Dec. 19, 1922.

1,439,063.

L. W. BUGBEE ET AL.

LENS GRINDING MACHINE.

FILED JUNE 7, 1915.

3 SHEETS—SHEET 1.

Fig. VII.

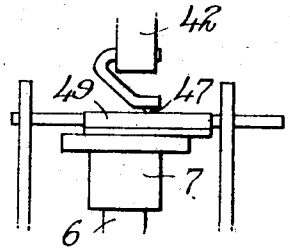
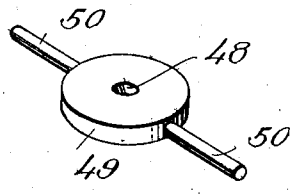


Fig. VI.



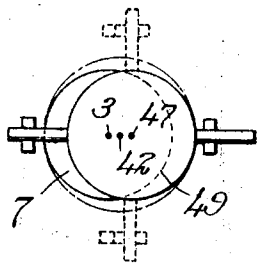


Fig. VIII.

Fig. I.

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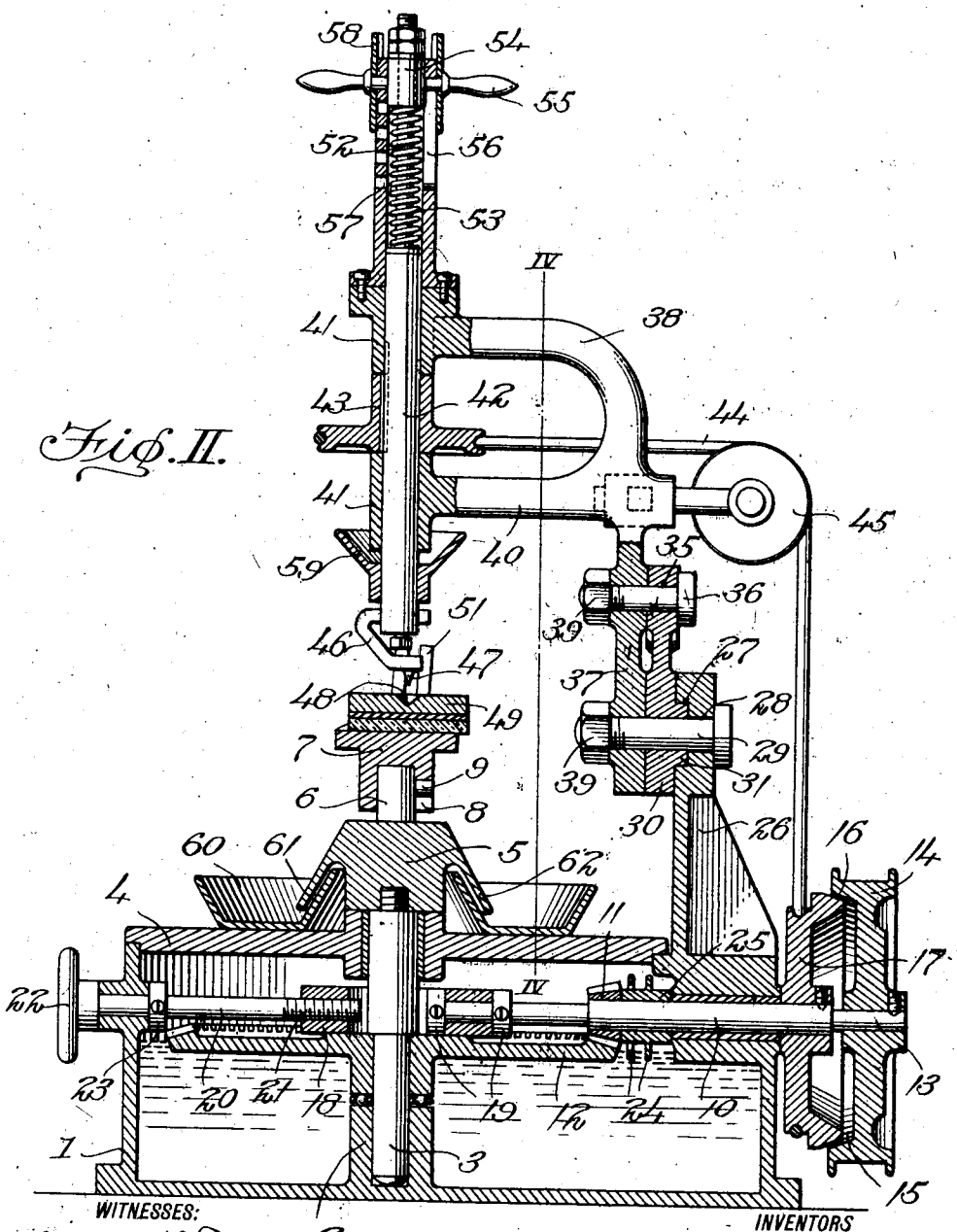
3 SHEETS—SHEET 2.

Fig. II.



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3 SHEETS—SHEET 3.

Fig. III.

