

W. TAYLOR.
METHOD OF AND APPARATUS FOR GRINDING GLASS.
APPLICATION FILED OCT. 28, 1920.

1,401,831.

Patented Dec. 27, 1921.
2 SHEETS—SHEET 1.

Fig. 1.

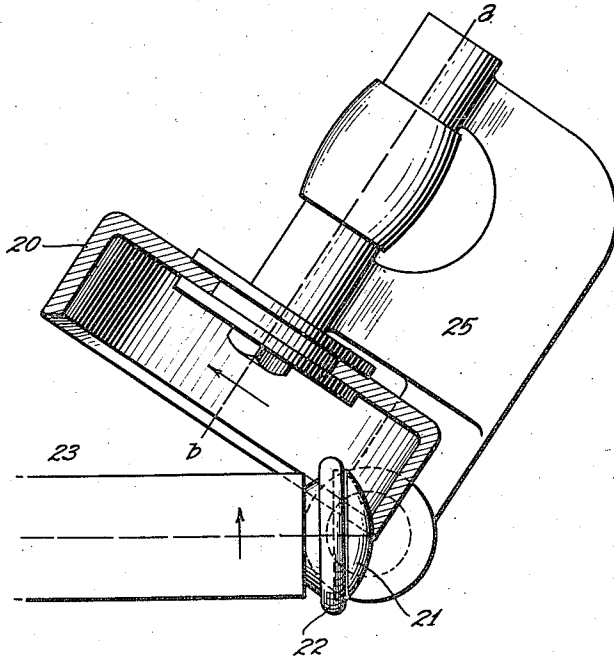
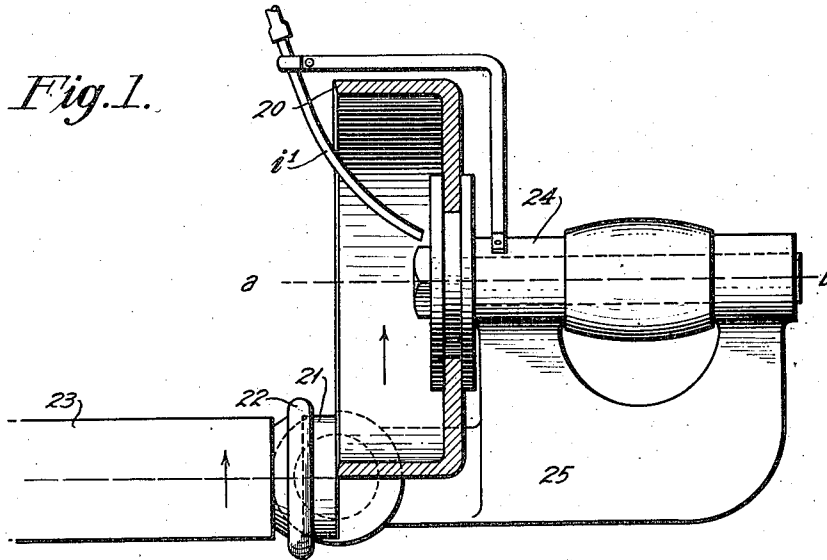


Fig. 2.

INVENTOR
William Taylor
BY *Arthur H. Kest*
his ATTORNEY

W. TAYLOR.
METHOD OF AND APPARATUS FOR GRINDING GLASS.
APPLICATION FILED OCT. 28, 1920.

1,401,831.

Patented Dec. 27, 1921.
2 SHEETS—SHEET 2.

Fig. 3.

