Nov. 3, 1970 T. L. FORD 3,537,214

OPTICAL SURFACING APPARATUS

Filed Aug. 21, 1967 2 Sheets-Sheet 1

FIG. 1.

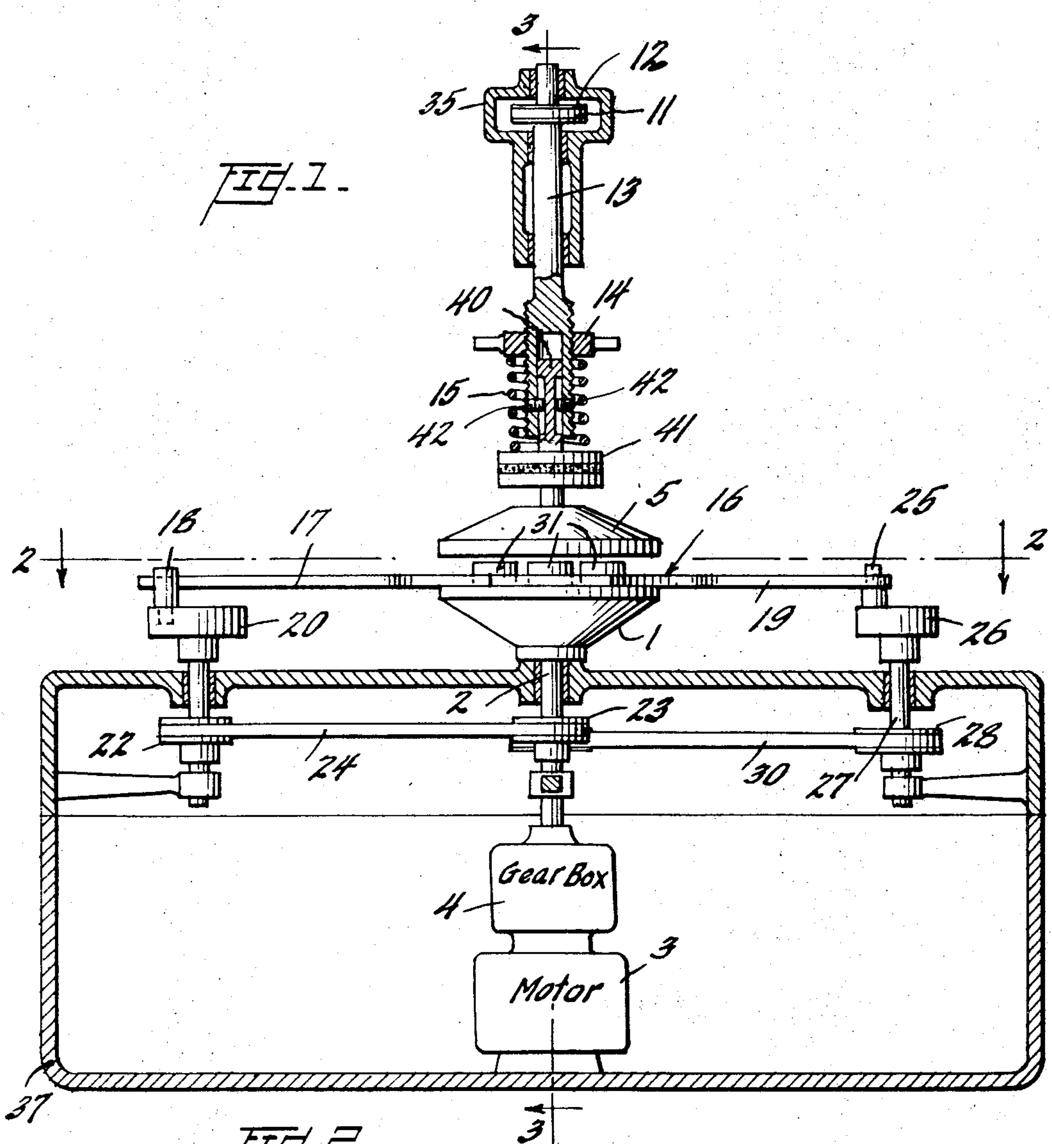

FIG. 2.

