

July 24, 1956

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2,755,602

LENS GRINDING MACHINE AND METHOD

Filed Dec. 17, 1951

5 Sheets-Sheet 1

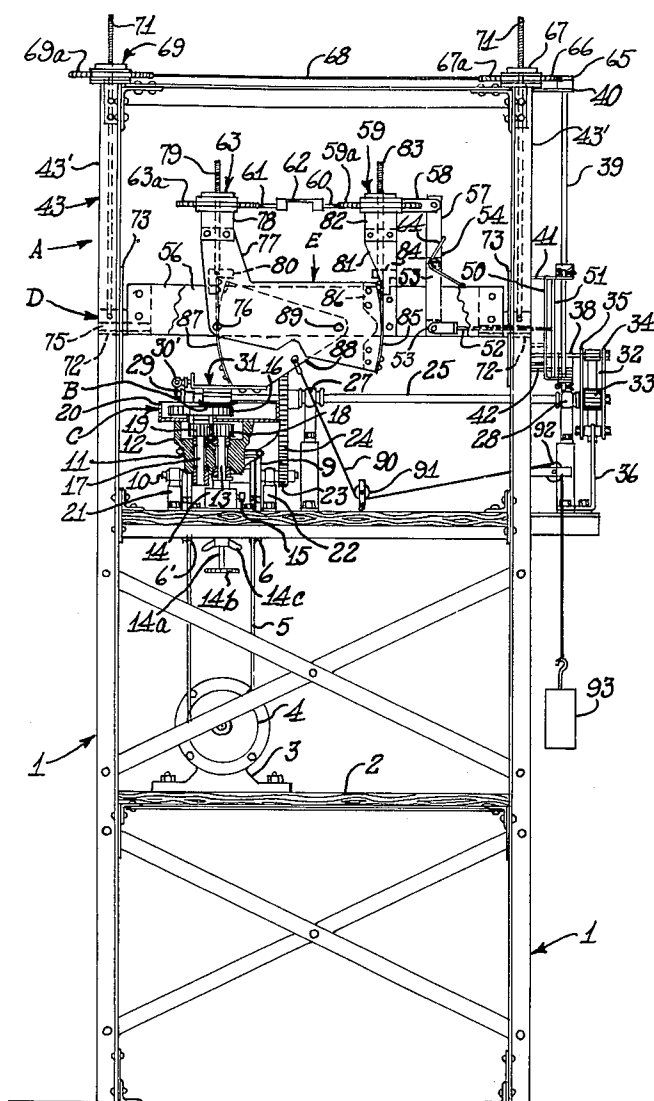


Fig. 1.

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5 Sheets-Sheet 3

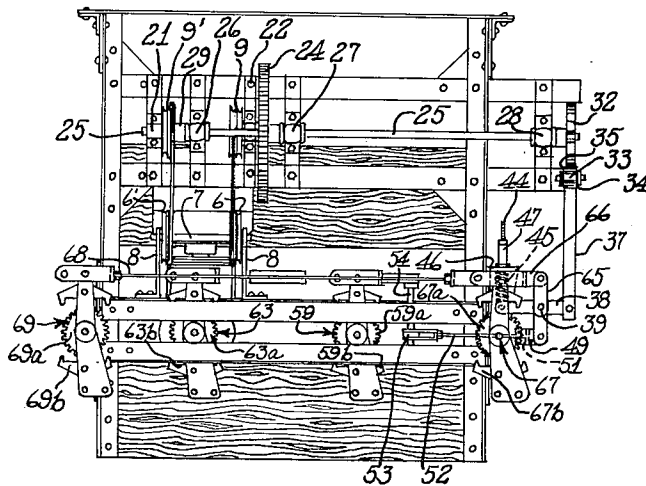


Fig. 3.

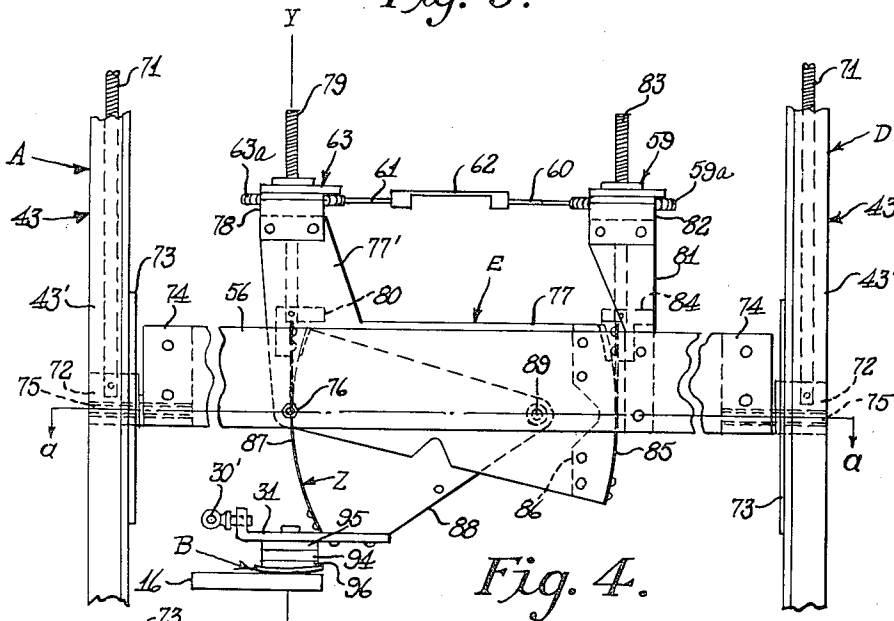


Fig. 4.

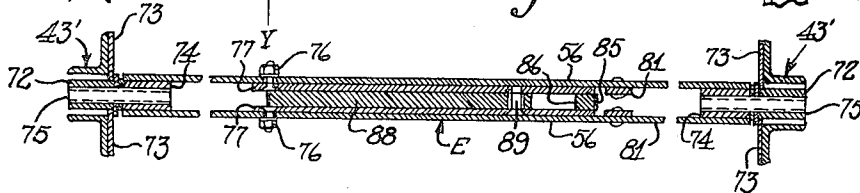


Fig. 5.

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5 Sheets-Sheet 4

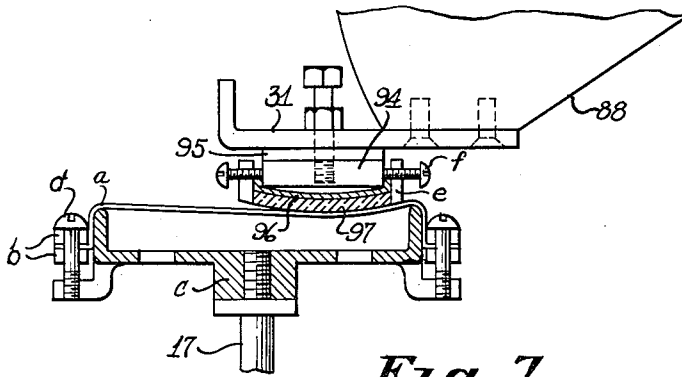


Fig. 7.

