radii of swing of the tool and the work about the axes of their respective supports and the angular disposition of the abrading tool about said second axis.

10. A surfacing device of the character described comprising a work holder and a support

for said work holder, an axially rotatable ring-type abrading tool having an effective abrading portion of arcuate shape in section, a tool support supporting said abrading tool for sweeping movement across the surface of the work when in abrading relation therewith about an axis disposed substantially normal to the axis of rotation of the tool, said tool being pivotally connected to said tool support for adjustment about a second axis disposed substantially parallel with the axis of the tool support and passing through the effective abrading portion of the tool, means for adjusting the spacing between said axis of rotation of the tool support and said axis about which the tool is adjustable to control the radius of sweep of the effective abrading portion of the tool across the surface of the work, the work holder being movable on its support in directions toward and away from said second axis to position the work within the sweep of the abrading portion of the tool, and said support for the work holder being mounted for movement about an axis disposed approximately normal to the axis of rotation of the tool support and lying within the plane defined by said sweep of the abrading portion of the tool across the surface of the work, and means for causing oscillatory movement of the work holder and its support about the axis of the support whereby a compound curvature may be formed on the surface of the work supported thereby controlled according to the radii of swing of the tool and the work about the axes of their respective supports and the angular disposition of the abrading tool about said second axis.

11. A surfacing device of the character described comprising a work-support and an axially rotatable ring-type abrading tool having an effective abrading portion of arcuate shape in section, a tool support supporting said abrading tool for sweeping movement across the surface of the work when in abrading relation therewith about an axis disposed substantially normal to the axis of rotation of the tool, said tool being pivotally connected to said tool support for adjustment about a second axis disposed substantially parallel with the axis of the tool support and passing through the effective abrading portion of the tool, means for adjusting the spacing between said axis of rotation of the tool support and said axis about which the tool is adjustable to control the radius of sweep of the effective abrading portion of the tool across the surface of the work, said work support being mounted for movement about an axis disposed approximately normal to the axis of rotation of the tool support and lying within the plane defined by said sweep of the abrading portion of the tool across the surface of the work, a first cylinder, a piston movable in said first cylinder and operatively connected with the work support, a second cylinder having a pair of conduits connected to adjacent the opposed ends of said first cylinder on opposite sides of the piston, a rotatable member in said second cylinder and a pair of reciprocating members co-operatively associated with each other to divide said second cylinder into a pair of chambers, each of said conduits entering a respective one of said chambers, and said rotatable member being of eccentric shape such that during its rotation fluid may be forced out of one chamber through the communicating conduit while being restricted from the other to reciprocate the piston and move the work support about its axis across the surface of the work whereby a compound curvature may be formed on the surface of the

13

work supported thereby controlled according to the radius of swing of the tool and the work about the axes of their respective supports and the angular disposition of the abrading tool about said second axis.

12. A surfacing device of the character described comprising means for supporting the work to be abraded, means for supporting a tool in surfacing action therewith, and a pivotally mounted support for at least one of said means, a first cylinder, a piston movable in said first cylinder and operatively connected with said pivotally mounted support, a second cylinder having a pair of conduits connected to adjacent the opposed ends of said first cylinder on opposite sides of the piston, a rotatable member in said second cylinder and a pair of reciprocating members cooperatively associated with each other to divide said second cylinder into a pair of chambers, each of said conduits entering a respective one of said chambers, and said rotatable member being of eccentric shape such that during its rotation fluid will be forced out of one chamber through the communicating conduit while being restricted from the other to reciprocate the piston and the said support operatively connected therewith to obtain a surfacing action by the tool upon the work.

13. A surfacing device of the character described comprising a pair of supports, one of said supports embodying means for supporting work and the other embodying means for supporting a tool, one of said supports being axially rotatable, and the other of said supports being mounted for movement about an axis disposed approximately normal to the axis of rotation of

14

the axially rotatable support, a first cylinder, a piston movable in said first cylinder and operatively connected with said other support, a second cylinder having a pair of conduits connected to adjacent the opposed ends of said first cylinder on opposite sides of the piston, a rotatable member in said second cylinder and a pair of reciprocating members cooperatively associated with each other to divide said second cylinder into a pair of chambers, each of said conduits entering a respective one of said chambers, and said rotatable member being of eccentric shape such that during its rotation fluid will be forced out of one chamber through the communicating conduit while being restricted from the other to reciprocate the piston and the said support operatively connected therewith, and means for adjusting the spacing between the axis of said support and the respective means carried thereby.

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