June 25, 1935. J. DESENBERG 2,005,718

GRINDING

Filed Oct. 26, 1931

FIG. I.

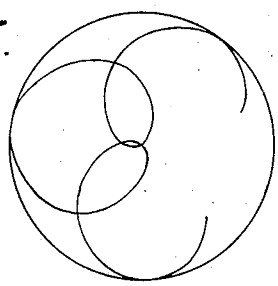


FIG. II.

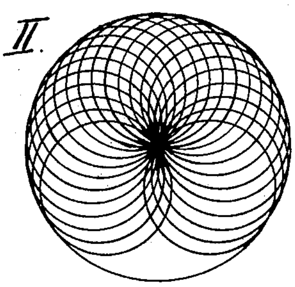


FIG. III.

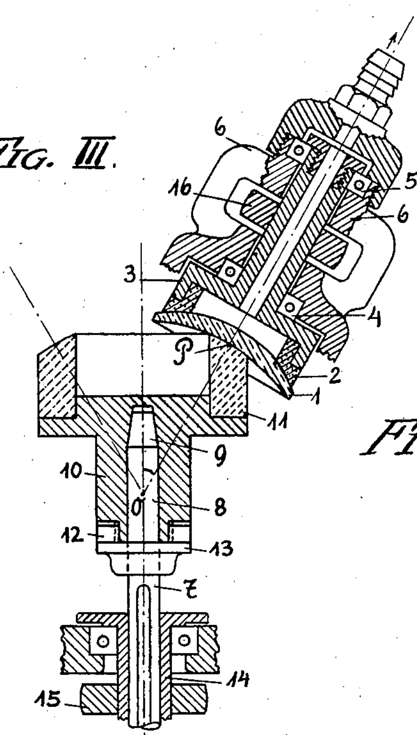



FIG. IV.

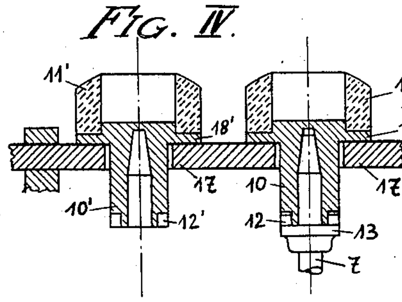



FIG. V.

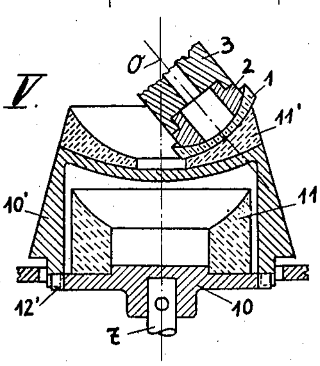



FIG. VI.

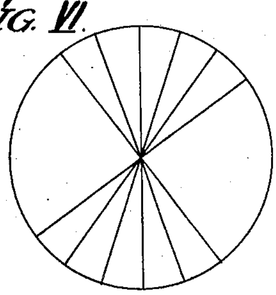


FIG. VII.

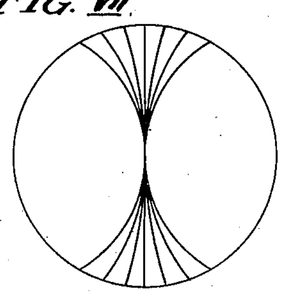
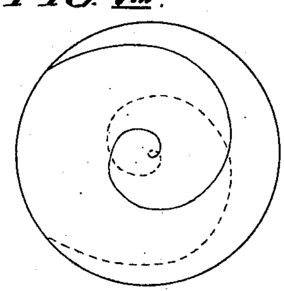


FIG. VIII.



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# UNITED STATES PATENT OFFICE

2,005,718

## GRINDING

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13 Claims. (Cl. 51—278)

This invention relates to methods for grinding and polishing spherical and aspherical lenses and similar objects.

In the ordinary lens-grinding machine fitted with loose grinding-surfaces working on universal joints and which surfaces by means of their ball-sockets are carried along in irregular movement through contact with the rotating opposed surface, it was admittedly impossible in actual practice to maintain distinct relative motions of both working surfaces inasmuch as the contact was constantly varying and, among other things, depended also upon the ever-changing consistency of the grinding grains, on the actual oscillating movement itself, on the size and quality of the effective contact-surface, on the friction-coefficients, and other factors.

