United States Patent

[11] 3,583,111

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[54] **LENS GRINDING APPARATUS**
10 Claims, 8 Drawing Figs.

[52] U.S. Cl. 51/358, 51/124
[51] Int. Cl. B24d 17/00
[50] Field of Search .... 51/358, 383, 390, 395—401, 206, 206.9

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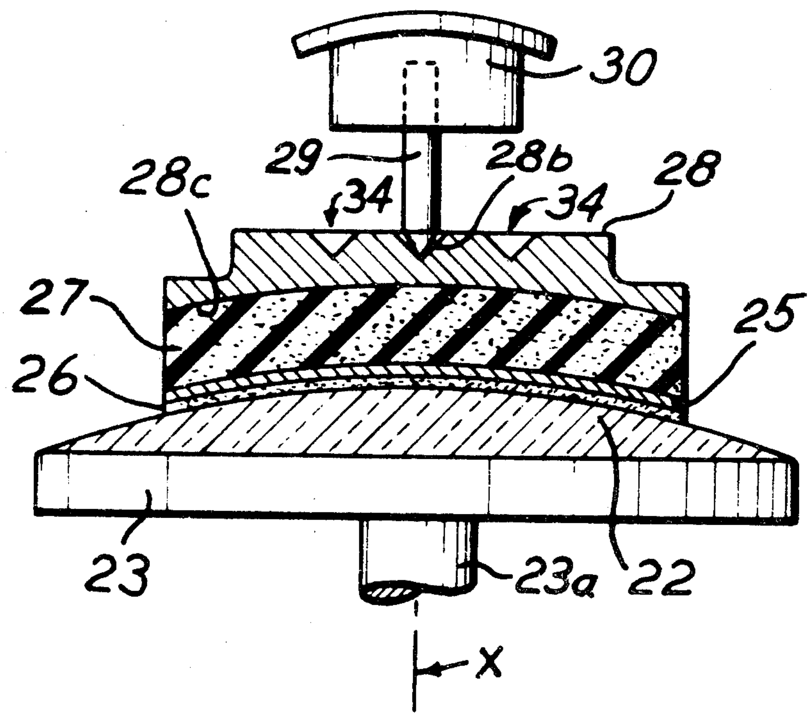
ABSTRACT: A lens grinding disc of thin sheet material having spring quality, such as brass shim material, is provided with slits extending inwardly from its periphery to enable it to conform to a lens surface when applying a fine abrasive material thereto in a grinding or polishing operation. Other slits may extend radially outwardly also. The disc may be of metal, or synthetic resin, or of woven mesh material. A cushion of sponge rubber or the like may be provided between the disc and a holder used for manipulating it.



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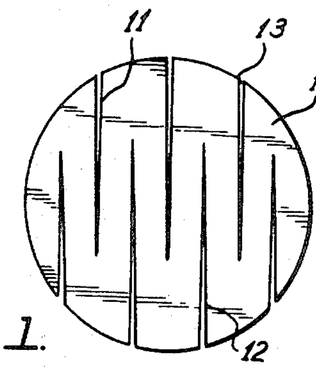

FIG. 1.

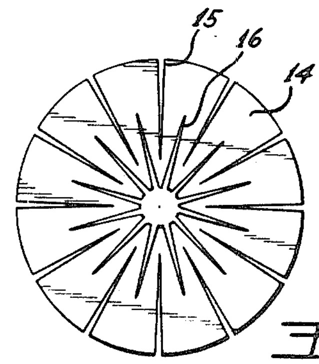

FIG. 2.

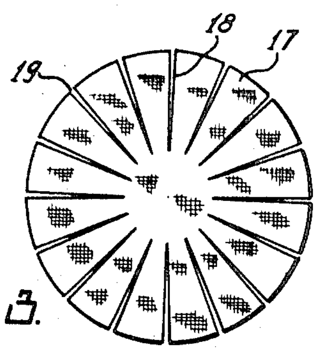

FIG. 3.