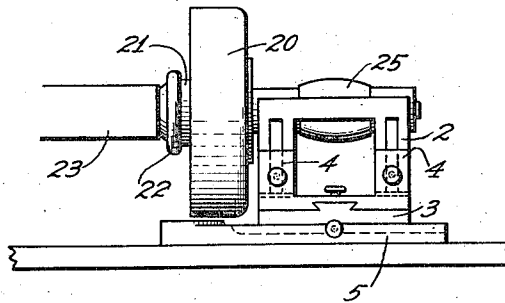
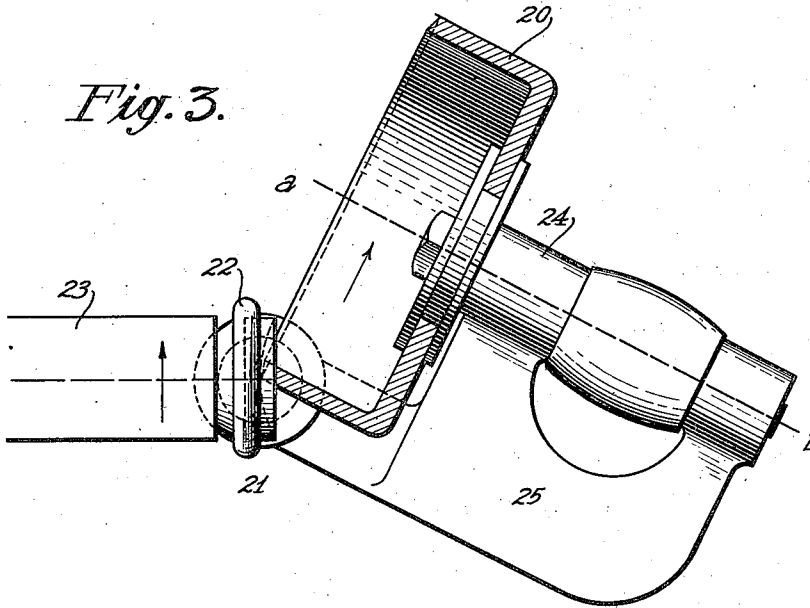


Fig. 4.

INVENTOR
William Taylor
BY *Arthur L. Kauts*
his ATTORNEY

UNITED STATES PATENT OFFICE.

WILLIAM TAYLOR, OF LEICESTER, ENGLAND.

METHOD OF AND APPARATUS FOR GRINDING GLASS.

1,401,831.

Specification of Letters Patent.

Patented Dec. 27, 1921.

Original application filed October 28, 1916, Serial No. 128,235. Divided and this application filed October 28, 1920. Serial No. 420,077.

To all whom it may concern:

Be it known that I, WILLIAM TAYLOR, a citizen of Great Britain, residing at Leicester, in the county of Leicestershire, England, have invented certain new and useful Improvements in Methods of and Apparatus for Grinding Glass, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

This invention relates to methods of and apparatus for grinding glass and similar hard, non-plastic materials by means of abrasive wheels.

Heretofore, although abrasive wheels, and particularly wheels made up of particles of abrasive materials such as carborundum and the like bonded with fusible earth or in other ways, have been used very largely in grinding metals, comparatively very little use has been made of such wheels in grinding glass. Before the advent of artificial abrasive wheels, certain natural stones were used for grinding the channels in what is known as cut glassware, and also for grinding the edges of spectacle lenses, and since their introduction artificial abrasive wheels have been used with some success for the above purposes as a substitute for the natural stones, but in such use they have not been run at the high velocities at which they are generally most efficient, nor have they been used with economy and success when much material has to be removed. Nor have they been used for grinding the surfaces of lenses.

The object of the present invention is to provide an improved method and means whereby glass and similar hard, non-plastic materials may be ground with artificial abrasive wheels which shall make it possible to grind plane and curved surfaces accurately with a degree of efficiency and rapidity beyond what has heretofore been obtained in the grinding of glass. Although the invention has been made with the idea of utilizing artificial abrasive wheels, and finds its greatest usefulness when wheels of such material are used, yet the invention may be carried out by the use of other kinds of grinding or abrasive materials and devices, as will be apparent.

I have found that the mode of applying an abrasive wheel to its work which is usual and proper in the case of grinding metal is