In the type of machine now under consideration, the axis of rotation of the grinders and lens-holders is maintained without the use of universal joints and these lines cut one another in or near the optical centre of curvature, with complete and unvarying surface-contact of both grinder and lens-holder, which results in the grinding movements shown in Figs. 1 and 2. By reason of their comparatively unfavorable grinding or polishing effect, this type of machine was generally speaking only suitable for particular operations, such as the manufacture of bi-focal lenses etc.

The working methods now to be described attempt to secure considerably better grinding and polishing effects in such lens-grinding machines whose axis of rotation cuts the optical centre of curvature by means of systematically controlled relative point lines (i. e. the mark made by the individual grinding grains on the lens and on the grinding surface by wet grinding medium, or the mark made on the lens when a hard grinding medium is used. The designation is also used in reference to the mathematical direction taken by the grinding grain, apart from the track it makes on the glass).

In particular, it has been proved to be specially advantageous in securing the quickest result when grinding and smoothing (in some cases also when pre-polishing) to do the work in as short a space of time as possible by choosing the right speed of rotation with the result that a very large number of hard (ceramically burnt) or soft (wet) grinding grains are brought into operation.

To secure more accurate results when finally polishing (in some cases also when pre-polishing, smoothing etc) it is in many cases advantageous either to shorten the point-lines on the grinder or systematically so to affect the said point-lines on the grinder (which not only revolves on its spindle but can move backwards and forwards or alter its speed or reverse its direction or be changed for a large tool producing other effects) so that the machine in question when working over one or several lenses can vary the point lines during the process by the means above referred to. By this means the work is more quickly and more economically executed and a greater accuracy in shaping is attained.

The grinding grains are thus mainly distributed over such lines which (lines) never appear as intersecting curves both on the lens and on the grinder simultaneously inasmuch as the speed etc of the lens and grinder do not co-incide. The method of executing the work is such that in coarse or fine grinding (also smoothing or pre-polishing) firstly one makes very short grinding strokes on the lens and then when finally polishing (or smoothing or pre-polishing) either short polishing strokes on the grinder or by oscillation etc special spiral or oscillatory curve strokes.

The procedure to effect comparatively short point lines simultaneously upon the lens and upon the grinder can also be effected by giving a greater angular velocity (and thereby the main action) to the smaller lens surface on its rotating spindle while using the larger grinder-surface with less angular velocity (and thereby subsidiary action) in conjunction. The effect of this difference in the action of grinder and lens creates definite (and comparatively short) spiral point lines on the lens-surface. Transferring the main work to the lens has the advantage of making quicker and more precise workmanship.

At the same time, in many cases it will be sufficient or necessary, in order to secure intersecting point-lines when grinding or polishing, for example, to alter the relative rotary speed or direction of rotation of the spindle in the process, or to select different sizes of grinder of uniform average diameter, or grinders of different widths.

For this purpose in order to facilitate the change of grinders on one and the same tool-spindle, one can arrange the various grinding and polishing tools in concentric form separate from one another. Thus an automatically consecutive grinding and polishing service is considerably facilitated. And the inaccuracies caused by dismounting the lens and engaging it with another spindle are completely avoided. The change of tools can be, for example, so effected that the grinders which work in a group together (concentric, mutually interacting) are mounted on spindles so arranged that various grinders come into action automatically one after another (by means of a capstan or such like).

The highest possible number of grinding or polishing grains are brought into play, which in spite of concentric surfaces, impinge from without on the lens material (a result impossible if the grains only remain between the two surfaces and do not impinge from without). Therefore the pressure of the two surfaces on one another can be reduced. In practice this renders possible, better working speed and a greater quantity of material cut away by the grinding process. Inasmuch as the various point lines are intentionally altered during the grinding process, the exact grinding of the lenses is more completely attained. The whole result is that the process is considerably accelerated and a speedy automatic manufacture is rendered possible, as has been proved in practice.