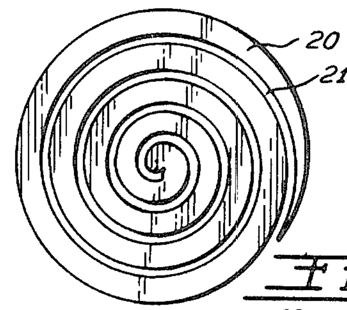

FIG. 4.

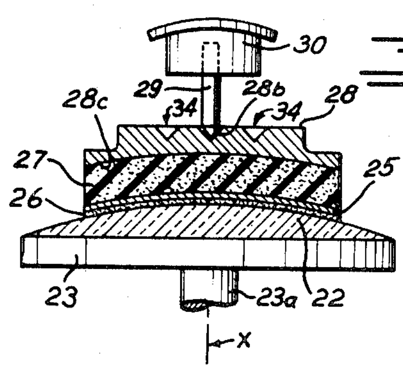

FIG. 5.

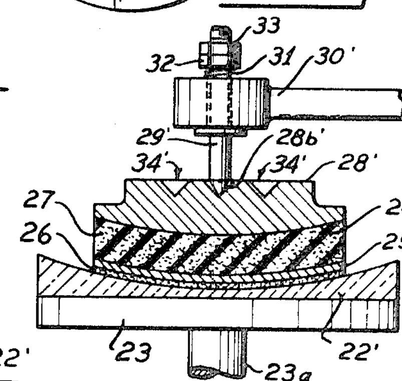

FIG. 7.

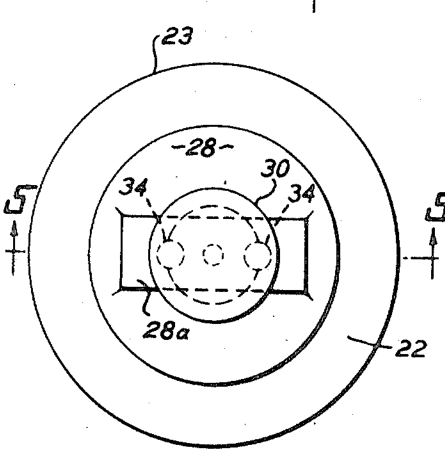

FIG. 6.

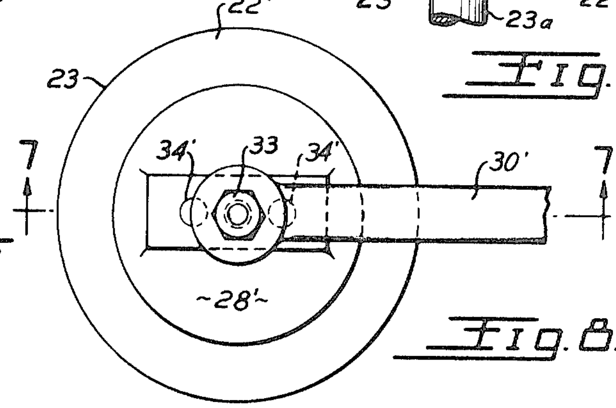

FIG. 8.

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LENS GRINDING APPARATUS

This application is a continuation-in-part application of my copending application Ser. No. 237,514, filed Nov. 14, 1962, now abandoned for Lens Grinding Apparatus.

This invention relates to improved apparatus for applying fine abrasive compound to a lens or mirror surface on optical material or metal in a smoothing operation between rough forming and polishing operations.

A more specific object of this invention as defined above is the provision of a disc of flexible resilient sheet material slitted in such a manner to provide ability to conform to a lens or mirror surface with fine abrasive material provided between the disc and the work surface, the edges of the slits providing edges of concentrated abrasive capability as the disc is moved relative to the work surface and all portions of the disc being integral and providing grinding surfaces.

A further object of the invention is to provide a resilient cushion backing the disc as it is applied to a lens or mirror surface and preferably with a holder on the side of the cushion opposite the disc so that the holder, cushion, and disc being attached together are movable as a unit over the lens or mirror surface whereby the disc can accommodate itself to spheric surfaces, aspheric surfaces of revolution including toric surfaces, aspheric surfaces not of revolution, nontoric surfaces of revolution, and surfaces not of revolution but of continuously varying curvature.