unsuitable for grinding glass quickly for the reason, as I believe, that while metal is comparatively soft and plastic and a good conductor of heat, glass is very hard and non-plastic at ordinary temperatures, and is a bad conductor of heat. When the face of a piece of metal is applied to the face of a rapidly moving abrasive wheel, particles of abrasive protruding from the face of the wheel surface attack the metal, heating it somewhat by impact and friction, increasing its plasticity by such heating, and cutting away a portion of the metal in a more or less well defined way. Plastic action seems to be a necessary part of all real cutting action, and has an important function in the so-called grinding of metal surfaces by rapidly moving abrasive surfaces. On the other hand, glass at ordinary temperatures has no plasticity; and when the pressure between the glass and the wheel is such as in the case of grinding metal would generate sensible heat and add to the efficiency of the operation by increasing the plasticity of the metal which is being removed, the result in the case of glass is apparently to heat and expand the surface locally (it being a bad conductor of heat), and produce in the glass strains which tend to detach splinters or particles from the surface. Such strains, together with the shock, pressure and tearing action of the surface of the abrasive wheel, shatters and breaks away the surface of the glass. When the abrasive wheel is applied in the usual way for grinding glass, that is, according to the practice in surface grinding of metal, with the peripheral face of the wheel bearing against the glass with a relative movement between the glass and the wheel in the direction of the plane of the wheel, and with the pressure of the wheel on the glass chiefly normal to the surface to be formed on the glass, the pressure of the wheel tends to oppose such separation of the splinters or particles of glass, and even when in spite of this, splintering and separation does occur, the splinters are unable to escape freely, being trapped between the wheel and the glass and the surface being formed is damaged by such splintering. The tendency of the glass to splinter under the action of the grinding wheel, thus interferes seriously with the grinding operation when this is carried on according to the usual practice, which prac-

tice is proper and highly efficient for grinding metals and similar relatively plastic or yielding materials. It has, therefore, been customary heretofore, when artificial abrasive wheels have been used in cutting glass, to run the same at relatively low velocities, so as to avoid or to reduce to a minimum the splintering or shattering of the glass, and such low velocity has resulted in low efficiency and slow grinding.

In accordance with my present invention, I turn to advantage this splintering of the glass under the action of the grinding wheel, with the result that the grinding wheel not only may be, but desirably is, operated at a high rate of speed, such as that which is employed in the grinding of metal, and which I believe may be as high as conditions of safety permit.

Instead of applying the grinding wheel to the glass in the usual way, I apply the grinding wheel to the work in such a way that an abrupt step or terrace is formed between the unground or original surface and the ground surface of the work, which is best normal to, but which may be from say 80° to 110° to the original surface, and that this step is cut backward by the edge of the grinding wheel acting on the side of the step, a feeding movement being caused between the wheel and the work in a direction transverse to such step and transverse to the direction in which the successively active portions of the edge of the grinder move in the rotation of the grinder; and I shape that face of the wheel which is contiguous to, or faces, the surface of the glass to be formed so that it makes contact therewith only at the base of the step, the wheel acting only on the side of the step, and the pressure of the wheel being in a direction approximately parallel to the surface to be formed and chiefly normal to the face of the step. In such "terrace grinding" it is the edge of the step which is continuously splintered by the action of the grinding wheel, and the detached glass particles are thus free to escape immediately, their detachment and escape being assisted, instead of being hindered, by the pressure of the wheel.

In grinding glass in this manner it is possible, and for the highest efficiency desirable, to run the grinding wheels at high peripheral velocities such as are commonly employed in grinding metal with abrasive wheels. On the other hand, the rate of traverse between the wheel and the work is much slower than has been customary heretofore in grinding glass with abrasive wheels, but this is much more than offset by the increased depth of cut or rate of feed.

The general application of "terrace grinding" is broadly claimed in my copending application, Serial No. 128,235, filed October

28, 1916, of which the present application is a division. The present application is directed particularly to a method for grinding spherical or approximately spherical surfaces incorporating my terracing method and to apparatus adapted to apply my terracing method of grinding to the forming of spherical or approximately spherical surfaces.

The accompanying drawings illustrate more or less diagrammatically apparatus embodying the present invention and adapted to carry out a method embodying the invention.

In said drawings—

Figure 1 is a plan view, partly in section, illustrating diagrammatically an apparatus for grinding flat or convexly or concavely curved surfaces;

Fig. 2 is a view similar to Fig. 1, but showing the grinding wheel adjusted for grinding a convex surface, and Fig. 3 is a similar view showing the grinding wheel adjusted for grinding a concave surface;

Fig. 4 is a side view of the apparatus shown in Fig. 1.