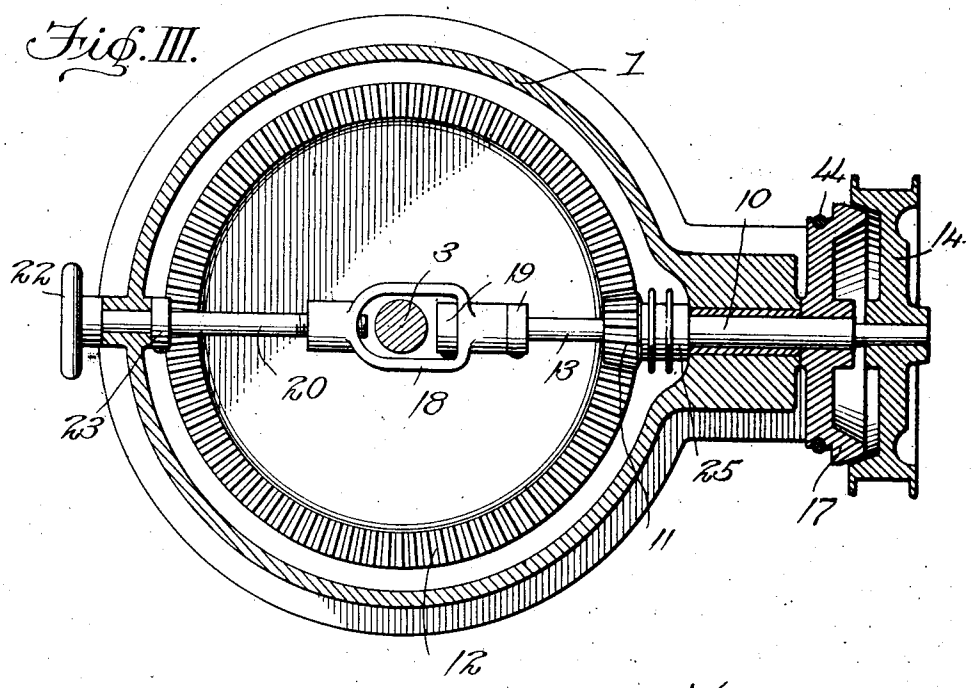


Fig. V.

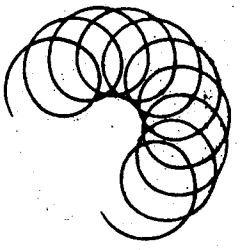
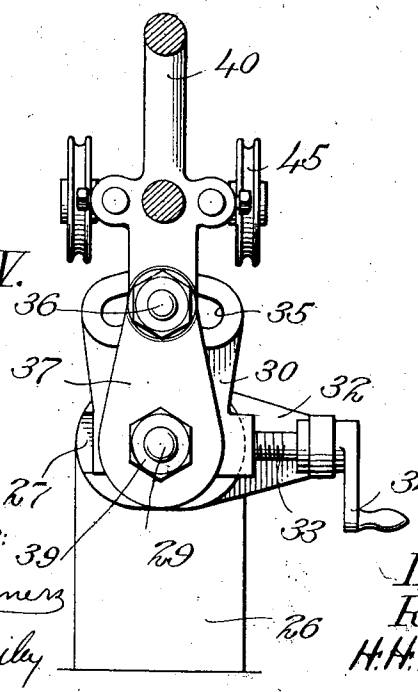


Fig. IV.



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Patented Dec. 19, 1922. 1,439,063

UNITED STATES PATENT OFFICE.

LUCIAN W. BUGBEE AND ROBERT L. GORDON, OF SOUTHBRIDGE, MASSACHUSETTS, ASSIGNORS TO AMERICAN OPTICAL COMPANY, OF SOUTHBRIDGE, MASSACHUSETTS.

LENS-GRINDING MACHINE.

Application filed June 7, 1915. Serial No. 32,590.

To all whom it may concern:

Be it known that we, LUCIAN W. BUGBEE and ROBERT L. GORDON, citizens of the United States, residing at Southbridge, in the county of Worcester and State of Massachusetts, have invented certain new and useful Improvements in Lens-Grinding Machines, of which the following is a specification.

This invention relates to lens grinding and polishing machines and has for its primary object to provide a machine of this character which is simple in construction and which is thoroughly reliable and efficient in operation.

Another object is to provide means whereby the path of movement of the lens over the tool is thoroughly broken up thereby preventing the formation of wave surfaces or other imperfections upon the lenses.

A further object is to provide means whereby the amount of pressure of the lens against the tool may be varied, and to so construct the machine as to permit of a direct pressure of the lens against the tool irrespective of the curve thereon.

Other objects are to provide novel and efficient clutch means for operating the machine, and to provide means for readily and easily swinging the lens so as to permit the same to bear directly against the curve of the tool.

With the foregoing and other objects in view the invention consists in the novel features of construction, combination and arrangement of parts as will be hereinafter more fully described, illustrated in the accompanying drawings, and claimed.

In the drawings:

Figure I is a front elevation of the complete machine.

Figure II is a vertical longitudinal sectional view therethrough.

Figure III is a horizontal sectional view through the base portion of the machine.

Figure IV is a vertical sectional view on the line IV—IV of Figure II.

Figure V is a graphic view illustrating the relative path of movement between the lens and lap during operation of the machine.

Figure VI is a detail perspective view of the lens block.

Figure VII is a side elevation illustrating the movement accomplished between the lens and lap.

