

This invention relates to a method of forming a round convergent lens within the thickness of a plate of transparent mineral material.

It is known to provide a watch glass with a convergent lens, with a view to facilitating the reading of the calendar. When the glass is of mineral material, the lens is stuck on and forms an added thickness. This, however, is unsightly. Additionally, unsticking of the lens cannot be completely avoided. When the watch glass is of organic material, the lens can be embedded within the thickness of the glass. Unfortunately, this type of material is softer and therefore more subject to scratching than mineral materials, in particular sapphire, which provide the watch glass with a remarkable resistance to abrasion.

That is why it is desirable to use glasses made of mineral material, that are provided with a convergent lens within their thickness.

Patent US-A-3905163 describes a method of machining lenses within the thickness of the plate. In this patent, each lens is formed by first cutting a groove around the part of the plate intended to have the lens, then machining the lens by a succession of grinding operations, to outline it, to form it and then to polish it. Everything suggests that the resulting lenses are of large size, such not being the case when for instance the plate is a watch glass.

Now, it has been found, with the above method, that the grinding member wears rapidly at its periphery, thereby modifying the curvature of the lens, particularly when the latter is small.

The object of the present invention is to overcome this drawback.

This object is achieved with the particular characteristic features of the method in claim 1.

It is indeed known from US-A-1491383 to machine a plate of transparent mineral material such as to have a convergent lens in its

central portion, by means of a method akin to that of claim 1. According to this method, the periphery of the plate is made thinner by simultaneously rotating the plate about a first axis, that is perpendicular to the region comprising the convergent lens and that extends through the centre of this region, grinding the periphery with a grinding member rotating about a second axis, and oscillating the plate about a third axis, that is perpendicular to the plane containing the first and second axes and which intersects the first axis. It should be noted that in this case, the oscillatory motion is controlled to be in synchronism with the rotary motion of the plate about the second axis by virtue of a cam that is solid with the plate's support and which cooperates with a finger that is solid with the frame of the machine.

The purpose of this oscillatory motion is to move the grinding member in relation to the centre of the plate to define the contour of the convergent lens, whose shape is advantageously non circular.

Under these conditions, it follows that the grinding member must have a diameter large enough to sweep across the entire area having to be machined at each revolution of the plate.

The method is not intended to form a convergent lens within the thickness of a plate. Moreover, it cannot achieve the above defined object.

In the method according to the invention, when the arc encompassed by the operative portion of the grinding member exceeds half the arc of the lens, the only function of the oscillatory motion is to provide self-dressing of the grinding member. If however the arc encompassed by the operative portion of the grinding member is smaller than half the arc of the lens, the rotary motion of the plate is not sufficient to ensure the machining of the whole surface of the lens. For such machining to be possible, the angle of oscillation must be at least equal to the angle corresponding to the difference between half the arc of the lens and the arc encompassed by the

operative portion of the grinding member.

The invention will be better understood on reading the following description, made with reference to the accompanying drawings, in which:

Figure 1 shows apparatus for carrying out this method;

Figures 2, 3 and 4 illustrate, in vertical cross-section, three different arrangements for a part of the apparatus shown in Figure 1.

The apparatus shown in Figure 1 comprises a bed 10 on which are mounted a knee-type column 12 and a head-stock 14. Column 12 holds a spindle 16 to the end of which is fitted a cylindrical grinding member 20 coaxial with the spindle and provided at its operative tip 20a with abrasive material, preferably diamond dust. A motor, not shown, rotatably drives the spindle 16 via a pulley 18 mounted thereon. Column 12 further comprises slideways 22, 24 and 26 which enable the grinding member 20 to be moved, in conventional manner, along three orthogonal axes. More particularly, slide-way 22 enables the grinding member to be moved along its axis by means of a micrometric screw 23, while slideways 24 and 26 enable the grinding member to be moved horizontally along two perpendicular axes by means of micrometric screws 25 and 27 respectively.