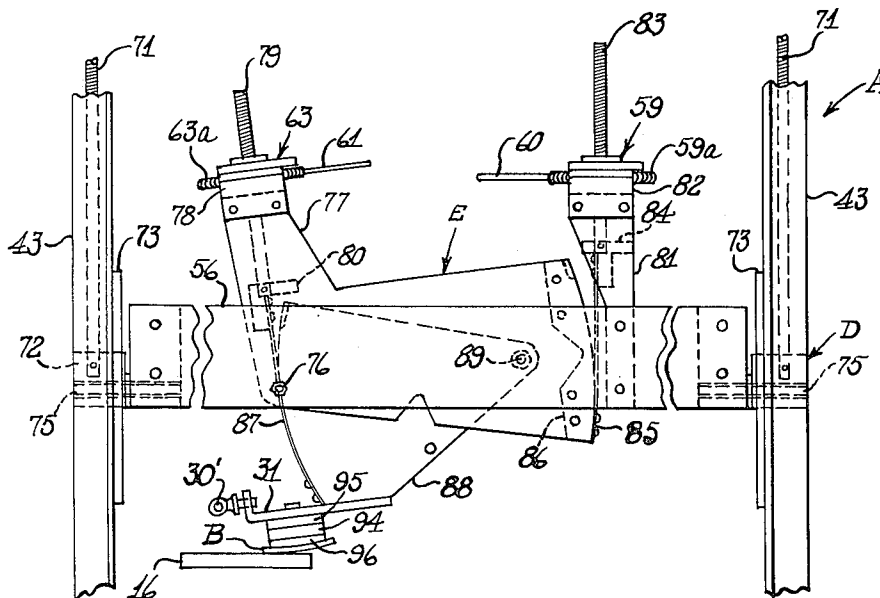


Fig. 6.

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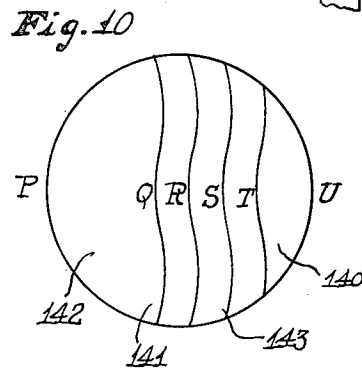
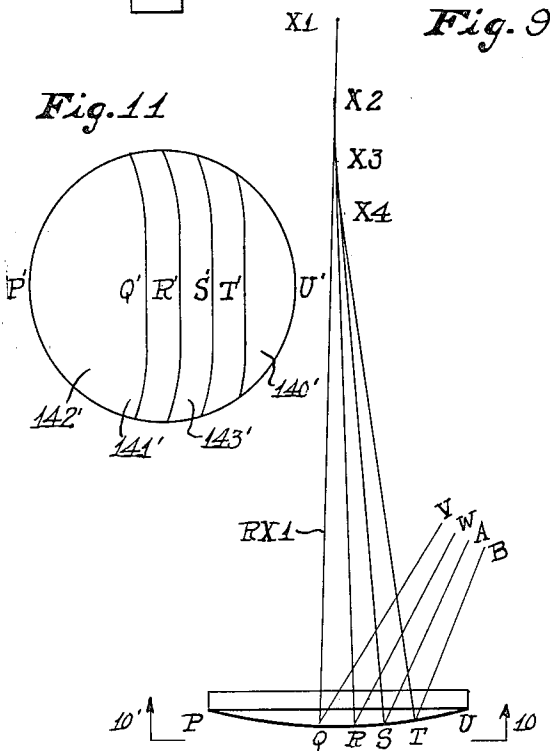
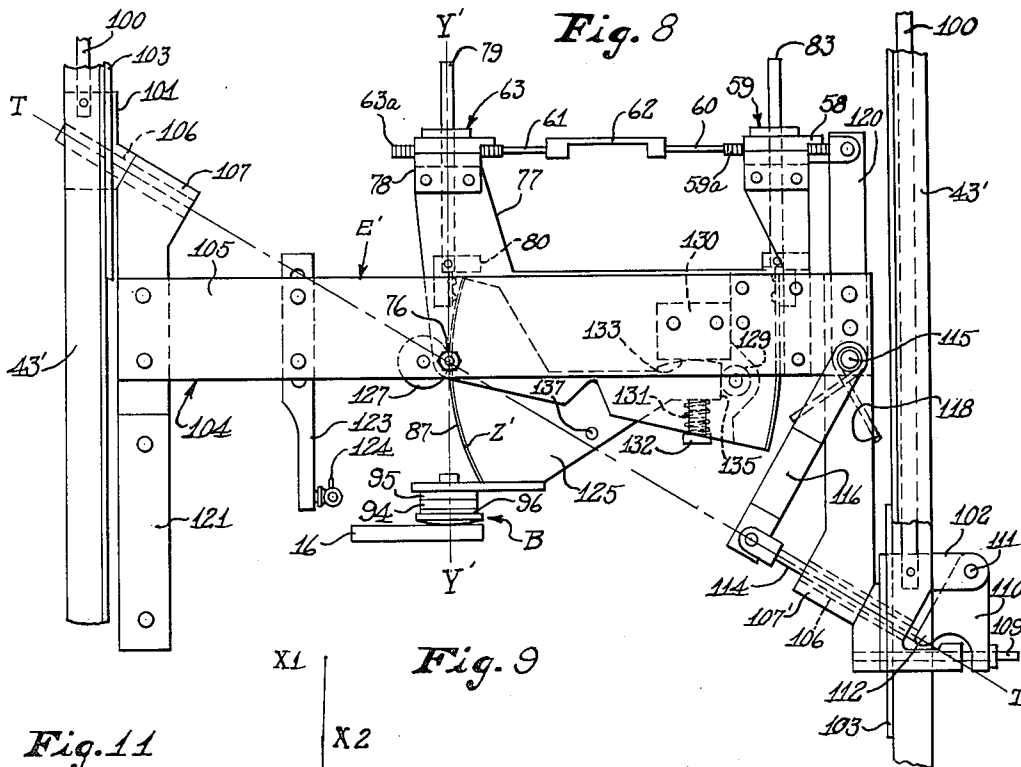
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5 Sheets-Sheet 5



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LENS GRINDING MACHINE AND METHOD

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Application December 17, 1951, Serial No. 262,068

23 Claims. (Cl. 51—120)

This invention relates to grinding machines for spectacle lenses and other objects and to spectacle lenses produced thereby.

It is an object of the present invention to provide an improved grinding machine adapted for producing surfaces of varying curvature.

It is a further object of the present invention to provide an improved spectacle lens.

In my Patent No. 2,109,474 issued March 1, 1938, and entitled "Spectacle Lens," I disclosed a lens having a graduated focal grinding which merged at either or both edges with spherical grindings for distance and, or, reading vision, so that the eye might be shifted from registration with one portion of the lens to another without experiencing any discontinuity or unevenness in vision. Heretofore, however, such a lens has had to be produced in several distinct grinding operations.

It is, therefore, an object of the present invention to provide a grinding machine for producing in a single grinding operation a lens having portions of different curvature including at least one graduated curvature or curvature of gradually varying radius.

In my Patent No. 2,112,836 issued April 5, 1938, and entitled "Lens Grinding Machines," I disclosed a grinding machine for generating an involute curve by actually rolling a circular gear segment on a rack. In the present invention, however, an involute is simulated without actually rolling one part on another.