Figure VIII is a plan view of the structure illustrated in Figure VII.

This invention is for a machine for surfacing lenses and is of the type known as a lap grinding machine wherein a tool or lap, as it is known, has thereon the curve which is to be reproduced on the lens, as distinguished from that type of machine wherein the curve is not reproduced from the tool but is generated as its manufacture progresses, the final curvature not depending on the curvature on the tool. In lap grinding the lens is produced by moving the glass stock over the lap or tool, or the reverse, in such a way that the curvature on the lap is reproduced on the glass stock, it being understood, of course, that the curves on the tool and the lens are opposite, that is to say, a convex tool will produce a concave surface lens. A machine of this invention will perform all of the operations necessary to surface a finished lens; that is to say, grinding, fine grinding, smoothing, polishing, etc. The grinding operations are performed usually by utilizing metal tools or laps with abrasives, such as emery in different degrees of fineness, while the polishing operations are performed usually by utilizing a felt or soft covered tool with polishing material, such as rouge. In the polishing operations the polishing tool follows the curvature that has already been made on the stock or work. The material of the polishing tool being soft assumes the shape of the work when pressed thereon, but need not necessarily be of the exact shape of the work when out of contact therewith, although it is usually of substantially the same shape. Both grinding and polishing are common and well known in the art. It will, therefore, be understood that this machine is not limited to any one of the grinding or polishing operations but will perform them all from start to finish, it being essentially a machine for manufacturing a complete lens.

Referring to the drawings by numerals, wherein is illustrated the preferred embodi-

...vention, 1 designates the base ...machine which is hollow and which is ...ded with the socket or bearing portion 2, in which is mounted the lower end of the spindle 3. This spindle is vertically arranged within the base 1, has the upper end thereof journaled within a bearing in the cover 4 of the base, and has secured at its upper end the member 5 carrying the stud 6, upon which the lap 7 is fixedly mounted, a slot 8 being formed in the lap for engagement with a pin 9 on the stud 6 to prevent rotation of the lap relative to the stud and to provide means whereby other laps may be readily and easily applied to the machine.

A hollow shaft 10 is mounted in the side wall of the base 1 and has fixedly secured to the inner end thereof the pinion 11 for engagement with the gear 12 on the shaft 3, whereby rotation of the shaft 10 will impart a rotary movement to the lap 7. A shaft 13 is longitudinally slidable within the shaft 10 and has fixedly secured to the outer end thereof the drive pulley 14 provided with the clutch face 15 for engagement with the correspondingly shaped face 16 of the operating pulley 17 which is fixedly secured to the outer end of the hollow shaft 10.

A yoke 18 is arranged about the shaft 3 for longitudinal sliding movement and has swivelled thereto, as by means of the collars 19, the inner end of the shaft 13, whereby this shaft is freely rotatable therein, but is held against longitudinal movement relative thereto. A rod 20 is rotatably mounted in the side wall of the base 1 and has the inner end thereof screw threaded as at 21, for engagement in a correspondingly screw threaded opening in the yoke 18, whereby rotation of the rod by means of the operating handle 22 will cause the yoke to be longitudinally moved and the clutch face of the pulley 14 thus brought into or out of engagement with the clutch face of the pulley 17 through the medium of the shaft 13, a collar 23 being mounted on the rod 20 and engaging the inner face of the side wall of the base in order to prevent longitudinal movement of the rod in either direction.

In order to thoroughly and efficiently lubricate all of the working parts contained within the base 1, the base is filled with oil or any other suitable lubricant to a level so that the flanges 24 of the spool 25 which is mounted upon the hollow shaft 10 will dip therein, and it will be understood that when the said shaft is rotated the flanges 24 will be caused to take up the oil and throw it to the various working parts of the machine contained within the base.

Rising vertically from the rear portion of the machine is a bracket 26 having formed in the front face thereof the channel 27 and having communicating with the said channel and extending any suitable distance throughout the width thereof the slot 28 in which is slidably mounted the stud 29.

A member 30 is provided with an opening to receive the stud 29 and has formed on the inner face thereof the extension 31 for engagement with the channel 27 whereby tilting movement of this member upon the bracket is effectually prevented. The laterally extending offset portion 32 is formed on the bracket 26 and has suitably journaled therein against longitudinal movement the screw threaded shank 33 provided with the operating handle 34. This shank is threaded into an opening in the member 30 so that by turning the handle 34 the said member 30 will be laterally shifted as will be understood. The upper portion of the member 30 is provided with a slot 35 which is radially described from the center of the stud 29 and has operating therein the stud 36 which has the outer end thereof received within an opening in the depending portion 37 of a frame 38, the lowermost portion of the depending portion 37 being journaled upon the outer end of the stud 29 for pivotal movement thereon, as is clearly illustrated in Figure II of the drawings, the slotted connection between the upper end of the member 30 and the stud 36 permitting of angular adjustment of the frame with respect to the base of the machine, and the nuts 39 being threaded on the outer end of the studs 29 and 36 for clamping engagement with the outer face of the portion 37 for locking the frame in any desired angular adjustment.

The frame 38 comprises the U-shaped arms 40 having at their outer ends the bearings 41 in which is rotatably mounted the spindle 42, a pulley 43 being keyed to the spindle between the bearings 41 and having a belt 44 trained thereover, thence over guide idler pulleys 45 on the frame 38 and finally over the pulley 17, whereby a rotary motion is imparted thereto.