Other objects and advantages of the present invention will be illustrated in the accompanying drawings and set forth in the accompanying specification and claims.

In the drawings,

FIGS. 1, 2, 3 and 4 are top plan views showing discs slitted in various manners appropriate to the carrying out of this invention;

FIG. 5 is a central sectional view taken along the line 5–5 of FIG. 6 and illustrating one assembly of apparatus adapted to carrying out this invention;

FIG. 6 is a top plan view of FIG. 5;

FIG. 7 is a central sectional view taken along the line 7–7 of FIG. 8 and illustrating another assembly of apparatus adapted to carry out this invention; while

FIG. 8 is a top plan view of FIG. 7.

The generation of surfaces, such as lens or mirror surfaces, on glass, plastic, or other optical material, or metal, by tools having diamond abrasive surfaces, or by tools made of metal, the abrasive action being supplied by free particles of abrasive material between the tool and the surfaces generated, leaves pits and scratches which must be removed prior to polishing the surfaces. With spherical surfaces, the use of very fine abrasive in the form of a paste or suspension between the rotating optical material and a rigid complementary metal grinding lap, rotating against the optical surface in a manner well known in the art, produces a finely ground surface ready for polishing. The grinding of toric surfaces with rigid laps is also well known in the art.

The present invention may be utilized to remove the pits and scratches left by the original generation operation in both spherical and toric lens or mirror surfaces without the necessity of making many iron laps, each of a specific curvature for a specific lens or mirror surface. Furthermore, the present invention is applicable to smoothing such surfaces which are neither spheric nor toric and for which it would be difficult or impossible to provide a rigid complementary metal grinding lap.

Wherever in the specification and claims I have referred to a disc of flexible resilient sheet metal material for the carrying out of this invention, I intend the term to include flexible sheet material such as brass, steel, phosphor bronze, or beryllium copper shim stock, in thickness varying from 0.002 inch to 0.015 inch and having sufficient spring quality as not to be permanently deformed during the lens smoothing operation. I also intend the term to include a sheet of synthetic resin material having approximately the stiffness of cellulose acetate. I also intend the term to include woven mesh material such as woven wire cloth or woven plastic. If woven wire cloth is used, I prefer a material of similar spring quality having at least 50 meshes per inch as this gives a better smoothing action.

A disc of flexible resilient sheet material as defined in the preceding paragraph, preferably of a diameter of between 2 and 10 centimeters, is slitted in such a way as to increase its ability to conform to a lens surface while leaving all portions of the disc integrally connected to each other. Four such slitting arrangements are shown in FIGS. 1 through 4. In FIG. 1, the disc is slitted along parallel chords entering alternately from opposite sides of the disc and each slit extending approximately two-thirds of the way across the disc at the particular location of the chord. The disc **10** has three chords **11** extending from the top down as viewed in the drawings and four chords **12** extending from the bottom upwardly as shown in FIG. 1 placed alternately between the chords **11**. Preferably each slit is widened slightly as it approaches the edge of the disc by removing a very thin wedge **13** of the disc material. This permits the edges of each slit to approach each other more closely as the disc accommodates itself to a curved surface.

FIG. 2 shows another form of the invention wherein the disc **14** is provided with a plurality of slits **15** extending from the periphery of the disc inwardly toward the center more than half the radius and longer than one-third of the diameter. The drawings show 12 such slits evenly spaced around the circumference of the disc but more or less might be used depending upon the problem of fitting the disc to the lens curvature. Note that thin wedges of the disc material are removed in forming slits **15** to permit the disc to conform easily to the curved surface to be smoothed. Another set of slits **16** is provided each extending from the center of the disc radially outwardly for more than one-half of the radius and preferably equally spaced between the slits **15**. In FIGS. 1 and 2 the oppositely extending slits overlap each other to give the disc flexibility.

In FIG. 3, the disc **17** is provided with 16 slits **18** extending radially inwardly from the periphery of the disc approximately two-thirds of the way toward the center. Here again, thin wedges of the disc material are removed as indicated at **19** to provide accommodation for the wedges of disc material between slits **18** to approach each other more closely around the periphery of the disc as it conforms itself to a curved lens surface.