This influence and the already mentioned facts connected with it have up till now not received sufficient attention. Therefore there has been no attempt, by suitable choice of relative rotary speed or other pertinent details, to shorten the point-lines on the principal working surfaces, to vary the choice of grinding and polishing strokes, as well as the time to which the direction and radial curves of the grinding and polishing strokes can be set in a particularly favourable conjunction.

Figure I is a diagrammatic view showing the outline of a lens and by a curved line the point path of a grinding grain over the face of the lens.

Figure II is similar to Figure I but showing a relatively long point path with numerous intersections.

Figure III is a central sectional detail view, partly broken away, of a grinding device adapted to carry out my invention.

Figure IV is a detail central sectional view of a modified form of device showing two grinding tools and their holders.

Figure V is a detail central sectional view of a further modified device showing a lens, polisher and the supporting means therefor and

Figures VI, VII and VIII are views similar to Figures I and II but showing point paths of different forms.

In general, when grinding and polishing, one chooses the point-lines illustrated in Figs. II and I, which in the main give infinitely long and frequently intersecting curves.

In the following examples, the process will be discussed and developed in greater detail by reference to schematic design.

In Fig. III the lens is fastened on the holder **2** which is supported by the hollow rotating spindle **3**. The spindle **3** is mounted on two ballbearings **4** and **5** which are mounted in the casting **6** and are adjusted with this to an invisible vertical axis-direction through spindle **3** to grinder-spindle **7** (i. e. adjusted to the central point P of the working surface) so that the two spindles **3** and **7** cut at every desired angle of axis in the optical centre "**0**" (below or above the working surface). The tool-spindle **7** carries on its mandrel-guide **8** (with conical head **9**) the tool-holder **10** with the annular grinding tool.

At the lower end of the tool-holder **10** a coupling-clutch **12** is provided, which locks with the opposing teeth of the disc **13**, so that the speed of the tool **11** is governed by the rotation of the disc **13** on spindle **7**. The bush **14**, by means of a key governs spindle **7** and is driven by its pulley **15**. Spindle **3** is driven from the pulley **16**.

By the process above-described, a spherical seating, with the distance of the grinding-surface from the axial point of intersection as radius, must be created with mathematical exactitude (even when the shape of the parts originally chosen varies) and must be attributed to the fact that both grinding pieces wear themselves away or work themselves down until complete surface-contact is achieved, which is only rendered possible by the spherical seating referred to.

A change in the various grinding and polishing tools for the above process can be carried out as in Fig. IV which is particularly applicable to automatic machines by a mechanical device e. g. the tool holder **10** is lowered by spindle **7** until the flange-ring **18** rests on the transport-plate **17**. A sideways motion of the transport-plate **17** is made and the succeeding tool **11'** comes into the position left by the tool taken out of action. The spindle **7** thus disengages from the teeth **12** of the tool **11** and engages again when **11'** is above it.

Fig. V is intended to show that the lower grinder **11** when smoothing or polishing can remain fixed to its holder **10** on spindle **7**. The larger hatlike carrier **10'** of the tool **11'** (next to be used) is fixed over the grinder **11** and the teeth **12'** are engaged in the teeth of the holder **10**. Either of these or other following tools can be fitted (when necessary) with a guard to prevent splashing of grinding grains. The two tools shown in the diagram V do not come simultaneously into contact with the lens. Either the grinder on the hatlike carrier **11'** or the grinder **11**, but not both at once.

Disconnecting, removing, engaging and fastening of the grinding disc **11** which is responsible for the grinding accuracy, is not necessary at every stage of the process nor by altering the course of the grinding-grains, as can be seen by Fig. V so that a saving is secured in working methods and precise fixing in the position. The lessening or absence of interruptions in the work to change tools of various degrees or groups of grinding lines when grinding, smoothing, pre-polishing or finally polishing is very advantageous in the application of the above process with automatic or semi-automatic machines with fixed (not ball-jointed) spindles. If necessary, the mounting and dismounting of the polishing head **11** can take place quite automatically without stopping the spindles.