Slidably mounted for radial adjustment in the lower end of the spindle 42 is a crank bracket 46 carrying the pin 47 for engagement in the recess 48 in the lens block 49 for a purpose which will subsequently appear.

The lens block 49 is provided with a pair of diametrically oppositely extending arms 50 which are adapted to operate between the bars 51 which are pivotally mounted at diametrically opposite points upon the member 5.

The upper end of the spindle 42 is provided with a reduced extension 52 about which is arranged a coil spring 53 which has the lower end thereof resting against the shoulder provided by the reducing of the spindle and normally exerts a tension to force the spindle downward and thus hold the lens in engagement with the lap, the upper end of the spring bearing against a

member 54 slidably arranged within the frame, as is clearly illustrated in Figure II of the drawings.

In order to provide means whereby the amount of pressure of the lens against the lap may be varied, the member 54 is provided with the hand grip handles 55 which are vertically movable within the slots 56 in the upper portion of the frame 38, and which are adapted to be engaged with the different offset recesses 57 in the sides of the slots to lock the spring in any desired tension position, suitable guard members 58 being arranged upon the handles 55 for engagement with the side of the frame in order to prevent the possibility of injury to the operator of the machine.

From the foregoing description taken in connection with the accompanying drawings, it is thought that the construction of the machine should be clearly apparent, the only remaining features to be described being the cup 59 on the lower end of the spindle 42 which prevents oil or water or any other foreign substance from coming in contact with the face of the lens being ground and the dish 60 which rests upon the cover 4 and is provided with the upwardly and inwardly extending flange 61 which is arranged beneath a flange 62 on the member 5 so as to prevent any of the abrasive material used upon the lens during grinding or polishing thereof from becoming engaged with any of the working parts of the machine contained within the base 1.

In operation a lap having the desired curve of the lens to be ground, is placed upon the stud 6 and the lens blank to be ground or polished is secured in any suitable manner to the under face of the block 49. The block is placed upon the lap 7 with the arms 50 thereof arranged between the pivoted bars 51. Next the frame 38 is laterally shifted any preferred distance by means of the handle 34, the nuts 39 loosened and the frame swung to an angle to cause the axis of the spindle 42 to lie in a plane at exact right angles to the tangent of the curve of the lap at its point of intersection of said axis therewith, so, therefore, the line of the axis of the work spindle will intersect the line of the axis of the tool spindle substantially at the common center of curvature of the tool and work surfaces, and the spring 53 then tensioned to hold the lens in firm engagement with the lap. Motion is imparted to the drive pulley 14 from any suitable source of power and by operating the wheel 22 it will be obvious that the power will be transmitted through the pulleys 17 and 43 to the spindle 42 and through the pinion 11 to the gear 12 to cause rotation of the lap.

From the assembly of the parts shown and described it will be seen that the axis of the spindle 42 is offset with respect to the point of the lap 7, and that the center of the crank pin 47 is offset with respect to the axis of the spindle 42 as shown in Figure VIII. Now it should be apparent that rotation of the spindle 42 will cause the block and lens carried thereby to be moved in an orbital path about the axis of the said spindle, or, in other words, the block and lens will be moved bodily about the axis of the spindle in a curved path eccentric with respect to the lap 7, as should be clearly apparent by reference to Figures VII and VIII of the drawings. It will also be apparent that because of the provision of the arms 50 upon the block 49 and their engagement with the bars 51, rotation of the lap will cause the block and lens to be rotated at a corresponding rate of speed, the connection between the bars 51 at their lower ends and the member 5 permitting of the eccentric movement of the lens upon the lap, as will be understood. In grinding or polishing spherical lenses it will, of course, be understood it is not necessary to prevent the relative rotary movement of lens and lap and in using the apparatus for grinding and polishing such lenses therefore means for preventing such relative movement need not be used.

By reference particularly to Figure II the general driving or actuation of the parts of our machine should be most clear, and it will be noted that the lap spindle 3 is driven through the medium of the large gear 12 meshing with the small pinion 11 and consequently will be operated at a relatively low rate of speed, while on the other hand the block spindle 42 is driven through the medium of the belt 44, passing around the small pulley on the spindle, and the larger driving pulley 17, and consequently the spindle 42 will be driven at a relatively high rate of speed, being driven at a somewhat more rapid rate than the main drive from the pulley 14, while as the spindle 3 is driven through the small pinion and large gear it will rotate at a considerably lower rate of speed than the main drive 14, there, therefore, being preferably a considerable difference in the relative speeds of the upper and lower spindles.

