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(54) **PROCESS FOR SHAPING AN OPHTHALMIC PRODUCT**

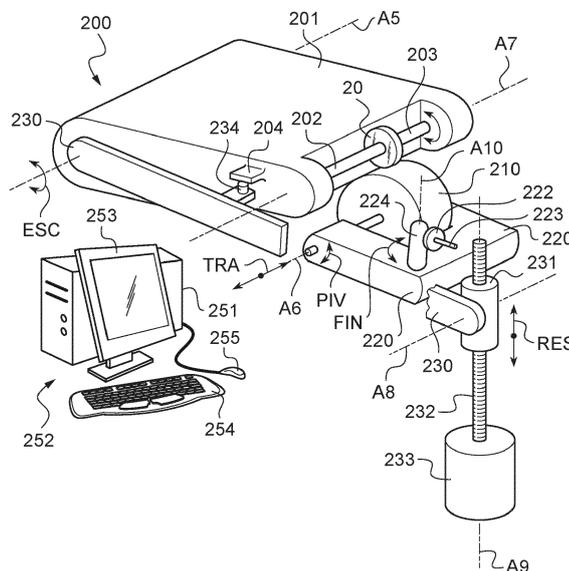
(57) The invention relates to a process for shaping an ophthalmic product (20) using a machining device (200) equipped with clamping means (202, 203) for clamping the ophthalmic product, a machining tool (210) for machining the ophthalmic product and a force sensor (234) adapted to measure a force that is related to the force applied by the machining tool to the ophthalmic product (20).

According to the invention, the process comprising:  
 - a step of clamping the ophthalmic product in said clamp-

ing means; and

- a step of roughing out the ophthalmic product by means of the machining tool so as to bring the initial outline of the ophthalmic product to a final outline of different shape, wherein, during the step of roughing out:
  - the value of said force is measured by the force sensor, and
  - the machining speed is continuously adjusted so as to maintain the measured value equal to a target value.

**Fig.1**



**Description**

## TECHNICAL FIELD OF THE INVENTION

**[0001]** The present invention generally relates to the field of eyeglasses.

**[0002]** This invention applies to machining devices comprising:

- clamping means for clamping an ophthalmic product,
- a machining tool for machining the ophthalmic product, and
- a force sensor adapted to measure a force that is related to the force applied by the machining tool to the ophthalmic product.

**[0003]** The invention more particularly relates to a process for shaping an ophthalmic lens, comprising:

- a step of clamping the ophthalmic product in said clamping means; and
- a step of roughing out the ophthalmic product by means of the machining tool so as to bring the initial outline of the ophthalmic product to a final outline of different shape.

## BACKGROUND INFORMATION AND PRIOR ART

**[0004]** The technical part of the work of an optician, which consists in mounting a pair of ophthalmic lenses in a spectacle frame selected by a customer, may be split into four main operations:

- the acquisition of the shapes of the outlines of the rims of the spectacle frame selected by the customer,
- the centering of each ophthalmic lens, which consists in determining the frame of reference of the lens using centering markings provided thereon, then in suitably positioning the outline of the rim acquired beforehand in the frame of reference of the lens so that, once edged to this outline then mounted in its frame, the lens is correctly positioned with respect to the corresponding eye of the customer and fulfils as best as possible the optical function for which it was designed,
- the blocking of each lens, which consists in attaching a blocking accessory to the lens, so that the lens can be easily extracted from the centering station and then be engaged in the edging station without loss of frame of reference, then
- the edging of each lens, which consists in machining this lens to the outline centered beforehand.

**[0005]** Here, the edging operation is more particularly of interest.

**[0006]** This operation is generally carried out by an

edging machine, as a function of the material of the lens to be edged.

**[0007]** Various processes are known to perform this operation.

**[0008]** In a known embodiment, the machining method aims at maintaining constant the machining speed, that is to say the speed of the contact point between the lens and the tool. The control parameters are consequently calculated before machining the lens, considering the material of the lens to be edged.

**[0009]** In a second known embodiment, when the lens is to be machined in several passes, at each pass, the machining depth is calculated according to the average power consumed by the motor at the previous turn, in order to reduce the time needed to edge the lens.