In every case, the wedges removed at **13, 15, 16, 18** and **19** provide recessed areas in which abrasive material may be carried during a smoothing operation.

In FIG. 4, the disc **20** is provided with a spiral slot **21** extending continuously between the center of the disc and the periphery thereof.

To perform a smoothing operation, the grinding disc should be backed up by a cushion of resilient material on the side of the disc away from the work surface being operated upon. A typical set up is shown in FIGS. 5 and 6. Here a piece of material to be worked upon, such as a glass lens or the like, is shown at **22** mounted on a supporting table **23** by means of pitch or other adhesive in a well known manner. Here the table is rigid with a central shaft **23***a* adapted to be rotated by a means not shown. A grinding disc is shown at **25** and this could be one of the forms shown in FIGS. 1 through 4 or other suitable forms as described herein. Between the disc and the work is a very thin layer **26** of a suitable abrasive mixture which might be a grinding compound of carborundum and water or any other known abrasive used in the industry. It should be understood that for the purpose of the drawing the layer **26** and the shim **25** are greatly exaggerated in dimension. On the upper side of the grinding disc is a cushion **27** of resilient material which is mounted to a holder **28** by suitable adhesive. The holder **28** is of any suitable rigid material capable of performing the backup function during the smoothing operation. Preferably, the resilient cushion **27** and the holder **28** are of approximately the same diameter as the disc **25**. It is not necessary to fasten the disc 25 to the cushion 27 if the latter is of foam rubber as adherence of metal to such a cushion occurs automatically during a smoothing operation. Otherwise adhesive should be used between the disc and cushion. The holder 28 is here shown as having a thick upstanding central rib 28*a* by means of which pressure is readily applied to the entire area of the holder. Centrally of the rib 28*a* is a conical recess 28*b*, into which may be inserted an arm of pin 29 for applying pressure to the holder. This pressure may be applied by a hand held knob 30 engaging the upper end of the pin 29 or a mechanically movable arm might be substituted in place of the knob 30 as will be readily understood by those skilled in this art.

The resilient cushion material 27 may be of sponge rubber, foam rubber, natural sponge, or other materials providing a cushion of this same nature. For instance, sponge rubbers known as Type 1 and Type 2 THERMOBAR sold by the B. F. Goodrich Company are satisfactory material for the resilient cushion 27. The Type 1 material has a density of approximately 7 pounds per cubic foot and requires approximately 2½ pounds per square inch pressure to compress it 25 percent. The Type 2 THERMOBAR material also has a density of about 7 pounds per cubic foot and requires approximately 6 pounds per square inch to compress it 25 percent. In other words, the Type 2 material is less easily compressed than the Type 1 material but both of them will operate satisfactorily. Foam rubber and natural sponge in the same general range of compressibility as the THERMOBAR material may be used for the cushion 27.

A typical example of the improved apparatus of this invention and the operation thereof will now be given. The metal holder 28 is circular in plan with an outside diameter of 2 centimeters. The curvature of the undersurface 28*c* of the holder is negative with a radius of curvature of about 8 centimeters. It will be noted that the surface 28*c* is concave upwardly so as to be complementary to the surface of lens 22 which is convex upwardly. In FIG. 7 the lower surface of the holder 28′ is convex downwardly as indicated at 28*c*′ so as to be complementary to the surface of lens 22′ which is concave upwardly. This is the preferred condition. The resilient cushion 27 consists of foam rubber or sponge rubber of approximately uniform thickness and usually between 0.5 to 1.5 centimeters thick, depending on the diameter of a given holder. It is also about 2 centimeters in diameter. The flexible metal seat 25 is made of shim stock brass 0.005 inch thick and about 2 centimeters in diameter. The layer 26 of grinding compound is very fine carborundum suspended in water. The lens material 22 is glass. The pattern of slits in the disc 25 may be any of those previously described but preferably for instance the structure shown in FIG. 1. The cushion 27 is made to adhere to the metal holder 28 with a rubber cement while the shim stock grinding disc 25 is applied directly to the under surface of the rubber pad without the use of cement, such being unnecessary as mentioned above.