Assume the middle diameter of the grinding tool-surface at point P to be "$d/1$", the diameter of the lens to be "$d/2$", the peripheral speed of the grinder at point P to be "$u/1$" and the peripheral speed of the lens to be "$u/2$", the result, for the outside calculation in the production is a completely straight grinding-line running through the centre of the working-surface diametric from circumference to circumference in flat grinding-surfaces and gives the mathematical formula

$$\frac{d/1}{d/2}=\frac{1}{2}\frac{u\,1}{u\,2}$$

This mathematical comparison is only exact when the spindle axes of both grinder and lens are parallel. This outside calculation gives, as Fig. VI demonstrates, theoretically and practically far more favourable grinding conditions than e. g. those of Figs. I and II. It should also be noted that in special grinding surfaces, very complicated spherical-trigonometrical data for a mathematical calculation present themselves. To counteract any idea that the grinding lines in Fig. VI only intersect in the middle of the surface of the lens, it should be pointed out that by an appropriate width of grinding tool a sheaf of curves can be secured which in practice provides a sufficient counteraction against any undesirable irregularities of surface.

Fig. VII is to illustrate a number of grinding strokes which go through the middle of the surface of the lens or grinder and make short transits.

Should the calculatory or pictorial description of the grinding strokes seem to be complicated, it is easy to make them ocularly visible by means of a small grinding ring with a comparatively coarse grinding grain and, if necessary, with the aid of a magnifying glass.

By changing over from a coarser to a finer grinding or polishing grain of hard or wet nature, especially when going over from the grinding to the polishing process, which can be done on the same or different spindles, it will possibly be better to alter the grinding or polishing strokes where the lens-surface or tool-surface are small. This can be done quite simply e. g. by changing the relative speed of the rotation or the direction of same, either during the operation or by using polishing stones or polishing discs whose diameter or working surface are intentionally different in proportion to the last tool used.

In Figs. III and IV the grinding or smoothing tool 11 consists of a small grinding ring. In Fig. V the polishing tool consists of a complete polishing disc or a wide polishing segment. The systematic alteration of or addition to curve-groups suffices in every case to provide a speedy preliminary polish or a good final polish in the working-method under consideration.

This is especially the case if the coarse and fine grinding (or smoothing) is executed in the already mentioned manner with short strokes on the lens, the pre-polishing or final-polishing (or smoothing) with short strokes or with spiral or oscillatory curve-strokes on the working-surface of the lens.

Fig. VIII is to illustrate a spiral point-line, which goes through the middle of the surface of the lens and makes comparatively short transit.

By systematic movement (by a grinding tool, composite lever-system, model, etc) by the lens-spindle 3 in Fig. III e. g. by oscillating or swinging at a curve or at an oscillating axis lying outside the optical centre during the work, or by systematically directed parallel movement of the tool-spindle 7, aspheric lenses can also be manufactured by short grinding strokes whereby in case of necessity (e. g. by irregular lenses) special carrier joints can be used.

As the grinding machines now under consideration have not only sufficient exactness for single-piece methods and also quicker polishing power, but have also a better centering and maintenance of the middle thickness of the glass etc. over the usual machines and methods with so-called multiple-polishing and multiple-grinding (group of lenses) a further noteworthy effect of the said process is that the machine under consideration now renders practically possible a very advantageous automatic or semi-automatic grinding or polishing system with single-piece (one lens) with a small and comparatively simple machine.

In consequence of the former use of grinding and polishing strokes with small power, it is useless under such conditions to use the machines last referred to for spherical and aspherical lenses from large to small diameters in mass-production such as is the pre-condition for an automatic system.

By means of the process now under consideration one can work on several lenses fixed in the usual manner to the same holder and using hard or wet grinding or polishing grains comparatively quickly with great working speed at one and the same time in multiple-grinding or multiple-polishing by means of one spindle whereby the total working surface is made up of several separate surfaces.

Though only one lens is fastened to the rapidly rotating spindle 3, nevertheless a number of such single-lens spindles can work to a quickly moving concave, flat or convex grinder 11, as can be seen in the dotted diagram (see Fig. III, left corner).

In case it appears advantageous, to secure a quicker machine-setting or when using outside-limit or calliper device for the axial tool-movement, to maintain the position of the grinding surface (point P) in one place, one can regulate the lens-holder 2 (which can, if necessary, be given varying lengths or axial variability for varying lens-curves) by a variable axis going through P as indicated in Fig. III.