**[0010]** These two methods are based on the assumption that the machining operations are repeatable and that the performances of the tools are constant over time.

**[0011]** But in practice, this assumption is wrong. Consequently, the edging machine is not used at the maximum of its possibilities.

## SUMMARY OF THE INVENTION

**[0012]** In this context, the present invention provides a solution enabling to use the edging machine to its maximum capacity in order to optimize productivity.

**[0013]** More specifically, the invention is directed to a process for shaping an ophthalmic product as defined in the introduction wherein, during the step of roughing out, the value of said force is measured by the force sensor, and the machining speed is continuously adjusted so as to maintain the measured value equal to a target value.

**[0014]** Consequently, at each instant, the tool is driven so as to machine the ophthalmic product at the maximum possible speed.

**[0015]** In a preferred embodiment, the target value is maintained at a level that is high in order to shorten the machining time, and that is such that the motor consumption does not exceed a maximum value that would harm the quality of the product.

**[0016]** Other preferred features of the invention are the following ones:

- during the step of roughing out, the machining tool follows a first path that is radiale relative to said clamping means until it reaches the final outline, and a second path along said final outline.
- the force sensor is adapted to measure a force component that is radiale relative to said clamping means.
- said target value is determined as a function of an electrical power consumed by the machining device.
- during said step of roughing out, a comparison operation is performed to compare the electrical power consumed by the machining device with a power threshold, and when the electrical power consumed by the machining device is greater than said power

threshold, said target value is reduced of a predetermined amount.

- the comparison operation is performed only when said target value is greater than a predetermined threshold.
- said machining speed is determined by means of a proportional derivative controller.
- said machining speed is determined as a function of a first difference between said measured value and said target value, and a second difference between the measured value, measured at a current instant, and a measured value measured at a previous instant.
- the final outline being characterized by first points (also named main points), intermediate points are defined between said first points, and during the roughing out step, at each sampling instant, said machining device is programmed to:

α select a next point to be reached among the first points and the intermediate points as a function of the difference between said measured value and said target value, and to

α control said machining tool and said clamping means such that the machining tool reaches said next point in a predetermined time amount that is constant from a sampling instant to another.

- the number of first points is determined as a function of a maximum machining speed and/or of a maximum speed of the machining device.
- said ophthalmic product is an ophthalmic lens or a mold for molding an ophthalmic lens.
- the process comprises, after said step of roughing out, a finishing step that is performed on the part of the ophthalmic product machined by said machining tool, by means of a finishing tool that is distinct from said machining tool.
- during said step of roughing out, said ophthalmic product is machined by the machining tool in a single pass around said clamping means.

#### DETAILED DESCRIPTION OF EXAMPLE(S)

**[0017]** The following description with reference to the accompanying drawings, given by way of non-limiting example makes it clear what the invention consists in and how it can be reduced to practice.

**[0018]** In the accompanying drawings:

- Figure 1 is a schematic view of a machining device adapted to implement a process according to the invention,
- Figure 2 illustrates an initial and a final outline of an ophthalmic lens before and after machining by means of the device of Figure 1,
- Figure 3 shows how some points of the final outline

are defined according to the invention, and

- Figure 4 is a flowchart of the process according to the invention.

5 **[0019]** Figure 1 shows a device 200 for machining an ophthalmic lens 20, comprising:

- means 202, 203 for clamping the ophthalmic lens 20;
- at least one tool 210, 222, 223 for machining the ophthalmic lens 20;
- a force sensor 234 adapted to measure a force related to the force applied by the machining tool 210, 222, 223 to the ophthalmic lens 20; and
- a unit 251 for controlling each machining tool 210, 222, 223 relative to the clamping means 202, 203.

**[0020]** This machining device 200 could take the form of any machine for cutting or removing material, able to modify the outline of the ophthalmic lens 20 in order to adapt it to that of the corresponding eyewire of a spectacle frame selected by an individual.