In the grinding and polishing of various lenses it will be apparent that with the construction illustrated in the accompanying drawings and described in the foregoing specification the movement of the crank pin over the tool will be as illustrated in Figure V of the drawings. If for sake of illustration the tool were covered with chalk or some such covering and the crank pin were let down onto the tool instead of being placed in contact with the work holder, it would engrave or mark on the chalked surface of the tool the diagram or configu-

Figure V. This movement involves a circular motion of the pin about its axis, but in addition thereto an advancing motion as well. This motion is a composite one composed of one motion of the crank pin being carried around in a circle about the axis of its spindle and another motion brought about by the rotation of the tool on its spindle. It is also affected by the relative speeds of the tool and crank pin spindles, these spindles being operated at different speeds, the crank pin spindle traveling at the higher rate of speed, as explained elsewhere herein. The position of this configuration on the lap is affected and regulated by the lateral shifting of the crank pin spindle on its base and by the lateral adjustment of the crank pin with respect to its spindle, as has been described herein. The effect of this motion is to give what is known in the art as a break-up motion, that is to say, the work as it passes over the tool will not travel in the same path each time it is turned around, as is best considered by taking a single grain of abrasive and watching its course. If the motion were a plain circular one the grain would pass around and around in the same circular path, scratching a deep cut in the lens. Several grains would cause concentric rings or scratches in the lens, but with the advancing motion just described these concentric rings do not occur, because the grain does not follow the first ring or scratch in its second time around, but follows a new path on each revolution. This is true of all the grains; hence the scratched concentric rings are not formed, but an even, uniform and unmarred surface is produced on the lens, and by means of the angular and lateral shifts of the crank pin spindle, the path of the configuration on the lap can be altered and changed at will and all parts of the surface of the lap utilized to prevent wear in any one particular location, or the lens may be shifted on the lap to any desired position to obtain the best surface on the lens and the truest curvature thereof.

The Diagram V illustrates as well the movement of a grain of abrasive over the surface of the work as well as the movement of the crank pin over the tool; hence it will be seen that the abrasive does not travel in concentric rings around the work but that it does travel in an ever changing path, not returning to its original path for periods of several revolutions at least, if at all, and so seldom as not to score the surface as would be the case in a non-advancing movement.

From the foregoing description taken in connection with the accompanying drawings, it will be seen that a machine has been provided which may be used in grinding or polishing spherical, cylindrical and toric lenses, which may either plano, concave or convex, and that the parts of the machine have been so arranged as to positively break up the movement between the lens and lap during the grinding or polishing operation, whereby the formation of wave surfaces or other imperfections upon the lenses is effectually prevented. Also that means have been provided for varying the tension engagement between the lens and lap and that the machine as an entirety is of very simple, reliable and efficient construction.

It is thought that the construction, advantages and operation of the machine will be clearly apparent without a further detail description, and while we have herein shown and described one specific form of our invention we do not wish to be limited thereto except as the claims may import.

We claim:

1. A machine of the character set forth, comprising a base, a lap mounted thereon, a frame adjustable laterally on said base, means whereby the frame may be swung at an angle with respect to said lap, a spindle mounted on said frame for longitudinal movement, a lens block operatable through said spindle, a spring exerting a pressure to force the block into engagement with the lap, means slidable in said frame to adjust the tension of the spring, means to rotate said spindle and said lap, and means engaging the block to rotate it with said lap but permit its lateral and vertical movement relative thereto.

2. In a machine of the character described, a lens grinding or polishing tool, a spindle, and a lens block operatable by said spindle, a frame in which said spindle is longitudinally slidable, said frame having a laterally notched longitudinal slot formed therein, a member slidable in said frame, a spring arranged between said member and said spindle, and means on said member for engagement with said notches to vary the tension of the spring.

3. A lens grinding and polishing machine, including a base or support, a spindle rotatably mounted therein, a lap carried by the spindle, guides carried by the spindle and projecting adjacent the lap, a lens block adapted to be mounted on the lap and having portions to interlock with the guides, a tiltable laterally adjustable spindle disposed above the lap, and a crank arm carried by the spindle and engaging the block, substantially as and for the purpose described.

4. A machine for grinding and polishing toric lenses, including opposed spindles, a lap carried by one of said spindles, a lens bearing block for engagement with the lap, interlocking connections on the block and lap for maintaining the axis of said parts

parallel to each other, and a crank arm carried by the other of said spindles and engaging the block for imparting a circular movement to the same in addition to the movement imparted by the lap and interlocking connections.

5. A lens grinding and polishing machine including a pair of opposed spindles, one of said spindles being angularly adjustable with respect to the other and having an offset crank pin.

6. A lens grinding and polishing machine including a pair of opposed spindles, one of said spindles being laterally and angularly adjustable as respects the other, said adjustable spindle having an offset crank pin.

7. A machine for grinding and polishing lenses including opposed spindles, means for rotating said spindles, a lap carried by one of said spindles, a lens bearing block for engagement with the lap, a crank arm carried by the other of said spindles to engage the lens bearing block and shift it in a circular path about the axis of the crank spindle extended as a center, means for securing the crank in laterally adjusted position as respects its spindle to vary the size of circle described by the block, and means for bodily laterally shifting the crank spindle with respect to the lap to vary the portion of the lap traversed by the block for a particular adjustment of the crank arm.

8. A machine of the character described including driven opposed spindles, lens engaging members comprising a lap for engagement by one of the spindles and a lens block for cooperation with the lap, means for holding said parts in sliding engagement but preventing their relative rotation, means for angularly adjusting one of the spindles, and a crank arm carried by the angularly adjustable spindle and engaging one of the lens engaging members for sliding said member in circles over the other of the lens engaging members while the parts are held against relative rotation.