This is then especially suitable when using hard or wet grinding or polishing grains with the usual automatic device in metal-working with a capstan-machine combining it effectively with the above-described process.

It is known that principally by the glass-grinding machines with universal-jointed lens-holders and so-called rocking motion, comparatively favourable polishing results have been obtained, especially by flat or slightly curved surfaces on large polishing-machines or grinding-machines where very many lenses are mounted together on a common holder which is made as large as possible.

But if one looks closer at the surface of single pieces done by this popular multiple method, one sees faults caused by the uncontrollable and constantly changing grinding; and, in general, the length and curvature of the strokes have grown in proportion to the above-mentioned increase of the grinding surface. The mounting of the glasses next to one another causes many difficulties (in regard to optical centralization, maintenance of a particular middle thickness, equality of polishing and grinding of all the lenses, safe mounting and unmounting, apart from freedom from scratches on the lenses themselves) and is by the nature of the case with sharply curved lenses unable to be carried out at all or only in a limited form.

The widely used coarse grinding process, generally adopted by metal-polishers with limited demands on exactness or fineness of surface (whereby the machine grinds forward step by step in relatively slow progress with very poor line-control and imperfect surface-contact) is not practicable for brittle optical glasses for various reasons although the grinding strokes admittedly show no deviations, or very few, and are very short.

It will be understood in the accompanying claims where I use the word "grinding" without reference to polishing, I use the word in a generic sense including polishing.

I claim:

1. The method of grinding and polishing a lens which is rigidly mounted on a rotary spindle and which is worked by a front side of a rigidly mounted tool, using uniform facial contact between the tool and lens, which method comprises rotating the tool and lens in such facial contact at such relative speeds and in such directions that the working point paths are short and numerous and changing systematically such of said paths as pass through or near the lens center whereby an accurate and automatic working is effected over the entire surface of the lens.

2. The method of grinding a lens which is supported on a rotary spindle having a fixed axis and which is worked by surface contact of the front side of a rotary tool mounted on a fixed axis intersecting said first named axis at a point which determines the curvature of the surface to be ground, which method consists in rotating said lens and tool at relatively high speeds and at relatively light contact pressure, the relative speed and directions of rotation of said lens and tool being such that the grinding point paths are short and numerous and further in systematically changing during such paths as pass through or near the center of the lens, whereby an accurate grinding is effected over the entire surface of the lens.

3. The method according to claim 2 wherein said change in point paths is effected by change in rotary speed.

4. The method according to claim 1 wherein said change in point paths is effected by change in direction of rotation.

5. The method according to claim 2 wherein said change in point paths is effected by change in rotation.

6. The method according to claim 1 wherein said change in point paths is effected by changing the tool dimensions during the operation.

7. The method according to claim 2 wherein said change in point paths is effected by changing the tool dimensions during the operation.

8. The method according to claim 2 wherein the change in point paths is effected by a swinging movement of tool and lens relative to one another about the point of intersection of tool and lens axis.

9. The method of grinding a lens which is rigidly mounted on a spindle having a fixed axis and which is worked by the front face of a tool and of a diameter relatively large in comparison with that of the lens, which tool is rotatably mounted on a fixed axis and is in facial grinding contact with said lens, which method consists in rotating said lens at a relatively higher speed than said tool so as to produce short point paths on said tool and short spiral grinding point paths on said lens and systematically changing such of said paths as pass through or near the center of the lens so that the lens is accurately ground over its entire surface and the formation of zone rings avoided.

10. The method according to claim 1 wherein the grinding is effected by relatively short point paths on the lens and the polishing is effected by relatively short point paths on the grinder.

11. The method according to claim 2 wherein the grinding is effected by short approximately straight paths on the lens, prepolishing is effected by short paths on the grinder and polishing is effected by short spiral paths on the lens.

12. The method according to claim 9 wherein said change is effected by changing the radii of point paths on the lens, one or more of said radii being of a length substantially equal to the length of radius of the grinding tool and the remaining radii being of greater length.

13. The method according to claim 1 wherein said change in point paths is effected by change in rotary speed.

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