The drawings illustrate an application of my method to the grinding and generating of spherical surfaces on lenses, the apparatus shown being also adapted for the grinding of a plane surface on a lens or other piece of glass or similar material. As illustrated in the drawings the grinding wheel 20 is a cup-shaped wheel having a cylindrical grinding portion annular in cross-section, the annular edge of the wheel being applied to grind the surface of the lens. The lens or disk of glass 21 to be ground is mounted in a chuck 22 on a rotating spindle 23 which is usually mounted so that it may be given a longitudinal feeding movement to feed the lens toward the edge of the grinding wheel. The grinding wheel is mounted with its axis of rotation in, or approximately in, a plane in which the axis of the work spindle 23 lies, and the wheel is set so that as it rotates its annular grinding edge will sweep over the center of the glass disk 21 carried by the work spindle; and the grinding wheel spindle 24 is mounted in bearings in a swinging support 25 mounted to turn about an axis which is perpendicular to the axis of the work spindle and which, in order to permit the inclination of the axes of the wheel spindle and work spindle to be varied without displacing the edge of the wheel from the center of the work, passes through the line of the axis of the work spindle at the point of contact of the edge of the grinding wheel with the work. The axes of the grinding wheel spindle and of the work spindle may thus be variously inclined to each other while remaining in the same plane, or in closely adjacent parallel planes, by swinging the work spindle support about its swivel, such vary-

ing of the inclination of the axes causing no displacement of the edge of the grinding wheel from the center of the work. For taking up wear on the annular edge of the grinding wheel, provision is made for advancing the wheel longitudinally of its axis of rotation, as by forming its swinging support of an upper part 2 adjustable in the direction of the axis of rotation of the wheel on a lower part 5, as shown in Fig. 4. The grinding wheel is driven at a high rate of speed, and the work spindle rotates at a low rate. The upper part 2 of the support should also be transversely adjustable on an intermediate part 3 as shown, and the support is also formed to provide for vertical adjustment of the wheel as indicated at 4, such vertical adjustment permitting a small adjustment of the wheel in the direction longitudinal of the axis of its swinging support, so that the wheel may be set with its axis slightly above or below the plane of the work spindle axis which is normal to the axis of its swinging support.

When the axis of the grinding wheel is set parallel to the axis of the work spindle, as shown in Fig. 4, a plane surface will obviously be ground on the glass coinciding with the plane of the annular edge of the grinding wheel. If now the axis of the grinding wheel spindle be set at an angle to the work spindle as shown in Fig. 2, there will be ground on the face of the glass disk a portion of a sphere whose radius depends on the diameter of the annular edge of the wheel and on the angular relation between the axis of the work spindle and the axis of the grinding wheel spindle. If the spindles are set with their axes nearly at right angles as in Fig. 2, there will be ground on the face of the glass disk a convex surface whose radius approaches the radius of the grinding wheel, and at any intermediate angle at which the spindle axes may be set a curved surface will be ground whose radius is somewhere between infinity and this inner radius of the grinding wheel. By swinging the grinding wheel in the opposite direction so that the grinding is done by the outer edge of the wheel, as shown in Fig. 3 a concave surface may be ground on the glass disk and the radius of curvature of such surface will similarly depend upon the angular relation between the axes of the two spindles. By feeding the cup-shaped grinding wheel forward longitudinally of its axis of rotation as it wears away, and just enough to compensate for such wear, any change in curvature of the lens produced is prevented. By providing graduations (not shown) on the swivel of the grinding wheel support, I facilitate the setting of the machine so that it may be readily set to grind curves of any desired radius.

In grinding a spherical surface in accordance with my terracing method and by the method and means illustrated by Figs. 1, 2, 3 and 4, the grinding wheel should be set with its axis a little to one side or the other of that plane of the work axis which is parallel to the axis of the wheel, according to whether a concave or a convex surface is being ground, and according to the direction of rotation of the work, so that the depth of cut will be slightly greater on one side of the lens center than on the other. Terrace grinding will then take place on the side of the greater depth of cut, and grinding more in the nature of ordinary abrasive action will take place on the other side of the center of the lens.

The grinding wheel should be set so that its active edge just slightly overlaps the axis of the work spindle, and the wheel should rotate in the direction so that its active edge shall move from the periphery toward the center of the lens on the side of the deeper cut where the terrace grinding is taking place, thereby reducing the risk of splintering the peripheral edge of the lens.