9. A lens grinding and polishing machine including a frame, a rotatable spindle carried thereby, an axially slidable spindle opposed thereto, an angularly adjustable support for said slidable spindle, means for holding said slidable spindle against vertical movement, and a crank carried by the angularly adjustable spindle, substantially as and for the purpose described.

10. In a device of the character described, the combination with a tool and an opposed glass holder, of pivotal means for adjusting the relationship between the tool and holder, said means including a pivot located substantially in transverse alinement with the operative face of the tool, substantially as and for the purpose described.

11. A lens grinding and polishing machine including a base, a bracket rising from the rear of the base, a spindle journaled in the base, a second spindle, transversely slidable connections between the bracket and second spindle whereby the spindles may be relatively laterally adjusted, a pivot connection between said bracket and upper spindle disposed slightly above the horizontal plane of the top of the lower spindle whereby the upper spindle may be angularly adjusted with respect to the lower spindle and the point of intersection of the axis of the upper spindle with the surface of the grinding member carried by the lower spindle maintained constant and a laterally offset crank carried by said laterally and angularly adjustable upper spindle.

12. Adjusting mechanism for a lens grinding and polishing machine including a spindle casing, a spindle slidably mounted within the casing, a spring for placing the spindle under tension, a collar for engagement with the spring, and a projection on the collar, the casing having a plurality of communicating notches formed therein adapted to selectively engage the projection to variably secure the collar in adjusted position to control the pressure of the spring against the spindle.

13. Adjusting mechanism for a lens grinding and polishing machine including a spindle casing, a spindle slidably mounted within the casing, a spring in the casing for placing the spindle under tension, a collar in the casing for engagement with the spring, and a projection on the collar, the casing having a slot and a plurality of notches formed therein adapted to selectively engage the projection to variably secure the collar in adjusted position to control the pressure of the spring against the spindle, and means carried by the spindle to engage the collar and retain the spindle in inoperative position upon raising of the collar.

14. In a lens grinding and polishing machine, the combination with a base, of a supporting bracket rising therefrom, bearings carried by the bracket, a spindle slidably and rotatably journaled in the bearings, a drive pulley splined on the spindle, means for rotating said pulley to drive the spindle, a tubular casing carried by the bracket and enclosing the upper end of the spindle, said upper end of the spindle being reduced and projecting upwardly within the casing, a spring encircling the reduced end of the spindle, a collar on the spindle above the spring, a stop carried by the spindle above the collar, and means for securing the collar in desired adjusted position within the casing whereby when the collar is raised its engagement with the stop will lift the spindle and when compressed it will compress the spring to resiliently force the spindle downward.

lens grinding and polishing machine, the combination with a spindle casing of a spindle slidable in the casing, a spring for actuating the spindle, a control for the spring slidably mounted within the casing, said control having a portion for interlocking engagement with the spindle, and means for selectively shifting the control to vary the spring tension or through said connections to shift the spindle into inoperative position.

16. In a lens grinding and polishing machine, the combination with a spindle casing, a spindle slidable in the casing, a spring for actuating the spindle, a control for the spring, said control having a portion for interlocking engagement with the spindle, means for selectively shifting the control to vary the spring tension or through said connections to shift the spindle into inoperative position, and means for selectively securing the control in desired adjusted position, said means including a rack portion on the casing and projections on the control for variable engagement with the rack member.

17. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting work and tool members one having a convex and the other a concave surface, means for imparting a concentric rotary movement to one of said members, and means for moving the other of said members bodily in a curved path the axis of said moving means intersecting the axis of rotation of the first said member substantially at the common center of curvature of the surfaces of the two co-acting members.

18. Apparatus for grinding and polishing spherically curved surfaces, comprising a pair of co-acting work and tool members one having a convex and the other a concave surface, means for imparting a concentric rotary movement to one of said members, means for moving the other of said members bodily in a curved path about an axis which intersects the axis of rotation of the first said member substantially at the common center of curvature of the surfaces of the two co-acting members, and means for pressing the two co-acting members together with a constant force.

19. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting work and tool members one having a convex and the other a concave surface, and a pair of rotary driving spindles for actuating said co-acting members, said spindles having their axes of rotation mutually inclined in the same plane and intersecting at substantially the common center of curvature of the surfaces of the co-acting members, one of said co-acting members being mounted concentrically on its driving spindle, and the other of said members being connected to its driving spindle eccentrically so as to be moved thereby bodily in a curved path on and about the surface of the first-mentioned member.

20. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting work and tool members one having a convex and the other a concave surface, means for imparting a concentric rotary movement to one of said members, and means for moving the other of said members bodily in an eccentric path on and about the surface of the first mentioned member, said moving means including a device to engage and move the said member and being adjustable to any position in a line radial to the common center of curvature of the two coacting members.

21. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting work and tool members one having a convex and the other a concave surface, a pair of rotary driving spindles for actuating said coacting members, said spindles having their axes of rotation mutually inclined and intersecting substantially at the common center of curvature of the surfaces of the coacting members, one of said members being mounted concentrically on its driving spindle and the other of said members being connected to its driving spindle eccentrically so as to be moved thereby bodily in a curved path on and about the surface of the other member, and spindle driving means whereby the spindle carrying the concentrically mounted cooperating member is rotated more slowly than the spindle driving the eccentrically mounted cooperating member.

22. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting members, one having a convex and the other a concave surface, a pair of rotary driving spindles for actuating said co-acting members, said spindles having their axes of rotation mutually inclined in the same plane and intersecting at substantially the common center of curvature of the surfaces of the co-acting members, one member being mounted concentrically on its driving spindle, and the other member being connected to its driving spindle eccentrically so as to be moved thereby bodily in a circular path on and about the surface of the other member, and spindle driving means whereby the spindles carrying the two members are rotated at different rates of speed.

23. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting tool and work members, one having a convex surface and the other a concave surface, means for imparting a concentric rotary movement to one of said members, and moving means for the other of said members, including an element maintained

by means independent of the contact between said members to move at a fixed distance from a line which intersects the axis of rotation of the first member substantially at the common center of curvature of the surfaces of the two coacting members and a connection between said element and said second member.

24. Apparatus for grinding and polishing spherically curved surfaces, comprising a pair of coacting tool and work members, one having a convex and the other a concave surface, means for imparting a concentric rotary movement to one of said members, means for moving the other of said members bodily in a circular path, said means including an element maintained by means independent of the contact between said members to move at a fixed distance from a line which axis intersects the axis of rotation of the first said member substantially at the common center of curvature of the surfaces of the two coacting members, and a connection between said element and said second member, and means arranged to press the two coacting members together.

25. Apparatus for grinding and polishing curved surfaces, comprising a pair of coacting tool and work members, one having a convex and the other a concave surface, means for imparting a concentric rotary movement to one of said members, and moving means for the other of said members including an element maintained by means independent of the contact between said members to move at a fixed distance from a line which is inclined to the axis of rotation of the first said member and intersects said axis substantially at the common center of curvature of the coacting surfaces of said members, a connection between said element and said second member and a spring to press said second member against said first member.

26. Means for grinding and polishing curved surfaces, comprising a pair of coacting tool and work members, one having a convex and the other a concave surface, means for imparting a concentric rotary movement to the convex member, and moving means for the concave member, including an element maintained by means independent of the contact between the coacting members to move at a fixed distance from a line which intersects the axis of rotation of the convex member substantially at the common center of curvature of the surfaces of the two coacting members, and a connection between said element and the concave member.

27. Apparatus for grinding and polishing spherically curved surfaces, comprising a pair of coacting tool and work members, one having a convex and the other a concave surface, means for imparting a concentric rotary movement to the convex member, means for moving the concave member bodily in a circular path, said means including an element maintained by means independent of the contact between said members to move at a fixed distance from a line which intersects the axis of rotation of the convex member substantially at the common center of curvature of the surfaces of the two coacting members, a connection between said element and the concave member, and means arranged to press the two coacting members together with a force which remains constant throughout the circular movement of the second mentioned member.

28. Means for grinding and polishing curved surfaces, comprising a pair of coacting tool and work members, one having a convex and the other a concave surface, means for imparting a concentric rotary movement to the convex member, moving means for the concave member, including an element maintained by means independent of the contact between said members to move at a fixed distance from a line which is inclined to the axis of rotation of the convex member and intersects said axis substantially at the common center of curvature of the surfaces of the two coacting members, a connection between said element and said concave member, and a spring to press the concave member against the convex member.

29. A machine for grinding and polishing curved surfaces, comprising a work holding tool and a grinding or polishing tool having a curved surface corresponding to the surface to be made on the work, means for giving one of said tools a rotary movement at a relatively low rate and for giving the other of said tools a bodily movement at a relatively higher rate in a curved path about a center offset from the axis of rotation of the rotating tool.

30. A machine for grinding and polishing curved surfaces, comprising in combination a work holding and a grinding or polishing tool having a curved surface corresponding to the surface to be made on the work, means for rotating one of said tools at a relatively low rate and for giving to the other of said tools a bodily movement at a relatively higher and substantially constant velocity and without sudden change of direction in a path the center of which is offset from the axis of the rotating tool.

31. A grinding and polishing machine, comprising in combination a work holding member and a grinding or polishing member, means for producing between said members a relative movement comprising a relatively slow rotary movement about a fixed axis and a movement in a curved path eccentric to the axis of said rotary movement and at a relatively higher rate, and means

adjustably varying the eccentricity of said curved path.

32. A grinding and polishing machine, comprising in combination a work holding member and a grinding or polishing member, means for producing between said members a relative movement comprising a rotary movement about a fixed axis and a continuous movement in a curved path whose center is offset from the axis of said rotary movement, and means for retaining the center of the curved path and the axis of the rotary movement at a fixed distance from each other during the grinding or polishing operation, such means being adapted to permit adjustably varying said distance.

33. A lens grinding and polishing machine including a tool having the curvature to be reproduced, and a pair of opposed tool and work operating members, one of said members being angularly adjustable with respect to the other, whereby the axial lines of the two members may be caused to intersect at any desired point, said member having an offset crank pin movable in a curved path about the axial line of said member and eccentric to the axial line of the other member.