It is, therefore, another object of the present invention to provide a grinding machine for generating a simulated involute curve.

It is still another object of the present invention to provide a grinding machine adapted for producing multifocal lenses including graduated focal surfaces, having improved side distant vision, side intermediate vision, and near vision.

It is yet another object of the present invention to provide an improved polishing assembly for polishing lenses, including an improved polishing wheel and an improved lens mounting and guard for cooperation therewith.

It is still another and further object of the present invention to provide an improved grinding wheel assembly adapted for use in the lens grinding machine of the present invention.

Other objects, features and advantages of the present invention will be apparent from the following detailed description of several embodiments of my invention taken in connection with the accompanying drawings, in which:

Figure 1 is a front elevational view, with certain parts broken away and others in section, illustrating one embodiment of a grinding machine according to the present invention;

Figure 2 is a right side elevational view of the machine of Figure 1;

Figure 3 is a plan view of the machine of Figure 1;

Figure 4 is a fragmentary enlarged front elevational view of an upper portion of the machine of Figure 1,

2

showing the jig for guiding the object being ground in central position;

Figure 5 is a partial horizontal sectional view taken substantially along the line *a-a* in Figure 4;

Figure 6 is a fragmentary enlarged front elevational view of the grinding jig of Figure 4, but showing the inner jig assembly pivoted away from central position during grinding of a portion of constant dioptric curvature adjacent one edge of the object being ground;

Figure 7 is a vertical sectional view of a polishing assembly according to the present invention;

Figure 8 is an enlarged fragmentary front elevational view similar to Figure 4, but showing a modified form of grinding jig;

Figure 9 is a diagrammatic view illustrating an improved lens produced with the use of the grinding jig of Figure 8; Figure 10 is a bottom plan view of the lens of Figure 9; and

Figure 11 is a plan view of a lens produced by the machine of Figure 1.

The embodiments of the grinding machine illustrated are adapted to grind portions of a surface of constant radius and portions of gradually varying radius, by way of example and not by way of limitation. The machines are further illustrated as being employed for grinding spectacle lenses, but it is not the purpose to limit the invention to such lenses, since, for example, dies for use in molding plastic lenses could also be ground by the machine.

Referring first to the embodiment of the invention illustrated in Figures 1 to 6 and particularly to Figure 1, a grinding jig A is utilized for guiding movement of a lens B or other object to be ground, in operative relation to a grinding wheel assembly C. The jig A includes an outer jig mechanism D for raising and lowering the lens B and an inner jig mechanism E for guiding the lens B in an oscillatory front-rear movement in a plane normal to the plane of Figure 1 and in a lateral movement in the plane of Figure 1.

The jig and grinding wheel assembly are illustrated by way of example and not by way of limitation as being mounted vertically in an upright framework including a lower generally rectangular frame 1 and a motor support 2. Motor 3 which is mounted on the support 2 drives the grinding wheel assembly C by means of grooved pulley 4 and belt 5 forming a closed loop around idler pulley 6 on pulley shaft 7 mounted by brackets 8, Figures 2 and 3, pulley 9 fixed to shaft 10, integral pulley 11 on the bearing casting 12, Figure 1, and idler pulleys 9' and 6', pulley 9' being journaled on shaft 10 and pulley 6' being journaled on shaft 7, Figure 3.

As seen in Figure 1, the bearing casting 12 is journaled on the fixed shaft 13, the lower end of which is rigidly held in the supporting block 14 by means of clamping screw 15, the supporting block being fixed to the lower frame 1. As the bearing casing 12 is rotated by means of integral pulley 11, the grinding wheel 16 is rotated on the axes of its mounting shaft 17 by means of gear 18 on fixed shaft 13 and planetary gear 19 meshing therewith and mounted on the grinding wheel shaft 17. The grinding wheel also revolves about the fixed shaft 13 which is the axis of rotation for the bearing casting 12.

In the base of the supporting block 14 is fitted an adjusting screw 14a which is supplied with a micrometer-like head 14b and a lock nut 14c. This screw bears against the lower end of shaft 13 and supplies vertical adjustment for shaft 13 and the assembly mounted thereon including bearing casting 12 and grinding disk 16, thus enabling accurate positioning of the grinding disk.

It will be understood that the direction of travel of the grinding wheel 16 is constantly changing with respect to the lens surface, at the point of contact between the

two, and also this point of contact is constantly shifting on the grinding wheel surface. This motion prevents grooving and scratching of the lens surface and tends to produce uniform wear on the grinding wheel and to keep the same true.

As seen in Figure 1, the shaft 10 is journaled between bearing members 21 and 22 which are supported by the lower frame 1, and is driven by the pulley 9 rigidly fixed thereon. Rotary motion of the shaft 10 is converted into a reciprocating movement to furnish the motive power for oscillating the inner jig assembly E by a first moving means including pinion 23 on shaft 10, gear 24 meshing therewith, rotatable shaft 25 carrying gear 24 and journaled by bearing members 26, 27 and 28, Figure 3, adjustable crank arm 29 rigidly fixed to rotatable shaft 25 adjacent bearing member 26, Figure 3, and rod 30, Figure 2 (extending generally horizontally above the uppermost run of pulley belt 5 at the level of shaft 25), rod 30 being connected at one end to crank arm 29 by means of a ball and socket joint (not shown). The opposite end of the rod 30 is operably fastened to lens block arm 31 by means of another ball and socket connection 30', Figures 1, 4 and 6 (adjacent lens B). The inner jig assembly E is thus oscillated in a front-rear direction about the bearing block journals 72, 72 of outer jig assembly D to cause what may be designated the width of the lens B to come into contact with the grinding wheel 16 (the length or height of the lens being shown in Figure 1). The path of travel of said carrier in said front-rear direction is controlled by a first control means comprising the journals 72 to produce an arcuate movement of said lens.

The inner jig assembly E is actuated by a pair of inner ratchet mechanisms 59 and 63 and the outer jig assembly D raises and lowers the inner jig assembly E by means of outer ratchet mechanisms 67 and 69, Figures 1 and 3. These ratchet mechanisms are driven by a cam member 32, Figure 3, rigidly fastened to the rotatable shaft 25. The cam member 32 operates against a roller 33 rotatably mounted between lever arms 34 and 35, Figure 1 (at the right), the lever arms being pivotally connected at their lower ends to supporting bracket 36, rigidly fastened to the lower frame 1. Between the upper ends of the lever arms 34, 35 is journaled one end of rod 37, Figures 2 and 3, which at the other end is pivotally connected to lever arm 38, Figure 3. It will be observed from Figure 2 that the cam member 32 has a pair of opposed lobes 32' which upon rotation of the cam member will impart to the rod 37 an intermittent fore-aft reciprocal motion, the ratchets being actuated twice each revolution of cam member 32. Since the lever arm 38 is rigidly fixed to a vertically extending shaft 39, Figures 1 and 2, the reciprocal motion is converted into an intermittent rotary oscillation of the shaft 39, which is journaled in bearing brackets 40, 41, 42 mounted on the upper frame comprising spaced upright frame members 43.