With the work spindle and the grinding wheel rotating in the directions indicated by the arrows in the drawings, the grinding wheel when set for grinding a convex lens, as shown in the plan view Fig. 2 should be set with its axis slightly below the work axis, and the annular edge of the grinder should be beveled both outwardly and inwardly from a substantially sharp edge so that its outer bevel will be adapted to cut in the glass the desired abrupt step with its side substantially at right angles to the ground surface, so that its inner bevel will make contact with the ground surface of the glass only at the base of the step. True terracing action will then take place from the periphery of the lens inward on that side of the center where the depth of cut is slightly greater, and on the other or lower side of the lens center where the depth of cut is less, abrasive action which is not true terracing will be accomplished by the inner portion of the end of the abrasive annulus which is beveled to give it clearance in the terracing action which takes place above the lens center. The difference in level of the two axes, that is, the distance between the parallel planes of the two axes must be only very slight so that the abrasive action when the cut has any appreciable depth shall take place clear across the lens surface. It is best to make the greatest depth of cut in grinding curved surfaces in this manner less than the depth which is found most suitable and efficient for terrace grinding in other ways, as, for example, in grinding edges of lenses or in grinding plane surfaces. A depth of cut of about .005" is cut on the

deeper side of the center of the lens where the terracing action takes place from the periphery of the glass to its center is ordinarily found about right: with a depth of say .002", on the other side of the center where ordinary abrasive action may occur. In such case the rate of work rotation suitable for the terracing action may also suit the abrasive action, so that there is a substantial net gain in rate of grinding from employing terracing action in the major part of the work.

When the grinding wheel is set for grinding a concave lens, as shown in plan in Fig. 3, its axis should be displaced slightly in the other direction from the parallel plane of the axis of the work spindle, or slightly above the plane of the work spindle axis in the position of the parts shown, so that in this case terrace grinding will take place as before from the periphery of the lens inward on the upper side of the center and ordinary abrasive action will take place below the lens center. For such concave grinding, the edge of the grinding annulus may be formed about as shown in Fig. 3 so that on the portion of the surface ground by the outer face of the grinding wheel an abrupt step will be formed and the inwardly extending edge or face of the annulus will clear the ground surface of the lens on this side of the center, contacting therewith only at the base of the step. With regard to the angle of the step-forming face or side of the grinding wheel, it should be noted that such angle, and the corresponding angle of the step to the ground surface, will be less, that is, steeper, toward the periphery of the lens than the angle shown at the center in Fig. 3; and as the rotary movement of the lens gives the highest velocity at and near the periphery where the step angle is best and material has to be removed from a greater perimeter, the somewhat excessive angle at the center is not ordinarily objectionable. By using wheels of suitable diameter any excessive angle may be readily guarded against.

It will be understood that the vertical adjustment of the swiveled or swinging support for the grinding wheel by the means indicated at 4 in Fig. 4 provides for setting the wheel axis slightly above or below the work spindle axis as and for the purpose above described.

With the grinding wheel set as shown in Fig. 2 for grinding a truly plane surface, the axis of the grinding wheel must of course be parallel with the work spindle axis, and in such case the depth of cut can not be made greater on one side of the center of the glass disk than on the other. Plane surface grinding with such apparatus may, however, be accomplished by merely causing a relative traversing movement between the abra-

sive wheel and the work in a direction parallel with the plane of the annular edge of the wheel, and the whole action would then be terracing action.

In carrying out the method described, a surface speed of the grinding wheel of about 5000 feet per minute has usually been found most satisfactory, this being a safe working limit for the artificial abrasive wheels such as are usually most desirable, and being about the speed which is considered the best practice in the case of grinding metals with abrasive wheels. On the other hand, the surface speed of the work, or the relative speed of movement between the work to the grinding wheel in the direction transversely of the edge of the latter, is far lower than is usual in metal grinding and less than is usual in grinding glass by the ordinary methods.

In grinding spherical surfaces by means of a cylindrical cup wheel, in accordance with my terracing method, where the wheel sweeps continuously over the center of the glass and at this point the terracing vanishes, it is impossible to have a deep cut, and it is necessary to compromise by running the work faster in order to obtain an efficient rate of grinding. In such a case a lens of 2 inches diameter may be rotated at about 60 revolutions per minute, and the feeding movement between the work and the grinding wheel may be at about .002 to .005 inch per revolution of the work. As will be gathered from the above, the thickness of the steps or terraces ground away, that is the rate of feed, may vary quite largely.