The entire grinding or smoothing apparatus is applied directly to the lens work which is attached to the work holder or table 23 by pitch or other adhesive as previously described. The work 22 and the holder 23 are caused to rotate about the central axis by means of the shaft 24 which is attached to suitable power driven mechanism so as to rotate the work table 23. A typical example of a lens workpiece 22 adapted to be ground by the method of this invention is a portion of a prolate ellipsoid of revolution of positive curvature having an apical radius of approximately 7 centimeters, an eccentricity of 0.7, and an outer diameter of 6.5 centimeters. As the work 22 revolves about the work axis X, the tool 25, 27, 28 is made to oscillate preferably along a fixed meridian of the work, the limits of the oscillation being such that the apex of the lens and the edge of the work, at least, are alternately covered by a portion of the tool. Here the tool is being shown as oscillatable by means of the hand knob 30 although those skilled in this art will understand that a mechanical arm might be applied to the work holder 28 to cause regular mechanical oscillation. Only moderate pressure needs to be brought to bear upon the work using the method here taught. As the work rotates about the work axis X, the frictional effect between the work and the tool due to the abrasive material 26 between them, results in the tool rotating about the bearing point 28*b*, in a manner well known in the art. The central area of the shim stock 25, because of its diameter, and because of the slits made therein, tends to conform to the surface contour of the work while the peripheral arms of the disc 17 between the slits 18 continually flex to conform to the changing surface curvature encountered as the tool revolves. If the grinder is applied to a positive nonspherical surface, each portion of the grinding surface of the disc 17 will contact the upper surface of the lens material in a twisted curved line of contact which continually changes its position and shape as the tool rotates and moves across the surface of the lens to be smoothed.

While the invention has been described with the work rotating and the tool oscillating, it should be understood that the work might be held stationary while the tool is rotated or the tool might be given oscillatory motion with neither the work nor the tool rotating. In other words, what is needed to carry out this invention is relative movement between the work and the tool either rotary, translatory, oscillatory or combinations of such motions so as to remove material from the work in a smoothing operation.

Another embodiment of the invention is shown in FIGS. 7 and 8. Here parts having a function similar to those described in FIGS. 5 and 6 are given similar reference characters with a prime suffix. Lens material 22′, having a lens surface concave upwardly, is secured by adhesive or otherwise to a table 23 rotatable by means of a rigidly connected shaft 23*a*. The holder 28′ is similar in all respects to the holder 28 previously described except that the lower face thereof 28*c*′ is convex downwardly so as to be complementary to the upper surface of the lens material 22′. The resilient cushion 27′ and grinding disc 25′ are secured to the holder 28′ as previously described in the first embodiment and a suitable grinding compound 26′ is used between the disc and the lens surface worked upon. Here the pin 29′ is seated in the conical holder recess 28*b*′ and the pin is mounted for limited vertical movement in the outer end of an arm 30′ adapted to be connected to any mechanical means whereby the arm 30′ may be reciprocated or oscillated so as to move the holder 28′ and the connected parts back and forth across the lens surface 22′. The mounting of the pin 29′ comprises a helical compression spring 31 held between the top of arm 30′ and a nut 32 held in fixed position on the pin 29′ by a locknut 33.

In this modification, the work is rotated by means of the table 23 rotated by means of the shaft 23*a* in any suitable manner. The disc 25′ backed up by the resilient cushion 27′ is oscillated or reciprocated in the holder 28′ by means of the arm 30′ and the pin 29′ as previously mentioned. The abrasive material 26′ reacts against the lens surface 22′ during this operation. It will be understood that, when grinding a negative lens surface as shown at 22′, the abrasive compound of layer 26′ concentrates along the slits 11, 15, 16, 18 or 21 of whatever form of disc is used at the location 25′ so that a multitude of continuously changing concentrated abrasive edges are presented to the work.