**[0021]** In the example schematically illustrated in figure 1, the machining device 200 consists, as is known per se, of an automatic grinder 200, widely referred to as a digital grinder. In this case, this grinder comprises:

- a rocker 201 that is mounted so as to freely pivot about a reference axis A5, in practice a horizontal axis, on a mounting (not shown), and that supports the ophthalmic lens 20 to be machined;
- at least one abrasive wheel 210 that is mounted so as to pivot about an abrasive-wheel axis A6 parallel to the reference axis A5, and that is also duly driven to rotate by a motor (not shown);
- a finishing module 220 that is fitted so as to rotate about the abrasive-wheel axis A6, and that is equipped with tools 222, 223 for finishing the ophthalmic lens 20.

40 **[0022]** The pivoting mobility of the rocker 201 about the reference axis is called retraction mobility ESC. It allows the ophthalmic lens 20 to be brought closer to the abrasive wheel 210 until the former makes contact with the latter.

45 **[0023]** This rocker 201 is equipped with two shafts 202, 203 for clamping the ophthalmic lens 20 to be machined and for driving it to rotate, which shafts 202, 203 correspond to the aforementioned "clamping means".

**[0024]** These two shafts 202, 203 are aligned with each other along a clamping axis A7 parallel to the axis A5. Each of the shafts 202, 203 possesses a free end that faces the other and that is equipped with a head for clamping the ophthalmic lens 20.

55 **[0025]** A first 202 of the two shafts is fixed in translation along the clamping axis A7. In contrast, the second 203 of the two shafts is mobile in translation along the blocking axis A7 in order to allow the ophthalmic lens 20 to be compressively clamped axially between the two clamp-

ing heads.

**[0026]** The grinder 200 schematically shown in figure 1 comprises only one cylinder abrasive wheel 210.

**[0027]** In practice, it rather comprises a set of abrasive wheels mounted coaxially on the abrasive-wheel axis A6, each abrasive wheel being used for a specific shaping operation of the ophthalmic lens 20 to be machined.

**[0028]** For the roughing-out of the lens, a roughing-out cylinder abrasive wheel is used. This roughing-out cylinder abrasive wheel is cylindrical, it has a diameter greater than 10 centimetres, and it comprises diamonds whose grain size is between 100 and 500 micrometers and is here equal to 300 micrometers.

**[0029]** For the beveling of the lens, which consists in machining a rib along the edge face of the lens, a shaping abrasive wheel (or "beveling abrasive wheel") can be used, this abrasive wheel containing a beveling groove of dihedral cross-section.

**[0030]** For the polishing of the lens, a cylinder abrasive wheel and a shaping abrasive wheel, of identical geometries to the two abrasive wheels mentioned above, are used, the grain sizes of these polishing abrasive wheels being particularly small.

**[0031]** The set of abrasive wheels is born by a slide (not shown) so as to move in translation along the abrasive-wheel axis A6. The translational movement of the slide bearing the abrasive wheels is called the "transfer" TRA.

**[0032]** It will be understood that here it is a question of producing a relative movement between the abrasive wheels and the lens and that provision could be made, as a variant, for the lens to move axially, the abrasive wheels remaining stationary.

**[0033]** Here, the grinder 200 furthermore comprises a link rod 230 one end of which is hinged relative to the mounting in order to pivot about the reference axis A5, and the other end of which is hinged relative to a nut 231 in order to pivot about an axis A8 parallel to the reference axis A5.

**[0034]** The nut 231 is itself mounted to move in translation along a restitution axis A9 perpendicular to the reference axis A5. The nut 231 is a tapped nut in screwed engagement with a threaded shank 232 that, aligned with the restitution axis A9, is driven to rotate by a motor 233.

**[0035]** The link rod 230 moreover comprises a force sensor 234, here consisting of a unidirectional strain gauge, that interacts with a stop 204 fixed to the rocker 201.

**[0036]** When, duly clamped between the two shafts 202, 203, the ophthalmic lens 20 to be machined is brought into contact with one of the abrasive wheels 210, it is the object of an effective removal of material until the stop 204 of the rocker 201 butts against the link rod 230 with a force that, acting on the strain gauge 234, is duly detected and measured by the latter.

**[0037]** Here, the strain gauge 234 is placed so as to measure a machining force of substantially vertical direction, corresponding to the radial component of the

force exerted by the ophthalmic lens 20 on the abrasive wheel 210 or finishing tool 222, 223 used.