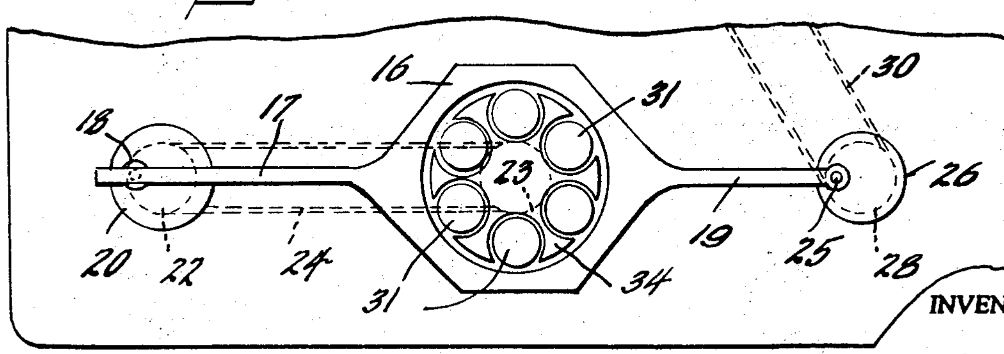

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FIG. 3.

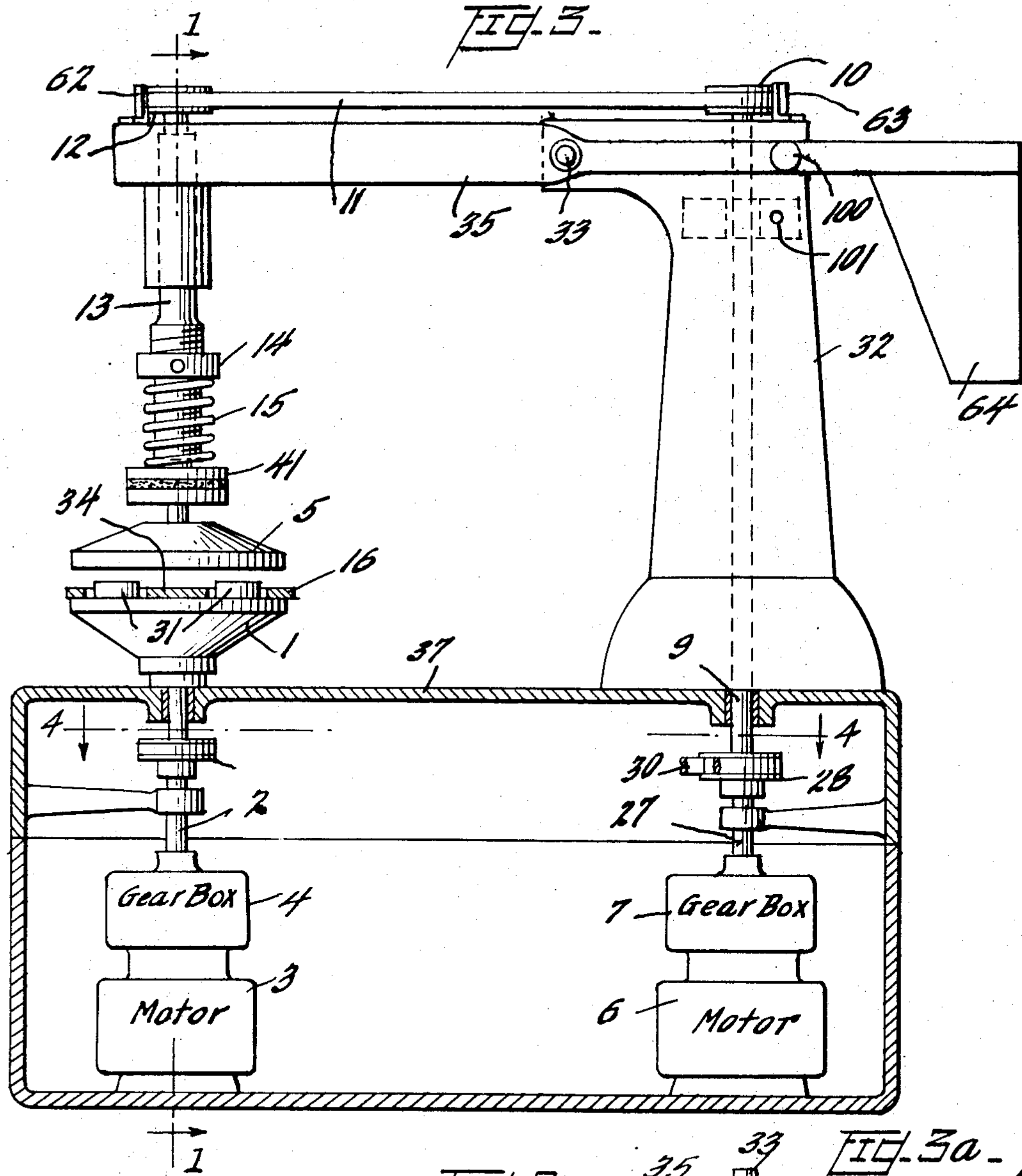


FIG. 4.

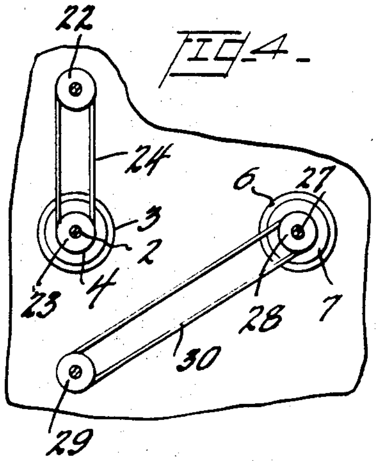


FIG. 5.

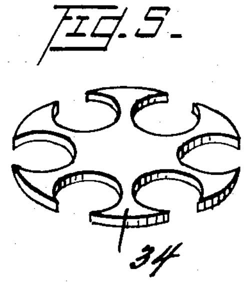
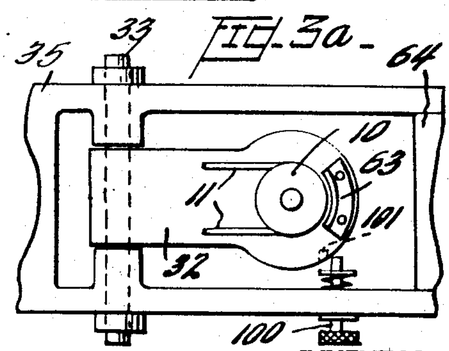


FIG. 3a.



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OPTICAL SURFACING APPARATUS

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U.S. Cl. 51—113 1 Claim

ABSTRACT OF THE DISCLOSURE

Apparatus for preparing optical surfaces by grinding and polishing comprising a work holder supporting one or more articles to be surfaced, a grinding and polishing tool for contacting the articles, and driving means imparting to the tool and articles relative asynchronous motions, e.g., in rotation, oscillation, and translation, to effect a random nonrepetitive grinding action. Preferably the articles are loosely retained on the work holder and are capable of limited freedom of movement thereon independently of the driving means, further insuring random abrasive action.

This invention relates to the working of optical glass and similar materials and especially to machines for automatically or semi-automatically grinding and polishing optical surfaces.

The basic techniques required in grinding and finishing optical parts such as flats, prisms and lenses have evolved over a long period of time. Basically, such glass surfaces are ground roughly to the desired shape, by the use of fast cutting coarse grinding material, and then fine ground and polished to provide a surface of the required smoothness. It is well known that the desired basic shaping must be achieved in the rough grinding since errors and flaws in shape seldom can be corrected economically, e.g., by special figuring, in the fine grinding and polishing steps.

In the prior art, therefore, the usual approach to optical working has been to do the rough grinding on one machine, transfer to another for fine grinding, and to still another for the final polishing. Although the same basic grinding motions may be used in all or most of the operations, there remains the requirement for different setups to provide for special figuring to rectify errors made in rough grinding, and to facilitate use of different grinding and polishing materals, grinding pressures, etc. In general, the optical part being processed must progress through a half dozen or more operations from the rough blank to the finished flat or other desired surface.