It has been mentioned previously that various means may be provided for causing relative motion between the grinding disc and the associated work face to accomplish the purpose of this invention. For instance, one might desire to rotate the grinding disc only while holding the workpiece stationary. In such a case, conical recesses 34, 34 in FIGS. 5 and 6 or 34′, 34′ in FIGS. 7 and 8 may be provided diametrically opposite each other and spaced from the central recess 28*b* or 28*b*′. Then, with a pin holding the center of the member 28 or 28′, a driving fork or yoke could be inserted in the openings 34 or 34′ and a rotative effect thus provided to the holder 28 or 28′. By this means one might rotate the grinding disc and at the same time rotate the workpiece also. Such rotation of these two parts might be at a different number of revolutions per minute or even in opposite directions.

By use of the shading lines in FIG. 3, it is intended to indicate that the disc 17 may either be of sheet material or of fine mesh wire as previously mentioned.

Wherever in the specification and claims I have used the word "disc" referring to members 10, 14, 17 and 20, I do not desire to be limited to a circular member but it might be oval or rectangular or any suitable shape to conform a flexible sheet to the workpiece to be smoothed.

For the grinding of doubly curved surfaces such as saddle-shaped toric surfaces, the surface 28*c* of the holder 28 might be made flat. Then, with small peripheral wedges 19 removed from the grinding disc 17, the disc will be able to conform to upward and downward curvatures of the lens surface as the tool moves over the work, and both the flat portions between slits 18, and the slitted edge portions of the disc will share the grinding action between positively and negatively curved portions of the surface of the work.

By use of the apparatus and method taught herein, it is possible to rapidly and completely remove pits and scratches from a variety of surfaces with a single flexible grinding tool to the point where polishing of the surface can proceed.

What I claim is:

1. Apparatus for applying a fine abrasive compound to a lens or mirror surface of continuously varying curvature in a smoothing operation between rough forming and polishing operations, comprising a smooth normally flat disc of flexible resilient sheet material having sufficient spring quality as not to be permanently deformed during said smoothing operation, there being slits in said material providing ability to conform generally to a lens surface, at least some of said slits extending to the periphery of said disc and opening outwardly there, some of said slits extending across said disc in direction opposite to others of said slits and said oppositely extending slits overlapping each other, the edges of said slits providing edges of concentrated abrasive capability, and all portions of said disc being integral and providing abrasive applying surfaces.

2. Apparatus as in claim 1, wherein said disc is sheet metal approximately 0.002 inch to 0.015 inch thick and having leaf spring characteristics.

3. Apparatus as in claim 1, wherein said disc is a synthetic resin material having approximately the stiffness of cellulose acetate.

4. Apparatus as in claim 1, wherein said disc is of woven mesh material.

5. Apparatus as in claim 1, wherein said disc is of woven mesh material having at least 50 meshes per inch.

6. Apparatus for applying a fine abrasive compound to a lens or mirror surface of continuously varying curvature in a smoothing operation between rough forming and polishing operations, comprising a smooth disc of flexible resilient sheet material having sufficient spring quality as not to be permanently deformed during said smoothing operation, there being slits in said material providing ability to conform generally to a lens surface, the edges of said slits providing edges of concentrated abrasive capability, a cushion of resilient material on the side of said disc away from said lens or mirror surface, and all portions of said disc being integral and providing abrasive applying surfaces.

7. Apparatus as defined in claim 6 including a holder, the side of said cushion opposite said disc being secured to a surface of said holder, and said holder surface being substantially complementary to the surface of said lens or mirror contacted by said disc.

8. Apparatus as defined in claim 6 including a holder, the side of said cushion opposite said disc being secured to a surface of said holder, and said holder surface being flat.

9. Apparatus as defined in claim 6 wherein said cushion is approximately the same diameter as said disc, a holder on the side of said cushion opposite said disc, and said holder and cushion and disc attached to each other so as to be movable as a unit over said lens or mirror surface.

10. Apparatus as defined in claim 6 wherein said cushion is of a material having the compressibility of sponge rubber having a density of approximately 7 pounds per cubic foot and requiring approximately 2½ to 6 pounds per square inch pressure to compress it 25 percent.