For maintaining operative relation between the roller 33 and the cam member 32, Figure 2, a rod 44 is pivoted to the lever arm 38 and carries a compression spring 45 which abuts at one end the lever arm 38 and is seated at the other end against an apertured plate 46, Figures 2 and 3, through which the rod 44 extends. For adjustably limiting the forward motion of the rod 44 under the urging of the spring 45 in returning the roller 33 toward the cam 32, a keeper nut 47 is threaded onto the free end of the rod 44 for abutment with the plate 46 in inactive position of the rod. By adjusting the motion of the rod 44 by means of keeper nut 47, the action of the ratchet mechanisms 59, 63, 67 and 69 can be regulated, thus controlling the rate of feed produced by the ratchet screws 71, 71, 79 and 83.

The inner ratchet mechanisms 59 and 63 are adapted to be driven from the vertical shaft 39 by means of lever arms 48 and 49, Figure 2, which are rigidly fixed to the

shaft 39 adjacent lower and intermediate bearing brackets 41 and 42. The lever arms 48, 49 pivotally mount a vertically extending slotted bar 50, Figure 1, to which is fixed in parallel relation a solid bar 51. A horizontally extending rod 52 extends through the slotted bar 50 and bears against the solid bar 51, Figures 1 and 3. The rotary motion of the shaft 39 due to the cam member 32 thus imparts to the rod 52 a sidewise intermittent reciprocating movement, while the arrangement of the slotted bar 50 and solid bar 51 permits vertical movement of the rod 52 relative to the bars during raising and lowering of the inner jig assembly E. The rod 52 extends through the right-hand pivot shaft 75 of the inner jig assembly E so that the assembly is also free to oscillate in a fore-aft direction about shafts 75.

As best seen in Figure 1, reciprocal motion of the rod 52 is transmitted to upright lever arm 53 which is rigidly fixed to rotatable shaft 54, pivotally supported by a movable support or carriage comprising horizontal side bars 56. As seen in Figure 3, the shaft 54 extends rearwardly and has at its rear end a lever arm 57, Figure 1, fixed thereto. The upper end of lever arm 57 is pivotally connected to the extension 58 of the lever arm of the reversible ratchet assembly 59 which in turn is operably connected to the reversible ratchet assembly 63 by means of removable bar 62 and rods 60 and 61. The rod 52 is kept in contact with the solid bar by means of wire spring 64 mounted on rotatable shaft 54 and bearing against lever arm 57 and side bars 56.

Thus the rotary oscillation of the shaft 39 due to the action of the cam member 32 is transmitted to the lever arms of the reversible ratchet assemblies 59 and 63. The ratchet assemblies 59 and 63 may consist of sleeves (not shown) which are journaled in blocks 78 and 82, Figure 4, and are internally threaded to engage the screws 79 and 83. Fixed to these sleeves are ratchet wheels 59a, 63a which are operated by means of ratchet pawls 59b and 63b, Figure 3, to drive the ratchets in either direction as desired, or, as shown in Figure 3, to set the ratchets in neutral, the ratchets can operate even while the assembly E is being raised and lowered and oscillated about pivot shafts 75.

The outer ratchet assemblies 67 and 69 are also actuated from the rotatable shaft 39. As seen in Figure 3, a lever arm 65 is rigidly fixed to the shaft 39 at one end and is pivotally connected at the other end to the extension 66 of the reversible ratchet assembly 67. The extension 66 is operatively connected by means of the rod 68 to the lever of the reversible ratchet assembly 69.

The ratchet assemblies 67 and 69 operate to raise and lower the inner jig mechanism E. As seen in Figure 2, blocks 70 which are bolted to the tops of spaced uprights 43' of the upper frame 43 journal the ratchet assemblies and have ratchet screws 71 extending downwardly there-through to a rigid connection with the bearing blocks 72, Figure 1, which journal the inner jig assembly E for fore-aft oscillation. The blocks 72 are vertically slidable between vertically extending plates 73, Figures 4 and 5, which are bolted to the upper frame uprights 43'. The plates 73 comprise normal movement mounting means mounting the carriage 56 for linear movement generally normal to the grinding surface. The ratchets 67 and 69 comprise bearing member moving means or carriage moving means for moving bearing members 72 and carriage 56 vertically and are also termed linear moving means or normal moving means.

It will be readily understood by those skilled in the art that the ratchet assemblies 67 and 69 may also consist of sleeves (not shown) journaled in the blocks 70, 70, the sleeves being internally threaded to engage the ratchet screws 71, 71. The ratchet wheels 67a, 69a, Figure 1, are fixed to the ratchet sleeves and are rotated by means of the ratchet pawls 67b, 69b, which are shown in Figure 3 in neutral position. Rotation of the ratchet wheels 67a,

69a rotates the ratchet sleeves in the blocks 70 to raise or lower the ratchet screws 71.

As best seen in Figure 5, the inner jig assembly E is journaled in carriage mounting means comprising the bearing members or blocks 72 by means of spacer blocks 74 mounted between the side plates 56 and rigidly carrying laterally projecting tubular pivot shafts 75. As will hereinafter be described, since the carrier for the lens or other object B is to be maintained at a substantially constant height above the grinding wheel 16, Figure 1, the crank arm 29 and rod 30 connected to the lens carrier arm 31 for oscillating the inner jig assembly E need not be raised and lowered with the raising and lowering of the side plates 56 and bearing blocks 72.

For cooperating with the inner ratchet mechanisms 59 and 63 in guiding the carrier for the object to be ground in lateral movement in relation to the grinding wheel 16, a pair of first outer plate members 77, Figure 4, are pivotally mounted within the space between the side bars 56 on first member mounting means or first pivot means comprising pins 76, Figure 5. These plate members 77 have generally upwardly extending arms 77' carrying therebetween spacer block 78 in which is journaled the reversible ratchet assembly 63, whose ratchet screw 79 extends downwardly between plate members 77 to a rigid connection with block 80 which slides between plates 77.

Referring particularly to Figure 4, the ratchet assembly or first member moving means 59 is operative to pivot a first member comprising plate members 77 about pivots 76. The assembly is supported by plates 81 extending upwardly from between the side bars 56 to which plates 81 are bolted. At the upper end of the plates 81, is fastened spacer block 82 in which is journaled the ratchet assembly 59. The ratchet screw 83 depends between the plates 81 and is rigidly connected at its lower end with block 84 which in turn slides between the plates 81. A thin metal band 85 connects the block 84 with the spacer plate 86 fastened between plates 77 for pivoting of the outer plates 77 about pins 76.

The other ratchet assembly or second or involute member or involute moving means 63 is operative to control movement of a second or involute generating member comprising inner plate 88 which is pivotally fastened to the plates 77 by a second or involute member or involute mounting means or second pivot means comprising a pin 89. The sliding block 80 of the ratchet assembly 63 is connected to the inner plate 88 by a means of another thin metal band 87. Thus vertical movement of ratchet screw 79 pivots the inner plate 88 about pivot 89.

The inner and outer guiding plates 77 and 88 are biased downwardly in the illustrated embodiment, by a counterweight 93, Figure 1, which is connected to inner plate 88 by means of hole 88 in the plate and flexible cable 90, the cable being guided by pulleys 91 and 92. The weight 93 thus acts to overcome the frictional resistance of the sliding surfaces and to take up the slack of the various parts and to hold the parts in proper position.