**[0038]** To machine the ophthalmic lens 20 following a given outline, it is therefore enough, on the one hand, to appropriately move the nut 231 along the restitution axis A9, under the control of the motor 233, in order to control the restitution movement RES, and on the other hand, to make the supporting shafts 202, 203 pivot together about the clamping axis A7. The restitution movement (and therefore the retraction movement of the rocker 201) and the rotational movement of the shafts 202, 203 are controlled and coordinated by a controlling unit 251, duly programmed for this purpose, so that all the points of the outline of the ophthalmic lens 20 are, in succession, brought to the correct diameter.

**[0039]** According to the invention, the retraction movement is in particular controlled depending on the machining force measured by the strain gauge 234, so as to maintain it equal to a target value.

**[0040]** As for the non-essential finishing module 220, it has a pivoting mobility about the abrasive-wheel axis A6, which mobility is denoted PIV. This mobility allows it to be brought closer to or moved further away from the ophthalmic lens 20.

**[0041]** The finishing tools 222, 223 with which the finishing module 220 is equipped here especially comprise a grooving disk 222 adapted to produce a groove along the edge face of the ophthalmic lens 20, and a milling cutter 223 adapted to chamfer the sharp edges of the ophthalmic lens 20.

**[0042]** These finishing tools 222, 223 are mounted to rotate about a given axis and are driven to rotate by a motor housed in a base 224 that is itself mounted to pivot on the finishing module 220 about an axis A10 orthogonal to the abrasive-wheel axis A6. This pivoting mobility of the base 224 about the axis A10, called the finishing mobility FIN, allows the tools 222, 223 to be best oriented relative to the lens.

**[0043]** The controlling unit 251 is an electronic and/or computing unit and it in particular allows the following to be controlled:

- the motor for driving the second shaft 203 to move in translation;
- the motor for driving the two shafts 202, 203 to rotate;
- the motor for driving the slide bearing the abrasive wheels to move in translation with its transfer mobility TRA;
- the motor 233 for driving the nut 231 to move in translation with its restitution mobility RES;
- the motor for driving the finishing module 220 to rotate with its pivoting mobility PIV; and
- the motor for driving the base 224 of the finishing tools 222, 223 to rotate with its finishing mobility FIN.

**[0044]** Lastly, the grinder 200 comprises a human-machine interface 252 that here comprises a display screen 253, a keyboard 254 and a mouse 255, which are adapt-

ed to communicate with the controlling unit 251. This HMI interface 252 allows the user to enter numerical values, such as the material of the lens, on the display screen 253, so that the tools of the grinder 200 can be appropriately controlled.

**[0045]** In figure 1, the controlling unit is implemented on a desktop computer connected to the grinder 200. Of course, as a variant, the software portion of the grinder could be implemented directly on an electronic circuit of the grinder. It could also be implemented on a remote computer, communicating with the grinder via a private or public network, for example using an IP (Internet) communication protocol.

**[0046]** Figure 2 shows a projection of the initial outline 21 of the lens 20 to be machined.

**[0047]** It also shows a projection of the final outline 22 of the lens 20 after machining. This final outline 22 corresponds to the bottom of a bezel of a rim of the spectacle frame selected by the individual that is suitable to receive the lens once machined.

**[0048]** Figure 2 also shows a "boxing system" of this final outline 22. As already known, this boxing system comprises a box 23 that is a rectangle drawn around the projection of the final outline 22, which has two horizontal sides.

**[0049]** The centre O of this box 23 is called boxing center. The lens is to be blocked between the two shafts 202, 203 such that the blocking axis A7 passes through this boxing center.

**[0050]** Before the machining of the ophthalmic lens 20, the controlling unit 251 acquires the geometry of the final outline 22.

**[0051]** As will be detailed below, this final outline 22 takes the form of a set of triplets  $(r_i, \theta_i, z_i)$  corresponding to the cylindrical coordinates of a plurality of points  $P_i$  characterizing the shape of this final outline 22.

**[0052]** These coordinates can be acquired from a database to which an optician has access, or by using an imaging device comprising image-capturing means and image-processing means suitable to process a photo of a sample lens delivered with the spectacle frame, or by feeling the bottom of the bezel of the rim of the frame selected by the individual.