34. A lens grinding and polishing machine including a tool having the curvature to be reproduced, and a pair of opposed tool and work operating members, one of said members being angularly adjustable with respect to the other, whereby the axial lines of the two members may be caused to intersect at any desired point, said member having an offset crank pin movable in a curved path about the axial line of said member and eccentric to the axial line of the other member, and a loose connection between the work and the crank pin whereby the work is free to rotate on the crank pin and adapt itself to the tool in any posititon of the travel of the crank pin, the other member being adapted to support and impart rotary movement to the tool.

35. A lens grinding and polishing machine, comprising coacting tool and work holding members, one of which members is mounted to have a concentric rotary movement and the other of which members is mounted to have a bodily movement about an axis which intersects the axis of rotation of the first said member and is free to rotate with respect to the part by which it is given its bodily movement, and means for angularly adjusting one of said axes with respect to the other.

36. A lens grinding and polishing machine, comprising coacting tool and work holding members, one of which members is mounted to have a concentric rotary movement, a spindle by which the other of said members is carried and from the axis of which it is offset and the axis of which spindle intersects the axis of the first said member, and means for angularly adjusting said spindle with relation to the axis of the first said member.

37. Apparatus for grinding and polishing spherically curved surfaces, comprising a pair of co-acting tool and work members, the surfaces of which are respectively convex and concave, means for imparting a concentric rotary movement to one of the members, and means for moving the other member bodily in a circular path about an axis which intersects the axis of rotation of the first member substantially at the common center of curvature of the surfaces of the two-co-acting members.

38. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting tool and work members, one having a convex, and the other a concave surface, means for imparting a concentric rotary movement to one of the members, means for moving the other member bodily in a circular path about an axis which intersects the axis of rotation of the first member substantially at the common center of curvature of the surfaces of the two co-acting members, and means for exerting pressure on the bodily movable member substantially in the direction toward said center of curvature.

39. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting tool and work members, one having a convex, and the other a concave surface, a pair of rotary driving spindles for actuating said co-acting members, said spindles having their axes of rotation mutually inclined in the same plane and intersecting at substantially the common center of curvature of the surfaces of the co-acting members, one of said co-acting members being mounted concentrically on its driving spindle, and the other of said members being connected to its driving spindle eccentrically so as to be moved thereby bodily in a circular path on and about the surface of the first mentioned member, and means for pressing the two co-acting members together acting substantially in the direction of the point of intersection of the axes of the driving spindles.

40. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting tool and work members, one having a convex, and the other a concave surface, a pair of rotary driving spindles for actuating said co-acting members, said spindles having their axes of rotation mutually inclined in the same plane and intersecting at substantially the common center of curvature of the surfaces of the co-acting members, one of said co-acting members being mounted concentrically on its driving

spindle, and the other of said members being connected to its driving spindle eccentrically so as to be moved thereby bodily in a circular path on and about the surface of the first mentioned member, and means for exerting pressure on the eccentric member substantially in the direction toward the point of intersection of the axes of the driving spindles.

41. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting tool and work members, one having a convex, and the other a concave surface, a pair of rotary driving spindles for actuating said co-acting members, said spindles having their axes of rotation mutually inclined in the same plane and intersecting at substantially the common center of curvature of the surfaces of the co-acting members, one of said co-acting members being mounted concentrically on its driving spindle, and the other of said members being connected to its driving spindle eccentrically so as to be moved thereby bodily in a circular path on and about the surface of the first mentioned member and means for adjusting the relative position of the spindles to cause their axes to intersect at substantially the common center of curvature of the surfaces of the two members.

42. Apparatus for grinding and polishing curved surfaces, comprising a pair of co-acting tool and work members, one having a convex and the other a concave surface, and a pair of rotary driving spindles for actuating said co-acting members, said spindles having their axes of rotation mutually inclined in the same plane and intersecting at substantially the common center of curvature of the surfaces of the co-acting members, one of the members being mounted concentrically on its driving spindle, and the other member being connected to its driving spindle eccentrically so as to be moved thereby bodily in a circular path and at constant velocity on and about the surface of the first member.

43. Apparatus for grinding and polishing curved surfaces, comprising a pair of coacting tool and work members, one having a convex, and the other a concave surface, a pair of rotary driving spindles for actuating said coacting members, said spindles having their axes of rotation mutually inclined and intersecting substantially at the common center of curvature of the surfaces of the coacting members, one of said members being mounted concentrically on its driving spindle and the other of said members being connected to its driving spindle eccentrically so as to be moved thereby bodily in a circular path on and about the surface of the other member, and spindle driving means, whereby the spindle carrying the concentrically mounted cooperating member is rotated more slowly than the spindle driving the eccentrically mounted cooperating member.

44. Apparatus as claimed in claim 19, wherein the mutual inclination of the axes of rotation of the spindles is varied by movement of one of the spindles about an axis which extends substantially perpendicular to the plane of the axes of the spindles.

45. Apparatus as claimed in claim 19, wherein the mutual inclination of the axes of rotation of the spindles is varied by movement of one of the spindles about an axis which extends substantially perpendicular to the plane of the axes of the spindles and passes substantially through the point of intersection of the axis of the spindle with the surface of the coacting member on the other spindle.

In testimony whereof we affix our signatures in presence of two witnesses.

LUCIAN W. BUGBEE.
ROBERT L. GORDON.

Witnesses:
CARROLL BAILEY,
EDITH M. HALVORSEN.