Head-stock 14 carries a shaft 28 whose end portion 28a, near column 12, is offset downwardly with respect to the rotational axis of the shaft by means of a crank 28b. A table 30 is mounted on a shaft 32 which is perpendicular to the axis of shaft 28 and which pivots in end portion 28a. A motor, not shown, drives shaft 32 via a pulley 34 carried thereby. A prop 36, secured to table 30, enables a plate 38 of transparent mineral material, such as a watch-glass, to be held in place in order to be provided with a lens.

Grinding member 20 and prop 36 rotate of course in opposite directions.

The thickness of prop 36 is such that the distance between the upper surface of plate 38 and the rotational axis of shaft 28 is equal to the radius of curvature R required for the lens.

Shaft 28 is associated with drive means, not shown, arranged to transmit thereto an oscillating motion of low amplitude.

In a first variant of the method according to the invention, the operative portion 20a of the grinding member defines, as shown in Figures 2a and 2b, a round concave surface having a radius equal to the radius of curvature of the lens. Further, when plate 38 is horizontal (Figure 2a), the axis 40 of shaft 32 and the axis 42 of spindle 16 coincide. In the other positions of plate 38, these two axes intersect the axis of shaft 28, shown as 44, and form between them an angle α whose maximum value $\alpha_{\max}$ corresponds to the extreme positions of the plate.

The oscillating motion of shaft 28 enables the time interval between two dressings of the grinding member to be increased. This oscillating motion is made possible by the fact that the diameter D of the lens is substantially greater than the diameter d of the grinding member. Preferably, the ratio d/D ranges from 1/3 to 2/3. The relationship between the angle $\alpha_{\max}$, diameters D and d and the radius of curvature R may be expressed by the following formula:

$$\tan \alpha_{\max} = \frac{2R(D-d)}{4R^2 + D \cdot d}$$

This relationship serves to define the maximum amplitude of the oscillating motion of the shaft, that enables a lens of required diameter and required radius of curvature to be produced with a grinding member of given diameter. By way of example, with a radius of curvature R having a magnitude between once and twice that of lens diameter D, and with a ratio d/D between 1/3 and 2/3, the angle $\alpha_{\max}$ ranges from 5 to 20° approximately.

Practice has shown that the greater the amplitude of oscillation, the better the self-dressing of the grinding member

becomes, for a given diameter of the member. In the variant shown in Figures 2a and 2b, this maximum amplitude corresponds to an oscillation such that α varies from $+\alpha_{\max}$ to $-\alpha_{\min}$. When the arc described by the operative portion of the grinding member is less than half the arc of the lens, the oscillation must have a minimum amplitude lying between $\alpha_{\max}$ and $\alpha_{\min}$, $\alpha_{\min}$ being equal to $\alpha_{\max}$ minus the difference between the angle associated with half the arc of the lens and the angle associated with the arc formed by the grinding member.

In the second variant of the method according to the invention shown in Figures 3a and 3b, axes 40 and 42 of shaft 32 and spindle 16 define a plane which coincide with the plane of these Figures and is perpendicular to the axis 44 of shaft 28. Axis 42 is at a distance e from axis 44.

When plate 38 is horizontal (Figure 3a), the axes of spindle 16 and of shaft 32 are parallel. In the other positions, the two axes form an angle α whose maximum value $\alpha_{\max}$ is reached when shaft 28 is at the peak of its oscillation (Figure 3b). This oscillation can only take place from the horizontal position towards an inclined position wherein the side of the lens remote from axis 42 is raised (Figure 3b). A rocking action in the opposite direction would cause the grinding member 20 to come into contact with the conical link surface 46, thereby damaging the grinding member and spoiling the state of the conical surface 46. In this variant, the relationship between the different parameters may be expressed by the following formula:

$$\tan \alpha_{\max} = \frac{2R(D - d + e)}{4R^2 + D(d - e)}$$

The value of $(d-e)$ typically ranges from $D/3$ to $2D/3$, which means that the value of $\alpha_{\max}$ here also ranges from 5 to 20° .

The greater the distance e , the greater the diameter of the grinding member may be, but if this diameter is too large the shape of conical surface 46 (Figures 3a and 3b) surrounding the lens becomes

deformed, widening outwards, thus causing the product to become less attractive.