The lens or other object to be ground is carried by the inner plate 88 on a carrier comprising the arm 31 connected to the lower end of the plate and a block 94 selectively spaced therefrom by means of shims 95 and rigidly fastened to the arm 31 by means of screws. If a lens is to be ground, the lens blank B is fastened to the lens block 94 by means of a layer of pitch or some other suitable material indicated diagrammatically at 96.

It will thus be seen that the inner jig assembly E may be reciprocated normal to the grinding wheel surface by means of ratchet assemblies 67 and 69 operated in conjunction, and that the entire inner jig assembly may be oscillated about an axis parallel to the grinding wheel surface. It will further be clear that the ratchet assemblies 63 and 59, operated separately, will cause the carrier assembly or carrier 31—94 to be selectively pivoted about one of two spaced pivots 89 and 76, respectively.

Operation

The manner of operation of the jig assembly A shown in Figures 4 and 6 will now be readily understood from the following description.

By way of example and not by way of limitation the grinding of a spectacle lens will be described, the lens to have a lower portion of constant dioptric power for use in reading, an upper portion of constant dioptric power for use in distance vision, and an intermediate portion of gradually varying dioptric power merging at the top and bottom with the constant power portions of the lens.

With the inner jig assembly E in the position shown in Figure 6, what may be designated the top or upper portion of the lens blank B is in contact with the grinding wheel 16. The connector bar 62, Figure 4, has been removed and the inner ratchet mechanism 59 has been actuated to pivot the inner jig assembly E counterclockwise about the pivot 76 from the position of Figure 4. The ratchet pawls are set in neutral position so that the ratchet mechanisms will all remain at rest.

To set the machine in motion, the motor 3 is started. The grinding wheel 16 will now be rotating on its own axis and revolving in planetary fashion about the fixed shaft 13, Figure 1. The entire inner jig assembly E will be oscillating fore and aft about the pivot shaft 75 by means of a driving connection with the ball and socket joint 30' carried by lens supporting arm 31, Figure 6.

This oscillating motion about pivots 75, 75 will bring what may be termed the width of the lens blank B into contact with the grinding disk 16, the blank will swing on a radius which is effectively the perpendicular distance between the axis X—X of the pivots 75, 75 and the surface of the grinding wheel. This radius may be designated RX for convenience. A circular arc of very narrow height is thus ground across the width of the top portion of the lens blank, the arc having a constant radius RX. It will be observed that the pivot 76 is on the axis A—A, so that radius RX equals the distance from pivot 76 to the point of contact of the lens blank with the surface of the grinding disk 16.

Lowering of the right-hand inner ratchet screw 83 by means of ratchet mechanism 59, for example at the end of the forward swing of the lens blank B about pivots 75, 75 and at the end of the rearward swing, will lower outer plates 77, and inner plate 88 therewith, clockwise about pivot 76 to grind successive narrow height circular arcs of radius RX. Since both crank 29 for oscillating the lens and cam member 32 for actuating the ratchet mechanisms are driven by the shaft 25, Figures 2 and 3, it will be readily apparent that the ratchet 59 can be synchronized with the oscillation to lower the lens blank about pivot 76 at each end of the swing of jig E on pivots 75.

It will be understood that since the lens is swung laterally about pivot 76 as well as being swung in the fore-aft direction about pivot 76, a generally segmental spherical curvature of substantially constant radius is generated by the machine. The portion of the lens ground corresponds in general location to the portion PQ in Figures 10 and 11, the radius RX corresponding to the distance between XI and the circular arc PQ in Figure 9.

If now it is desired to grind an intermediate portion of the lens with a gradually varying radius, the intermediate portion corresponding in general location to the portion Q, R, S, T in Figures 10 and 11, the left hand inner ratchet 63 may be actuated to raise the inner plate member 88 to pivot the lens clockwise about pivot 89, Figure 4, the outer ratchets 67 and 69 being actuated in exact synchronism to correspondingly lower the entire inner jig assembly E. Since all the ratchets are actuated from the same cam member 32, such synchronism is readily obtained. The means for moving the carrier into operative relation with the grinding member, in-

cluding cam member 32 and inner ratchets 59 and 63 and outer ratchets 67 and 69, will be termed the second moving means. The second moving means move the lens in a second direction transverse to the front-rear direction and the path of travel in said second direction is confined by means of a second control means which comprises the first member 77, pivot 89 and second member or inner plate 88.

Largely for convenience in illustration, the inner plate member 88 is illustrated as being generally in the shape of a sector of a circle having an arcuate outer margin Z of radius equal to the distance between pivot 76 and pivot 89. Instead, however, of actually rolling the arcuate margin Z on the vertical line Y—Y, which is a line normal to the grinding disk at the point of contact of the lens therewith, Fig. 4, to generate an involute in a manner which may now be perceived to be slightly similar to that disclosed in my above mentioned Patent No. 2,112,836, I simulate the rolling movement by lowering the entire inner jig E in synchronism with the pivoting of the plate 88 upwardly about the pivot 89, or the reverse.

The radius RX of fore-aft oscillation about pivots 75, 75 will thus be decreased, each time the plate 88 is raised slightly by the ratchet 63 to expose a new portion of the lens to the grinding disk 16. The intermediate portion of the lens thus will be composed of a very large number of transversely extending arcs, as with the constant radius upper portion of the lens. Each arc will be of constant radius across the width of the lens but of different radius from adjacent transverse arcs. With the inner jig illustrated, the radii of the successive arcs will vary as the involute of a circle of radius equal to the perpendicular distance between pivot 89 and the normal contact lines Y—Y of the lens and the grinding wheel. In other words the contour of the lens in the plane of Figure 4 will be an involute curve.

It will be understood by those skilled in the art that the radius of curvature at any point in the intermediate portion of the lens or other object in the horizontal or transverse direction will be substantially equal to the radius of curvature in the vertical or longitudinal direction, so that each arc will be substantially spherical in contour. It will be further understood that adjacent arcs will be substantially tangent to each other on a meridian (in Figure 9, PU would be designated the principal vertical meridian) common to all arcs. The height of each arc is determined by its intersection with the two adjacent arcs.

The final constant radius lower portion of the lens may be ground by placing the outer ratchets 67 and 69 and the left-hand inner ratchet 63 in neutral, removing bar 62 and adjusting inner ratchet 59 to lower plate members 77 about pivot 76.

The first outer members 77 are thus operative to confine the path of travel of the carrier 31—94 for the lens or other object for generating a first curvature of the object in the longitudinal direction and the second inner member 88 is operative to confine the path of travel of the carrier for generating a second curvature of the object in the longitudinal direction, the first curvature being in the present instance a circular arc and the second curvature being an involute arc.

Further the machine will grind these different curvatures during a single grinding operation.

In Figure 7 I have shown a polishing wheel for threaded insertion onto the revolving and rotating planetary shaft 17 of the machine of Figure 1. The wheel comprises a piece of flexible material such as felt, *a*, clamped between two rings, *b*, which are secured to the bowl-like member, *c*, by means of screws, *d*. The tension in the flexible material may be adjusted by means of the screws, *d*.