Typically, in an optical surfacing arrangement, a tool is charged with a grinding or polishing material, placed in contact with the work to be surfaced, and moved under pressure in rotary and translatory motions which are selected to produce the desired shaping or polishing. As the grinding material, such as Carborundum or emery, becomes worn, it must be removed and replaced. From time to time the surfaces must be checked to insure that the desired shape, smoothness or other characteristic is being effected. A primary factor in all such grinding is the relative overall motion between the tool and the work, and a major difficulty is that of preventing zonal distortions which result from nonuniform grinding. It is to the solution of these problems that the present invention is directed.

Traditionally, and until quite recent times, high quality optical work has required hand processing to insure optimum characteristics such as shape, size, and minimum distortion. In hand grinding the optical worker applies certain chosen motions for awhile, using abrasives of the desired coarseness, and tests his work from time to time to determine progress. As defects are discovered, corrective motions and figuring are applied. Finally, the finished part is tested very carefully to determine the resultant flatness, curvature or other desired characteristic. Such a procedure obviously is time--consuming and has been replaced in industrial optical plants long ago by automatic or semi-automatic grinding and polishing machines.

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While automatic machines effect a great speed-up in optical processing, there have been many difficulties with zonal distortions due to nonuniform grinding. In machine grinding the motions tend to be more recurrent and, of course, more powerful than in hand grinding. Further, the grinding speeds are so greatly increased that zoning or similar distortion may progress rapidly and become uncorrectable by the usual procedures. Thus, in high quality surfacing it has been necessary to grind in stages, check the progress, and make corrections where practical as the grinding proceeds. This step-by-step machine grinding and polishing also is relatively time-consuming and increases the cost of producing high quality optical parts.

In the prior art it has been understood that a combination of rotary and translatory motions is required to provide uniform grinding of optical surfaces. Accordingly, many arrangements have been devised to produce such motions. Perhaps the most widely used approach has been to utilize a planetary gearing arrangement in which the tool is moved in various spiral motions across the work. While processing speed is increased greatly, all such gear arrangements, utilizing definite fixed ratios between the various motions, have resulted in nonuniform grinding.

Another approach to increasing the production rate has been to grind many parts on the same machine simultaneously. For example, a large number of flats or prisms may be assembled and held in proximity in plaster of paris, or similar matrix material, on a work support, so as to permit multi-element grinding and polishing. Although such a procedure facilitates processing, it is apparent that the same limitations apply, with respect to nonuniform grinding, as for separate processing.

In accordance with the present invention, improved surfacing is provided by machine arrangements in which the necessary rotary and translatory or other motions are combined in a purely random manner so as to result in a minimum of nonuniform grinding.

Accordingly, it is an object of this invention to provide improved apparatus for surfacing optical parts of high quality in which the relationship between the various grinding and polishing motions is purely random. A further object is to provide an apparatus in which a large number of optical parts may be simultaneously surfaced by a random relationship of the grinding motions. Still another object is to provide for accurate grinding and polishing of optical parts on a single machine. Further objects will be apparent from the following description and the accompanying drawings, in which:

FIG. 1 is a transverse vertical section on the line 1—1 of FIG. 3, illustrating a preferred form of apparatus embodying the invention;

FIG. 2 is a plan view taken on the line 2—2 of FIG. 1;

FIG. 3 is a side elevation of the same apparatus;

FIG. 3*a* is a partial plan view of FIG. 3;

FIG. 4 is a fragmentary view on a reduced scale of the primary driving means; and

FIG. 5 is a view in perspective of the inner mask or cage which hold the optical elements in relative, but not rigid, relationship.

Referring to FIG. 1 of the drawings, there is shown a work support **1** which may be mounted on a base housing **37** for rotation on a vertical axis. Work support **1** may be rotated by shaft **2** which is suitably journaled in housing 37 and driven by motor 3 through a gear reduction box 4. The speed and torque applied to work support 1 may be varied by appropriate regulation of motor 3, or of the gearing, to meet the particular surfacing requirements.