**[0053]** The lens is then subjected to a centering operation followed by a blocking operation.

**[0054]** These two operations are well known to those skilled in the art and do not form part of the subject matter of the present invention, hence they are only briefly described.

**[0055]** During the centering operation, the positions of markers marked or etched on the lens are determined, and the position required for the final outline 22 is deduced therefrom (so that once the lens has been shaped following this outline and fitted into the selected frame, its optical centre is correctly located relative to the corresponding eye of the spectacle wearer).

**[0056]** During the blocking operation, a gripping accessory is adhesively bonded to the lens in a position cen-

tered on the boxing centre, then, by virtue of this gripping accessory, the lens is clamped between the shafts 202, 203 of the edger 200 such that the boxing centre is located centered on the clamping axis A7.

**[0057]** The shaping is then carried out in two operations, namely a roughing-out operation and a finishing operation.

**[0058]** For the roughing-out of the lens, the roughing-out cylinder abrasive wheel 210 is used to coarsely decrease the radii of the lens 20 to the shape of the final outline 22. More precisely, the shafts 202, 203 and the rocker 201 are here controlled relative to each other so as to decrease, for each angular position  $\theta_i$  of the lens about the clamping axis A7, the radius of the lens to a length equal to the radius  $r_i$  of the final outline 20.

**[0059]** To finish the lens, the shaping abrasive wheel and/or any other finishing tool is used to form, on the edge face of the lens, a "bevel" or a groove or any suitable form, and to polish the obtained edge.

**[0060]** The invention is more particularly directed to the step of roughing-out.

**[0061]** During this step, the abrasive wheel 210 follows, relative to the lens 20, a first path Pa1 that is radiale relative to the axis A7 until its peripheral edge reaches the final outline 22. Then, it follows a second path Pa2 along the final outline 22 (see Fig.2).

**[0062]** Consequently, the lens 20 is machined in a single pass around the axis A7.

**[0063]** According to the invention, the roughing-out step is performed so as to reduce the time required to machine the edge of the lens 20.

**[0064]** To this end, during the step of roughing out:

- the value  $F_{meas}$  is measured by the gauge 234, and
- the machining speed MSp is continuously adjusted so as to maintain the measured value  $F_{meas}$  equal to a target value  $F_{targ}$ .

**[0065]** To this end, the rotation of the shafts 202, 203 is controlled depending on the difference between these values  $F_{meas}$ ,  $F_{targ}$ .

**[0066]** Before explaining more precisely how this process is performed, we can define the notion of "machining speed MSp" (also called "machining rate").

**[0067]** This machining speed could be defined as being the rotation speed of the shafts 202, 203.

**[0068]** But preferably, the machining speed is defined as the speed of the point of contact between the lens 20 and the abrasive wheel 210. Hence, this machining speed MSp depends on the rotation speed of the shafts 202, 203 and on the radius of the contact point relative to axis A7.

**[0069]** It will be noted here that the grinder 200 is designed so that the machining speed MSp can reach a known "maximum machining speed" or a known shaft rotation speed.

**[0070]** It will be noted here that the grinding machine 200 is designed such that it can reach a known "maximum

shaft rotation speed" or so that the machining speed MSp can reach a known "maximum machining speed".

**[0071]** The process for roughing-out the lens 20 is performed in loops so that the machining of the lens edge progresses at each loop point by point along the final outline 22.

**[0072]** In the following, the notion of "sampling interval  $\Delta t$ " will be defined as the time between two successive loops.

**[0073]** Here, the idea of the invention is to discretise the final outline 22 into several main points and to search in real time for the next point to be reached at the end of each instant sampling interval  $\Delta t$ . In parallel, it is proposed to regularly adjust the target value  $F_{\text{targ}}$  (not necessarily at each loop but at least once per second) considering the power consumed by the grinder 200.

**[0074]** First, we can explain how the main points discretising the final outline 22 are defined.

**[0075]** The first main point  $P_0$  can be selected randomly.

**[0076]** Then, the number  $N$  of main points  $P_i$  (with  $i$  lying from 0 to  $N-1$ ) is determined as a function of said maximum machining speed and/or of said maximum shaft rotation speed.