The ring, *e*, the lower edge of which is approximately

shaped to the contour of the lens 97 ground by the machine of Figure 1, prevents the edge of the lens from being rounded off during polishing operation and is secured by screws, *f*, to the lens block 94.

The bowl-like member, *c*, is supported above the bearing casting 12 so that is free to revolve and rotate in a manner similar to grinding wheel 16, in Figure 1, the protective guard 20 having been removed from the casting 12. The jig A is preferably operated during polishing to regenerate the lens surface, and thus improved contact between the polishing surface and all points on the lens surface is obtained.

Referring now to Figures 8, 9 and 10, a modification of the grinding jig mechanism A, shown in Figures 1 to 6 is illustrated.

In the embodiment shown in Figure 8, instead of oscillating the carriage about an axis which is parallel to the grinding surface of the grinding wheel, the axis of oscillation of the carriage extend obliquely to the surface of the grinding wheel. Further, instead of generating an involute of a circular arc, the inner jig assembly of the present embodiment is adapted to generate an involute of an involute curve. It has been found that the dioptric power of a lens having a contour which is an involute of an involute will have a more uniform rate of change.

The ratchet mechanism for raising and lowering the inner jig assembly E' and the drive therefor may be the same as that shown in Figure 1. Outer ratchet screws 100 are connected to first control means or carriage mounting means comprising bearing members or bearing blocks 101 and 102 which are vertically slidable in spaced pairs of uprights 43' in guideways defined by normal movement mounting means comprising plates 103. Carriage 104 comprising side bars 105 is pivotally mounted in the bearing blocks or members 101 by means of tubular shafts 106 carried by the carriage mounting arms 107 and 107'. The carriage 104 is thus mounted for oscillation about an obliquely extending axis T—T.

For driving the inner ratchet mechanisms which are identical with those of Figure 1 and have, therefore, been given the same reference numerals, a rod 109 extends through the lower right hand bearing block 102 and is actuated in a manner entirely similar to the actuation of the rod 52 in Figure 1. Reciprocation of the rod 109 in the manner shown in Figure 1 pivots a crank 110 about a pin 111 carried by the bearing block 102. An extension 112 of the crank 110 is connected to a rod 114 extending through the tubular shaft 106 of the carriage mounting arm 107'. The inner ratchet mechanism is thus operated in a manner similar to that shown in Figure 1 in spite of oscillation of the carriage 104 on the axis T—T and in spite of vertical reciprocation of the carriage by means of the ratchet screws 100. Reciprocation of the rod 114 along the axis of oscillation, T—T, rocks the shaft 115 pivotally mounted by the carriage 104 due to a rigid connection between the shaft 115 and the arm 116 which is pivotally connected to the rod 114. A wire biasing spring 118 bears against the carriage mounting arm 107 and the arm 116 to bias the arm 116 in the counterclockwise direction to bias the actuating rod 109 outwardly away from the upright 43'. Rocking movement of the shaft 115 is transmitted to extension 58 of the ratchet 59 by means of a vertically extending arm 120 to actuate the inner ratchet mechanism in the same manner as in Figure 1. The extension 121 serves to balance the carriage 104 in its oscillation about the axis T—T.

Instead of operating the carriage by means of a universal connection to the lens carrier assembly as in Figures 1 to 7, an adjustable hanger bar 123 depends from the cross bars 105 of the carriage for universal connection at its lower end with an actuating rod similar to the rod 30 in Figure 2. The actuating rod is adjusted to swing the carriage more than is necessary in the lowest

position of the carriage so that in the highest position of the carriage an adequate swing will still be imparted to the carriage. The universal joint connection is indicated at 124. The first moving means thus comprises hanger bar 123 and universal joint 124.

Instead of a pivotally mounted inner plate member for generating an involute of a circular arc, a second or involute member comprising an inner plate member 125 is provided which is mounted for simulated rolling movement to generate an involute of an involute. To this end, an outer margin Z' of the inner plate member 125 adjacent the pivot 76, defines an involute curve. This involute margin Z' is constrained to simulate rolling on the axis Y'-Y' normal to the grinding wheel surface.

In the present instance the constraining means or second member mounting means comprise a roller 127, rotatably mounted by the crossbars 105 which is tangent to the vertical line Y'-Y', an opposing roller 129, guide block or constraining member 130 and spring 131. The spring 131 is mounted by means of a bolt 132 extending through the end of the plate member 125 through an aperture therein which is designed to afford adequate clearance for rocking of the plate member. The bolt 131 is secured in the constraining block 130. It will be observed that the margin 133 of the plate member 125, which faces the constraining block 130, is arcuate and may be of such curvature as to tend to promote the accuracy of simulated rolling of the plate member 125. Specifically, the curvature of the margin 133 is such that for a perfectly simulated involute, the margin 133 will perfectly accommodate the proper movement of the end portion of the plate member 125. Movement of the lens in the radial direction is thus under the control of a second control means comprising first member 77, constraining member 130 and second member 125.

The same may be true of the margin 135 contacting the roller 129. If the margins 133 and 135 are properly designed, there need be no looseness between the constraining member and the plate 125 during the generation of the curve.

The plate member 125 is thus so constrained that, for example, upon the intermittent raising of the flexible strap 87 secured to the involute margin Z', the constraining members will ideally retain contact with the plate member 125 and constrain it to simulate an involute curve. The spring 131 is of sufficient size to substantially resist movement of the plate 125 downwardly under the urging of the counterbalance such as 93 shown in Figure 1 which is connected to the opening 137 in the plate 125.

The operation of the embodiment of Figure 8 is similar to that of Figure 1. During grinding of a constant radius portion of the lens, the connecting bar 62 is removed and the ratchet mechanism 59 raises or lowers the outer plates 77, the inner plate 125 and lens carrier assembly moving therewith. For example, the ratchet mechanism 59 may raise the plates 77 one-thousandth of an inch for each half oscillation of the carriage 104 on the axis T-T. If it is now desired to generate an involute of an involute—namely, the involute of the margin Z' of the plate member 125, the connecting bar 62 is connected and the ratchet mechanism 63 is energized to raise the plate 125 while the entire inner jig assembly E' is lowered by means of the ratchet screws 100.

It will be observed that the machine of the present invention generates a series of minutely or infinitesimally narrow, substantially spherical segments of gradually varying diameter, the spherical center of all segments lying in the same plane, each segment being tangent to adjacent segments on a common meridian lying in this plane (e. g. meridian PU in Figure 9), and the area of each segment being determined by its natural intersection with the adjacent spherical segments. Certain lines of natural intersection Q, R, S, T, are shown in Figure 9

10, for example. In the embodiment of the machine illustrated in Figure 1, the segments are generated about an axis parallel to the surface of the grinding wheel and in the embodiment of Figure 8, the segments are generated about an axis sloping with respect to the surface of the wheel.

In Figure 9 is illustrated the principle of the generation of an involute of an involute. For example, if the curve X1, X2, X3, X4, is an involute corresponding to the involute margin Z' and the line X1Q is considered to represent a string to be wrapped onto the involute curve X1, X2, etc., it will be observed that the arc QRST is generated, the line X2R extending tangent to the involute curve X1—X4 at point X2, the line X3S extending tangent to the curve X1—X4 at point X3 and the line X4T extending tangent to the involute curve at point X4. The arc QRST is part of the principal vertical longitudinal meridian PU shown in Figures 9 and 10 and corresponds to the contour of the lens seen in elevation in Figure 8.