Mounted above work support 1 for rotation on a vertical axis is a grinding and polishing tool 5, the tool being rotated by motor 6 through gear reduction box 7, shaft 9, pulleys 10 and 12 with belt 11, and upper driving shaft 13. Grinding tool 5 is preferably fitted with a pressure control collar 14, threaded on shaft 13, and cooperating spring 15 by means of which adjustments of the grinding pressure may be made. Thus driving member 40 may be splined or keyed within shaft 13 to slide axially within and be rotated by shaft 13. Set screws 42, threaded in opposite sides of shaft 13, engage longitudinal slots in driving member 40 to retain the driving member within upper driving shaft 13 while permitting relative axial movement therebetween. When pressure control collar 14 is threaded downwardly on shaft 13, the compressive force of spring 15 is transmitted to grinding tool 5, resulting in increased grinding pressure on optical elements 31 as they rest on work support 1. The rotary speed and torque applied to grinding tool 5 may be adjusted, in similar manner to work support 1, by use of suitable electrical controls of motor 6 or by regulation of gear box 7.

Between driving member 40 and work support 1 there is interposed a self-adjusting driving joint 41, for the purpose of providing parallelism between the surfaces of the grinding tool 5 and work support 1 during the surfacing operation. This self-aligning action of driving joint 41, shown as a conventional flexible coupling, may be a double gimbal, a ball-joint or other universal joint drive, is essential in the grinding of optical elements 31 as parallel flats. The various random grinding motions, hereinafter described, plus the self-adjusting feature of driving joint 41, provide the grinding and/or polishing action necessary to produce parallel flats of exceedingly high quality.

Resting movably on work support 1 is outer mask or cage 16 which is fitted with reciprocating drive rod 19 and lateral drive rod 17. Reciprocating drive rod 19 is journaled on crank pin 25, which is rotated by reciprocating crank disk 26 which in turn is driven by motor 6 through gear reduction box 7, pulleys 28 and 29, associated belt 30 and shaft 27. Lateral drive rod 17 is shaped so as to fit loosely and slidably in crank pin 18, carried by lateral crank disk 20, which is rotated from motor 3 through gear box 4, pulleys 23 and 22, and belt 24. Thus outer mask 16 is driven in the horizontal plane by reciprocating motion of crank pin 25 and by essentially lateral motion of crank pin 18.

Motors 3 and 6 are asynchronous, and the relative speeds at which work support 1 and grinding tool 5 are rotated will therefore vary with time, as will the rate of rotation of crank disks 20 and 26. The two motors and/or their associated gear boxes are preferably so regulated as to establish, apart from this variation, a differential rotation between work support 1 and grinding tool 5; usually the support and tool are driven in opposite directions and the rate of rotation of each is selected to provide optimum grinding conditions.

While the relative speeds of the several elements is not critical, the tool is preferably rotated at about three times the speed of the work support, usually varying from about 5 r.p.m. to about 30 r.p.m. Oscillatory and translatory movements in a speed ratio of $3:L$ and in the range of 5 to 10 strokes per minute are effective. All of these relative speeds vary widely in practice, depending upon the stage of grinding the particular work requirements, and various other factors and are within the skill of the artisan to select.

One or more optical elements 31 are placed on work support 1 and are held loosely in position thereon by inner mask 34, shown separately in FIG. 5. The arrangement of outer mask 16 and inner mask 34 with respect to the optical elements 31 may be understood more clearly from FIG. 2 in which there is shown also the driving arrangement for the outer mask. As will be noted, the optical elements 31 are placed loosely in holes cut in the inner mask 34, which itself is held loosely within the larger circular opening provided in the outer mask 16. Additionally, the periphery of inner mask 34 is discontinuous so that in certain positions the outer edges of the optical parts 31 may contact and be moved by outer mask 16. It will be noted also, as shown in FIG. 1, that inner mask 34 and the optical elements 31 rest on the rotating work support 1.