Artificial abrasive wheels of a suitable degree of softness have been found most desirable for most grinding in accordance with my terracing method, but the method is of course not to be limited to the use of such wheels, and other suitable grinding wheels may be employed. For example, in grinding curved surfaces of very small radius with a cup-shaped grinding wheel, it has been found desirable to use a diamond charged tubular metal cutter, or grinder, since an ordinary abrasive wheel of suitable small diameter would not have sufficient durability. In using artificial abrasive wheels, it is most desirable that the bond holding the abrasive particles should be such as to hold the same with such a degree of tenacity that the wheel shall be what is ordinarily called "soft," so that when the particles of abrasive become somewhat blunt in use they may break out and expose fresh cutting particles. This is the common action of such abrasive wheels, but in grinding glass in accordance with the present method it is desirable to use wheels considerably softer than those which are best for grinding metal, and it is found desirable also to select wheels of degrees of softness to suit different kinds

of glass, and generally the faster the work is crowded on the wheel the harder the wheel should be.

It is desirable that the grinding wheel and work be kept cool by means of water or other suitable cooling agent, as usual in grinding operations. For this purpose, I direct by suitable means such as the nozzle shown at *z'* in Fig. 1 a jet of cooling liquid on to the active side or face of the wheel at a point near the wheel axis where its velocity is low, the jet being directed in the direction of rotation of the wheel. The liquid is thus supplied to the wheel without splashing and spreads by centrifugal action outwardly to the active edge of the wheel. Any suitable cooling liquid or lubricant may be used for this purpose.

What is claimed is:—

1. The method of grinding curved surfaces of glass and the like hard non-plastic materials, which comprises rotating the glass to be ground upon an axis passing through the surface to be ground, applying the annular edge of a rapidly rotating grinding wheel to the surface to be ground, the grinding wheel being set with its axis of rotation to one side of a plane parallel thereto and containing the axis of rotation of the glass, the axis of rotation of the grinding wheel being at an acute angle with the axis of rotation of the glass, and the grinding edge of the wheel passing approximately through the axis of rotation of the glass as it sweeps over the surface thereof, the annular edge of the grinding wheel being shaped to form an abrupt step between the ground surface and the original surface of the glass on one side of the axis of rotation of the latter and to contact with the ground surface adjacent the step only at the base of the step, the rate of rotation of the glass being such that a substantial portion of the material removed is removed by splintering the side of the step.

2. The method of grinding curved surfaces of glass and the like hard non-plastic materials, which comprises rotating the glass to be ground about an axis passing through the surface to be ground, applying the annular edge of a rapidly rotating grinding wheel to the surface to be ground, the grinding wheel

being set with its axis of rotation to one side of a plane parallel thereto and containing the axis of rotation of the glass, the axis of rotation of the grinding wheel being at an acute angle with the axis of rotation of the glass, and the grinding edge of the wheel passing approximately through the axis of rotation of the glass as it sweeps over the surface thereof, the annular edge of the grinding wheel being shaped to form an abrupt step between the ground surface and the original surface of the glass on one side of the axis of rotation of the latter and to contact with the ground surface adjacent the step only at the base of the step, the grinding edge of the grinding wheel passing from the periphery of the glass inwardly along said step.

3. Grinding apparatus comprising means for rotating the work about an axis passing through the surface to be ground, and a rotary grinding wheel whose axis crosses the axis of the work and lies in a plane parallel to but spaced from the axis of the work, said wheel being formed and arranged to contact with the ground spherical surface of the work along a line extending from one side of the said surface through the work axis, the grinding surface of the wheel moving along said line by the rotation of the wheel.

4. Grinding apparatus, comprising means for rotating the work about an axis passing through the surface to be ground, a grinding wheel rotary about an axis crossing the axis of the work, said wheel being formed and arranged to contact with the ground surface of the work along a line extending from one side of the said surface through the work axis, the grinding surface of the wheel moving along said line by the rotation of the wheel, and means for moving the work and grinding wheel relatively so as to set their axes in or out of a common plane.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

WILLIAM TAYLOR.

Witnesses:

MAISIE MAURUS,
LILLIAN R. FOX.