Figure 10 illustrates certain lines of natural intersection (Q, R, S, T) between adjacent segments generated by the machine of Figure 8. Figure 11 illustrates corresponding lines (Q', R', S', T') in a lens generated by the machine of Figure 1. It will be observed that the lines Q, R, S, T in Figure 10 define a reading area 140 which is somewhat more ample as measured for example on the principal longitudinal meridian from U to T, than the reading area 140' of the lens of Figure 11. The corner portions 141 of the distance area 142 are also more ample than portions 141' of the distance area 142' of Figure 11 and thus provide better distance vision. Further, there is less distortion in the intermediate dioptric curvature portion 143 than in the corresponding portion 143'. It has been found in practice that lenses produced by the machine of Figure 8 are superior to those produced by the machine of Figure 1 in these respects.

It will further be observed that the lens shown in Figure 10 is theoretically generated in one direction by a generating line extending from a particular point in the principal meridian such as Q to the axis T—T and at right angle to the axis. This generating line is then oscillated on the axis T—T. The transverse generating line such as QV extends obliquely to the radius of curvature line QX1 of the principal longitudinal meridian PU at the point Q. It will be observed that transverse generating axis T—T intersects the radius of curvature line QX1 at the end of the radius curvature line X1, at the time of starting generation of a theoretical segment Q.

While generation of convex lens surfaces have been described, concave lens surfaces could also be generated by the use of a suitable grinding surface, such as a spherical grinding surface and with other suitable adjustments of the jig mechanism. Also, parabolic or cylindrical lenses could be generated by a suitable adjustment of the jig mechanism. For example, to generate a cylindrical lens, pivot 76 could be raised or lowered in Figure 4 relative to the axis of oscillation in which case the new lens would be oscillated about the new axis and would be rotated transversely about point 76. The invention is not limited to lenses, since dies for plastic lenses could be formed by means of the apparatus of my invention.

In my Patent No. 2,112,836, above mentioned, a pair of radius arms of different lengths were swung around fixed points to control the curvature transversely. The segments thus generated could not be spherical throughout since the action of the radius arms introduces a slight error. However the machines of the present invention are such that a succession of substantially spherical surfaces of gradually varying diameter are ground and the lenses produced by the machines of the present invention are more nearly theoretically perfect than the lenses produced by the machines of my former patent, especially at the outer margins.

It will be understood that modifications and variations

may be effected without departing from the scope of the novel concepts of the present invention.

I claim as my invention:

1. In a grinding machine for operation in conjunction with a grinding member, a movable support, a carrier for the object to be ground carried by said support, first moving means for moving said support and carrier in a first direction across the grinding member, first control means for controlling the path of travel of said carrier in said first direction for determining the curvature of the object in said first direction, second moving means for moving said carrier into operative relation with the grinding member in a second direction transversely of said first direction of movement, and second control means for confining the path of travel of the carrier for determining the curvature of the object in said second direction, said last mentioned control means comprising a first member operatively mounted on said movable support for confining the path of travel of said carrier for generating a first curvature of the object in said second direction, and a second member operatively mounted on said first member for confining the path of travel of said carrier for generating a second curvature of the object in said second direction.

2. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a carriage, normal movement mounting means mounting said carriage for movement generally normal to the grinding surface, first control means mounting said carriage for movement to generate a curvature in a first direction, a first member pivotally carried by said carriage for generating a first curvature in a second direction transverse to said first direction and a second member carried by said first member for movement to generate in conjunction with the movement of said carrier along said normal movement mounting means a second curvature in said second direction.

3. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a carriage, normal movement mounting means mounting said carriage for movement generally normal to the grinding surface, first control means mounting said carriage for movement to generate a curvature in a first direction, a first member carried by said carriage for generating a first curvature in a second direction transverse to said first direction and a second member carried by said first member for movement to generate in conjunction with the movement of said carrier along said normal movement mounting means a second curvature in said second direction.

4. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a carriage, normal movement mounting means mounting said carriage for movement generally normal to the grinding surface, first control means mounting said carriage for oscillation in a first direction about an axis extending in a direction transverse thereto, a first member carried by said carriage for generating a first curvature in a second direction transverse to said first direction and a second member carried by said first member for movement to generate in conjunction with the movement of said carrier along said normal movement mounting means a second curvature in said second direction.

5. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a carriage, normal movement mounting means mounting said carriage for reciprocating movement in a direction generally normal to the grinding surface, first control means mounting said carriage for oscillation about an axis, a first member, first pivot means mounting said first member on said carriage for pivotal movement on an axis intersecting said axis of oscillation, a second member carried by said first member, normal moving means for moving said carriage normal to the grinding surface, and second member moving means for moving said sec-

ond member in synchronization with said normal moving means.

6. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a pair of spaced frame members extending generally normally to said grinding surface, bearing members carried by said frame members for movement parallel to said frame members, a carriage pivotally carried by said bearing members for oscillation about a first axis, a first member carried by said carriage for pivotal movement on a second axis intersecting said first axis of oscillation, and a second member carried by said first member for movement in a locus of planes substantially intersecting said first axis of oscillation.

7. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a pair of spaced frame members extending generally normally to said grinding surface, bearing members carried by said frame members for movement parallel to said frame members, a carriage pivotally carried by said bearing members for oscillation about a first axis, a first member carried by said carriage for pivotal movement on a second axis intersecting said first axis of oscillation, a second member carried by said first member for movement in a locus of planes substantially intersecting said first axis of oscillation, bearing member moving means for jointly moving said bearing members generally normally to said grinding surface, and second member moving means for moving said second member in synchronism with said bearing member moving means.

8. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a pair of spaced frame members extending generally normally to said grinding surface, bearing members carried by said frame members for movement parallel to said frame members, a carriage pivotally carried by said bearing members for oscillation about a first axis, a first member carried by said carriage for pivotal movement on a second axis intersecting said first axis of oscillation, a second member carried by said first member for movement in a locus of planes substantially intersecting said first axis of oscillation, first moving means for oscillating said carriage on said first axis, and first member moving means for moving said first member in synchronization therewith.

9. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a pair of spaced frame members extending generally normally to said grinding surface, bearing members carried by said frame members for movement parallel to said frame members, a carriage pivotally carried by said bearing members for oscillation about a first axis, a first member carried by said carriage for pivotal movement on a second axis intersecting said first axis of oscillation, a second member carried by said first member for movement in a locus of planes substantially intersecting said first axis of oscillation, first reversible ratchet means carried by said frame members for moving said bearing members generally normally to said grinding surface, second reversible ratchet means carried by said carriage for pivoting said first member on said second axis, and reversible ratchet means carried by said first member for movement of said second member in synchronization with movement of said bearing members.

10. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a pair of spaced frame members extending generally normally to said grinding surface, bearing members carried by said frame members for movement parallel to said frame members, a carriage pivotally carried by said bearing members for oscillation about a first axis, a first member carried by said carriage for pivotal movement on a second axis intersecting said first axis of oscillation, a second member carried by said first member for movement in a locus of planes substantially intersecting said

13

first axis of oscillation, first reversible ratchet means carried by said frame members for moving said bearing members generally normally to said grinding surface, second reversible ratchet means carried by said carriage for pivoting said first member on said second axis, reversible ratchet means carried by said first member for movement of said second member in synchronization with movement of said bearing members, and crank means for oscillating said carriage in synchronization selectively with said first and third ratchet means or with said second ratchet means.

11. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a pair of spaced frame members extending generally normally to said grinding surface, bearing members carried by said frame members for movement parallel to said frame members, a carriage spanning between and pivotally carried by said bearing members for oscillation about a first axis, a first member carried by said carriage for pivotal movement on a second axis intersecting said first axis of oscillation, and first pivot means carried by said carriage for controlling pivoting of said first member about said second axis.

12. In a grinding machine, the combination with a grinding wheel having a generally plane grinding surface of a pair of spaced frame members extending generally normally to said grinding surface, bearing members carried by said frame members for movement parallel to said frame members, a carriage pivotally carried by said bearing members for oscillation about an axis, an involute generating member carried by said carriage for movement in a locus of planes substantially intersecting said axis of oscillation, bearing member moving means for moving said bearing members parallel to said frame members, and involute member moving means for moving said involute member in synchronization with said bearing member moving means.

13. In a grinding machine jig mechanism for generating an involute curve, a frame, a carriage carried by said frame for movement in one direction, an involute generating member carried by said carriage for arcuate movement having at least a component in a direction opposite to said one direction, carriage moving means for moving said carriage in said one direction, and involute member moving means for moving said member in synchronization with said carriage but with the member having at least a component of movement in a direction opposite to said one direction to move the member as a function of an involute curve.

14. In a grinding machine jig mechanism for generating an involute curve, a frame, a carriage carried by said frame for movement in one direction, an involute generating member carried by said carriage and having an arcuate margin of curvature to generate said involute curve, constraining means including a constraining member constraining said member for arcuate movement having a component in a direction opposite to said one direction to bring successive points on said arcuate margin into opposition to said constraining member, carriage moving means for moving said carriage in said one direction, and involute member moving means for moving said involute generating member in synchronization with said carriage but with the member having a component of movement in a direction opposite to said one direction, the arcuate movement of said involute generating member defining an involute curve.

15. In a grinding machine jig mechanism for generating an involute of a circular arc, a frame, a carriage carried by said frame for linear movement in one direction, an involute generating member carried by said carriage for pivotal movement having a component in a direction opposite to said one direction, carriage moving means for moving said carriage in said one direction, and involute member moving means for pivoting said member in synchronization with movement of said car-

14

riage by said carriage moving means but with the member having a component of movement in a direction opposite to said one direction to move said member as a function of an involute of a circular arc.

16. The grinding machine of claim 14 wherein said arcuate margin has an involute curvature and the arcuate movement of said involute generating member defines an involute of the involute curvature of said arcuate margin.

17. The grinding machine of claim 4 wherein said carriage mounting means mounts said carriage for oscillation about an axis that is at an inclination to said plane grinding surface.

18. In a grinding machine, a carrier for an object to be ground, first moving means for oscillating said carrier arcuately about a given axis, involute mounting means constraining said carrier for arcuate movement radially relative to said axis in accordance with a predetermined function, involute moving means for actuating said carrier to move through successive increments of said last mentioned arcuate movement radially of said axis, and linear moving means for linearly moving said carrier in successive increments in a direction generally opposite to the last mentioned arcuate movement and in timed relation to said first and second mentioned increments of arcuate movement of said carrier under the control of said first moving means and said involute moving means to progressively vary the radius on which said carrier is moved about said axis in accordance with an involute of said predetermined function.

19. In a grinding machine, a carrier for an object to be ground, first moving means for cyclically moving said carrier transversely on a circular arc about a given axis, involute mounting means constraining said carrier for movement in a radial direction relative to said axis in accordance with a predetermined function, and involute moving means for actuating said carrier to move radially of said axis in successive increments in timed relation to the cyclical transverse movement of said carrier about said axis to generate a surface composed of successive transverse arcs of radii progressively varying in accordance with said predetermined function.

20. In a grinding machine, a carriage, first control means mounting said carriage for arcuate movement about a given axis, an involute generating member carried by said carriage and pivotal relative thereto, a carrier for an object to be ground carried by said involute member, involute member moving means for progressively moving said involute member about its pivot as the involute member moves about said axis, and carriage moving means for progressively shifting said axis in timed relation to the progressive movement of said second member about its pivot but in an opposite general direction to generate a surface having an involute curvature.

21. In a grinding machine, a carriage, carriage mounting means mounting said carriage for arcuate movement about a given axis, an involute member carried by said carriage and constrained for rocking movement relative to a surface carried by said carriage, involute member moving means for progressively moving said member under the constraint of said surface carried by said carriage, and carriage moving means for progressively shifting said axis in timed relation to the progressive movement of said involute member by said involute member moving means but in an opposite general direction to generate a surface having an involute of the curvature defined by the rocking movement of said involute member.

22. In a grinding machine having a generally planar grinding surface, a carrier for an object to be ground, a carriage supporting said carrier, carriage mounting means mounting said carriage for arcuate oscillation on a given axis, first moving means for oscillating said carriage on said axis to oscillate said carrier back and forth across said grinding surface in a first direction, an involute

15

generating member carried by said carriage for oscillation therewith and carrying said carrier, involute member mounting means constraining said involute generating member for arcuate movement having a radial component relative to said axis and having a normal component relative to said grinding surface, involute member moving means connected to said involute generating member and operative to move said involute generating member step-by-step through successive increments under the constraint of said involute member mounting means, normal movement mounting means mounting said carriage mounting means for movement normal to said grinding surface, linear moving means connected to said carriage mounting means and operative to move said carriage mounting means along said normal movement mounting means to move said carriage step-by-step in a direction normal to said grinding surface, said linear moving means being synchronized with said involute member moving means and said first moving means to move said carriage normal to said grinding surface a step in one sense when said involute member moving means moves said involute member a step having a component normal to said grinding surface but in the opposite sense and when said first moving means oscillates the carriage to an extreme position about said axis with the object to be ground out of engagement with said grinding surface, and power means for energizing said first moving means, said linear moving means and said involute member moving means to generate a surface on said object whose curvature varies as an involute function.

23. A method of forming a surface with a gradually varying curvature, which comprises relatively moving an object to be ground transversely across a grinding surface about a first radius to form a first transverse arc on said object of given radius of curvature, minutely shifting

16

said object arcuately in a direction having a component parallel to the longitudinal axis of the object and having a component normal to the grinding surface, and linearly moving the object in a direction normal to the grinding surface and moving the object across the grinding surface about a slightly different radius to form a second transverse arc on said object of slightly different radius of curvature, repeating the transverse moving and longitudinally shifting steps to generate an involute curvature on the object along the longitudinal axis thereof, and controlling the longitudinal shifting of the object in relation to the successive transverse radii of curvature so that each transverse segment in the surface generated on said object will have a substantially fragmental spherical contour.

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