**[0077]** For instance, to simplify, the maximum shaft rotation speed is considered. In this example, the latter is regarded as being equal to 10 rpm when the sampling interval  $\Delta t$  is settled to 1 ms.

**[0078]** In this example, the number  $N$  of main points  $P_i$  is calculated in the following way:

$$N = 60/10.1000 = 6000$$

**[0079]** In other words, the final outline 22 is initially characterized by 6000 main points  $P_i$  the coordinates  $(r_i, \theta_i, z_i)$  of which are defined.

**[0080]** In the uppermost drawing of Figure 3, we have represented a part of the final outline 22 and three of these 6000 main points, named  $P_0, P_1$  and  $P_2$ .

**[0081]** We can understand that, if the machining speed MSp is equal to its maximum, the time required for machining the lens from point  $P_0$  to point  $P_1$  (or point  $P_1$  to point  $P_2$ ) is equal to 1 ms.

**[0082]** These main points  $P_i$  are defined before the roughing out step.

**[0083]** But during the roughing-out step, if the value  $F_{\text{meas}}$  of the measured force is too high, it is necessary to slow down the machining speed MSp to reduce this value. In order to achieve this aim, intermediate points  $P_{0j}$  (with  $j$  lying from 1 to  $n$ ) are added between the main points  $P_i$ . Thanks to these points, the grinding wheel 210 will not have to go from one main point  $P_i$  to another main point  $P_{i+1}$  at each loop, but it will be able to reach only one of the intermediate points  $P_{0j}$ .

**[0084]** In practice, these intermediate points  $P_{0j}$  are added in real time during the roughing-out step and they are defined only by one of their coordinates: their orien-

tation  $\theta_j$ . Hence, the use of intermediate points  $P_{0j}$  rather than a greater number  $N$  of main points  $P_i$  enables not to have to determine a great number of triplets  $(r_i, \theta_i, z_i)$ .

**[0085]** The method used to add these intermediate points  $P_{0j}$  is named sampling. In practice, it consists in adding, at each loop and only if it is necessary, a predefined number  $n$  of intermediate points  $P_{0j}$  between the two next main points  $P_i$ .

**[0086]** As shown in the uppermost drawing of Figure 3, at a first sampling instant  $t$  (at the beginning of the first loop), these intermediate points  $P_{0j}$  are added between the main points  $P_0$  and  $P_1$ . The predefined number  $n$  of added intermediate points  $P_{0j}$  is at least equal to 10, and is here equal to 100.

**[0087]** Then, the next point  $P_{t+1}$  to be reached at the next sampling instant  $t+1$  (at the end of the first loop) is selected between these intermediate points  $P_{0j}$  and the second main point  $P_1$ , so as to maintain the measured value  $F_{\text{meas}}$  equal to a target value  $F_{\text{targ}}$  (see the second drawing of Figure 3).

**[0088]** As shown in the last drawings of Figure 3, at each loop, the process is repeated, with a new sampling only if it is necessary.

**[0089]** As explained above, to select a next point at each loop, it is proposed to determine two parameters in parallel.

**[0090]** The first parameter is the target value  $F_{\text{targ}}$  of the measured force, and the second parameter is the machining speed Msp.

**[0091]** The method for adjusting the target value  $F_{\text{targ}}$  according to the intrinsic characteristics of the material of the lens (kind of material, amount of material to machine...) and to the operating conditions of the machine (electrical voltage, state of maintenance...) is shown in the left part of Figure 4. It comprises several steps.

**[0092]** These steps are performed in loops, but these loops can be desynchronized from the above-mentioned loops. In other words, the sampling interval of these desynchronized loops can be distinct from said sampling interval  $\Delta t$  and can vary from one loop to another.

**[0093]** The first step S0 shown in Figure 4 represents the beginning of the roughing-out step.

**[0094]** The second step S2 consists in determining an initial target value  $F_{\text{targ}}$ . Here, this initial target value depends only from the operating conditions of the grinder 200, and more specifically from its nominal power.