Thus a rotary motion is applied to optical elements 31 by work support 1 and a combined translatory oscillating motion is imparted to the inner mask 34 by the motion of outer mask 16. It will be seen that the reciprocating drive rod 19 of the outer mask is connected to crank pin 25 so as to drive outer mask 16 in essentially longitudinal or reciprocating motion when reciprocating drive box 26 is actuated. Likewise, the lateral drive rod 17 fits in slotted lateral motion crank pin 18 so as to move outer mask 16 in essentially lateral motion when lateral drive crank disk 20 is actuated. Thus the overall motion of outer mask 16 is under the randomly associated control of motor 3 and motor 6 by way of the separate gearing and power transmission means. Since the two motors are asynchronous, a repetitious pattern of grinding is precluded.

Referring again to FIG. 1, the upper surfaces of the optical elements 31 project slightly above the upper sides of inner mask 34 and outer mask 16; thus the grinding pressure from grinding tool 5, along with the rotary motion, is applied only to the upper surfaces of optical elements 31.

From the description of the several motions, drives and loose couplings, it should be apparent that the novel surfacing arrangement is intended to produce the necessary grinding or polishing motions in an essentially random relationship so as to prevent nonuniform grinding of "zones." Likewise, reciprocating drive box 26 and lateral drive box 20 are driven in opposite directions and at different speeds, so that the translatory oscillating motion of outer mask 16 is random in nature. Still another random motion is introduced as optical elements 31 move on the work support 1 independently of masks 16 and 34. The resultant overall grinding path of optical elements 31 is thus derived from a considerable number of translatory and rotational motions and forms a randomly oriented rosette-shaped figure with reference to the center of the driving force system which is completely nonrepetitive. As a result, surfacing is quite uniform, zoning distortions are eliminated or minimized, and it is possible to accomplish all or most of the surfacing on a single machine.

Certain precautions common to the optical surfacing art should be observed for best results. For example, the surfaces of grinding tool 5 and work support 1 should be arranged with grooves or slots to facilitate access of the grinding fluid or compound to all parts of the working surfaces. The work support thus serves both as a support and a surfacing or grinding tool, opposite surfaces of the work being thus concurrently surfaced or ground. Similarly, provision may be made for introducing the grinding material automatically, at least for rough grinding, and for circulating the material. All such procedures are well known and widely used in optical workshops.

The driving system for grinding tool 5 may be enclosed in a protective column 32 and upper housing 35 so as to prevent damage by grinding or polishing material. As shown in FIG. 3, housing 35 is pivoted at 33 on column 32 in order that grinding tool 5 may be swung upwardly for adjustment, cleaning, adding grinding material and similar operations. Belt retainers **62** and **63** mounted on housing **35** retain belt **11** in place when housing **35** is tilted. Counterweight **64** serves to balance out some of the weight of tool plate **5**, shaft **13** and housing **35**, so as to bring the grinding pressures within the desired range. Base housing **37** is sufficiently heavy and rigid to prevent vibration and other movements which might result in nonuniform surfacing. When desired, housing **35** may be held in upward position by means of spring-loaded retaining pin **100** and associated indentation **101** in column **32**.

In the interest of clarity the preferred embodiment of the invention has been illustrated and described in detail. It will, nevertheless, be understood that the invention is not limited except as hereinafter defined, and that various changes and alterations within the scope of the appended claim are contemplated.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. Apparatus for preparing optical surfaces by abrasion comprising, in combination:

a work support having a surfacing face for articles to be surfaced,

a surfacing tool supported to engage the articles,

driving means imparting relative asynchronous rotation to said work and surfacing support and said surfacing tool, and

reciprocating means for displacing said articles on said work support in random, nonrepetitive fashion during the surfacing operation, said reciprocating means comprising,

an inner mask loosely embracing and separating the articles,

an outer mask loosely embracing said inner mask and said articles as they rest on said work support to allow limited but independent freedom of movement of the articles on the support during the surfacing operation, and

devices connected to said outer mask for imparting concurrently thereto movement to said mask and the embraced articles in a plurality of different directions.

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