This drawback can be avoided if the diameter d of the grinding member, the diameter D of the lens and the angle $\alpha_{\max}$ fit the inequality:

$$D \cos \alpha_{\max} > d.$$

The shape of the grinding member tip 20a is, in this case, a part of a torus whose radius of the generating circle is equal to the radius of curvature R of the lens and in which the distance between the generating axis and the centre of the generating circle is equal to e . In so doing, a grinding member of greater diameter can be used, thus increasing its lifetime, as it is subjected to less wear. The adjustment of the apparatus is however more difficult.

The rules concerning the minimum amplitude of oscillation also apply to this variant except that with a diameter of the same size, the arc described by the operative portion of the grinding member is substantially half the corresponding arc in the first variant, due to the fact that the operative portion has the shape of part of a torus instead of that of part of a sphere.

The variant shown in Figures 4a and 4b is akin to that in Figures 3a and 3b but with an angle α which is never zero. These operating conditions are obtained by causing shaft 28 to oscillate between two extreme positions in which axes 40 and 42 form an angle $\alpha_{\min}$ (Figure 4a), such that the grinding member contacts the central part of the lens, and an angle $\alpha_{\max}$ (Figure 4b), such that the grinding member contacts the peripheral region of the lens.

If in this case a grinding member is used similar to that in Figures 3a and 3b, the conical link surface would have a large angle and the result would be unattractive. This drawback can be eliminated by resorting to a grinding member whose operative part 20a, shaped as part of a torus, is connected to the body of the grinding member by a frusto-conical part 20b having at its apex an angle of $2\alpha_{\max}$. In

this case, parts 20a and 20b can be manufactured independently of the body of the grinding member and then fixed to the latter by conventional attachment means. Because angle $\alpha_{\max}$ is relatively large, the central region of the concave torus part protrudes and can therefore readily be truncated to provide access to the assembly means, not shown.

In all three variants described, the oscillating motion is applied to the table bearing the plate. The same effect is obtained if the grinding member oscillates about axis 44.

Mechanical tests carried out with plates made according to the method have shown that, with a sapphire thickness of 0.6 mm and a lens thickness of 0.2 mm, the mechanical resistance of the plate is in no way affected.

This method is well suited to the machining of sapphire plates, but also to other materials, e.g. mineral glass.



CLAIMS

1. A method of forming a round convergent lens within the thickness of a plate of transparent mineral material, characterised in that it simultaneously involves:

- rotating said plate about a first axis which is perpendicular to the region where said lens is to be formed and which extends through the centre of said region;
- grinding said region with a grinding member having an operative portion which is of lesser diameter than that of the lens and which rotates about a second axis;
- oscillating the plate or the grinding member about a third axis perpendicular to the plane containing the first and second axes, intersecting said first axis and located at a distance from said region equal to the radius of curvature required for the lens; and
- independently controlling the drive means for rotating the plate about the first axis and the means for oscillating the plate or the grinding member about the third axis.

2. A method according to claim 1, characterised in that the second axis intersects the third axis and in that the operative portion of said grinding member defines a round concave surface having a radius equal to the radius of curvature of the lens.

3. A method according to claim 1, characterised in that the second and third axes are spaced a constant distance apart from each other by a constant value not equal to zero and in that the operative portion of the grinding member is shaped as a portion of a concave torus whose generating axis coincides with said second axis, and whose generating circle has a radius equal to the radius of curvature of the lens, the distance between the generating axis and the centre of the generating circle being equal to the distance between the second and third axes.

4. A method according to claim 3, characterised in that the diameter d of the grinding member, the diameter D of the lens and the



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maximum angle $\alpha_{\max}$ formed by the first and second axes fit the inequality:

$$D \cos \alpha_{\max} \gg d.$$

5. A method according to claim 4, wherein said grinding member has a body of cylindrical shape, characterised in that said body is connected to the operative portion of the grinding member by a frustum of a cone whose narrow portion adjoins said body, the angle at the apex of said cone being $2\alpha_{\max}$.