**[0095]** Then, the machining of the lens starts and the following steps are performed.

**[0096]** At step S4, the determined target value  $F_{\text{targ}}$  is compared with a predetermined threshold  $F_{\text{up}}$ .

**[0097]** This predetermined threshold  $F_{\text{up}}$  depends on the used grinder 200. It is for instance equal to 2500g. It corresponds to a minimum value of the force below which it is considered that no problem can arise.

**[0098]** If the target value  $F_{\text{targ}}$  is lower than this predetermined threshold  $F_{\text{up}}$ , the step S12 (described hereinafter) is implemented.

**[0099]** Else, during step S6, the instant electrical power

$P_{el}$  consumed by the grinder 200 is acquired and compared with a power threshold  $P_{max}$ .

**[0100]** This power threshold  $P_{max}$  depends on the used grinder. It is for instance equal to 900W. It corresponds to a power equal or next from the maximum power the grinder can consume.

**[0101]** If the instant electrical power  $P_{el}$  is lower than this power threshold  $P_{max}$ , step S12 is implemented.

**[0102]** Else, during step S8, the target value  $F_{targ}$  is reduced of a predetermined amount. This amount is for instance equal to 500g.

**[0103]** Then, during step S10, a temporisation is triggered, then step S12 is implemented. This temporisation is for instance of 0.8s.

**[0104]** Step S12 consists in determining whether the roughing-out step is finished or not.

**[0105]** If it is finished, the process ends (step S14). Else, the process is restarted at step S4.

**[0106]** Thanks to this process, the target value  $F_{targ}$  is adjusted as a function of the grinder possibilities.

**[0107]** Concomitantly, a new machining speed  $M_{sp}$  is determined at each loop defined by the sampling interval  $\Delta t$ .

**[0108]** In other words, the process for adjusting the machining speed  $M_{sp}$  according to the target value  $F_{targ}$  and to the measured value  $F_{meas}$  is implemented in parallel of the determination of said target value.

**[0109]** This process is based on a proportional derivative controller and comprises the following steps.

**[0110]** During a first step S20, the processing unit 251 determines a first difference between the measured value  $F_{meas}$  and the target value  $F_{targ}$ , named force error  $\Delta F$ .

**[0111]** Then, during a second step S22, it approximates the derivative  $\delta F$  of the measured value  $F_{meas}$ . To this end, here, it calculates the difference between the measured values  $F_{meas}$  at the sampling instant  $t$  and at the previous sampling instant  $t-1$ .

**[0112]** After, during a third step S24, the processing unit 251 calculates the machining speed  $M_{sp}$  according to the force error  $\Delta F$  and the derivative  $\delta F$ .

**[0113]** Here, this calculation is based on the following equation:

$$M_{sp} = K_p \cdot \Delta F + K_d \cdot \delta F$$

**[0114]** In this equation, the constants  $K_p$  and  $K_d$  are determined by means of test sessions on the grinder 200.

**[0115]** Finally, thanks to the machining speed  $M_{sp}$ , the processing unit is able to determine the next point  $P_{t+1}$  to be reached at the end of the sampling interval  $\Delta t$ .

**[0116]** Then, if this next point does not belong to the main points  $P_i$ , the processing units determines its coordinates  $(r_j, \theta_j, z_j)$ . Indeed, only the orientations  $\theta_j$  of the intermediate points  $P_{0j}$  are known. The other coordinates can be determined by interpolation, on the basis of at least the orientation  $\theta_j$  and the coordinates  $(r_i, \theta_i, z_i)$  and  $(r_{i+1}, \theta_{i+1}, z_{i+1})$  of the two main points located on either

side of the next point  $P_{t+1}$ .

**[0117]** Then, during the instant sampling interval  $\Delta t$ , the shafts 202, 203 rotate so that the contact point between the lens 20 and the roughing-out wheel 210 reaches this next point  $P_{t+1}$ . And the process restarts a new loop.

**[0118]** The present invention is in no way limited to the embodiment described and shown.

**[0119]** In particular, the process can apply to the machining of other ophthalmic products, for instance to the machining of molds suitable for molding ophthalmic lenses.

## 15 Claims

1. A process for shaping an ophthalmic product (20) using a machining device (200) equipped with clamping means (202, 203) for clamping the ophthalmic product (20), a machining tool (210) for machining the ophthalmic product (20) and a force sensor (234) adapted to measure a force that is related to the force applied by the machining tool (210) to the ophthalmic product (20), the process comprising:

- a step of clamping the ophthalmic product (20) in said clamping means (202, 203); and
- a step of roughing out the ophthalmic product (20) by means of the machining tool (210) so as to bring the initial outline (21) of the ophthalmic product (20) to a final outline (22) of different shape,

**characterized in that**, during the step of roughing out:

- the value ( $F_{meas}$ ) of said force is measured by the force sensor (234), and
- the machining speed is continuously adjusted so as to maintain the measured value ( $F_{meas}$ ) equal to a target value ( $F_{targ}$ ).

2. The process for shaping according to claim 1, wherein, during the step of roughing out, the machining tool (210) follows a first path (Pa1) that is radiale relative to said clamping means (202, 203) until it reaches the final outline (22), and a second path (Pa2) along said final outline (22).

3. The process for shaping according to claim 1 or 2, wherein the force sensor (234) is adapted to measure a force component that is radiale relative to said clamping means (202, 203).

4. The process for shaping according to any one of claims 1 to 3, wherein said target value ( $F_{targ}$ ) is determined as a function of an electrical power ( $P_{el}$ ) consumed by the machining device (200).

5. The process for shaping according to claim 4, wherein, during said step of roughing out, a comparison operation is performed to compare the electrical power ( $P_{el}$ ) consumed by the machining device (200) with a power threshold ( $P_{max}$ ), and when the electrical power ( $P_{el}$ ) consumed by the machining device (200) is greater than said power threshold ( $P_{max}$ ), said target value ( $F_{targ}$ ) is reduced of a predetermined amount. 5
6. The process for shaping according to claim 5, wherein the comparison operation is performed only when said target value ( $F_{targ}$ ) is greater than a predetermined threshold ( $F_{up}$ ). 10
7. The process for shaping according to any one of claims 1 to 6, wherein said machining speed is determined by means of a proportional derivative controller. 15
8. The process for shaping according to claim 7, wherein said machining speed is determined as a function of: 20
- a first difference between said measured value ( $F_{meas}$ ) and said target value ( $F_{targ}$ ), and 25
  - a second difference between the measured value ( $F_{meas}$ ), measured at a current instant ( $t$ ), and a measured value ( $F_{meas}$ ) measured at a previous instant ( $t-1$ ). 30
9. The process for shaping according to any one of claims 1 to 8, wherein, the final outline (22) being **characterized by** first points ( $P_0, P_1, P_2$ ): 35
- intermediate points ( $P_{01}, P_{02}, P_{03}$ ) are defined between said first points ( $P_0, P_1, P_2$ ), and 40
  - during the roughing out step, at each sampling instant ( $t$ ), said machining device (200) is programmed to: 45
- select a next point to be reached among the first points ( $P_0, P_1, P_2$ ) and the intermediate points ( $P_{01}, P_{02}, P_{03}$ ) as a function of the difference between said measured value ( $F_{meas}$ ) and said target value ( $F_{targ}$ ), and to 50
  - control said machining tool (210) and said clamping means (202, 203) such that the machining tool (210) reaches said next point in a predetermined time amount ( $\Delta t$ ) that is constant from a sampling instant ( $t$ ) to another. 55
10. The process for shaping according to claim 9, wherein the number of first points ( $P_0, P_1, P_2$ ) is determined as a function of a maximum machining speed and/or of a maximum speed of the machining device (200).
11. The process for shaping according to any one of claims 1 to 10, wherein said ophthalmic product (20) is an ophthalmic lens or a mold for molding an ophthalmic lens.
12. The process for shaping according to any one of claims 1 to 11, comprising, after said step of roughing out, a finishing step that is performed on the part of the ophthalmic product (20) machined by said machining tool (210), by means of a finishing tool (222, 223) that is distinct from said machining tool (210).
13. The process for shaping according to any one of claims 1 to 12, wherein during said step of roughing out, said ophthalmic product (20) is machined by the machining tool (210) in a single pass around said clamping means (202, 203).

Fig.1

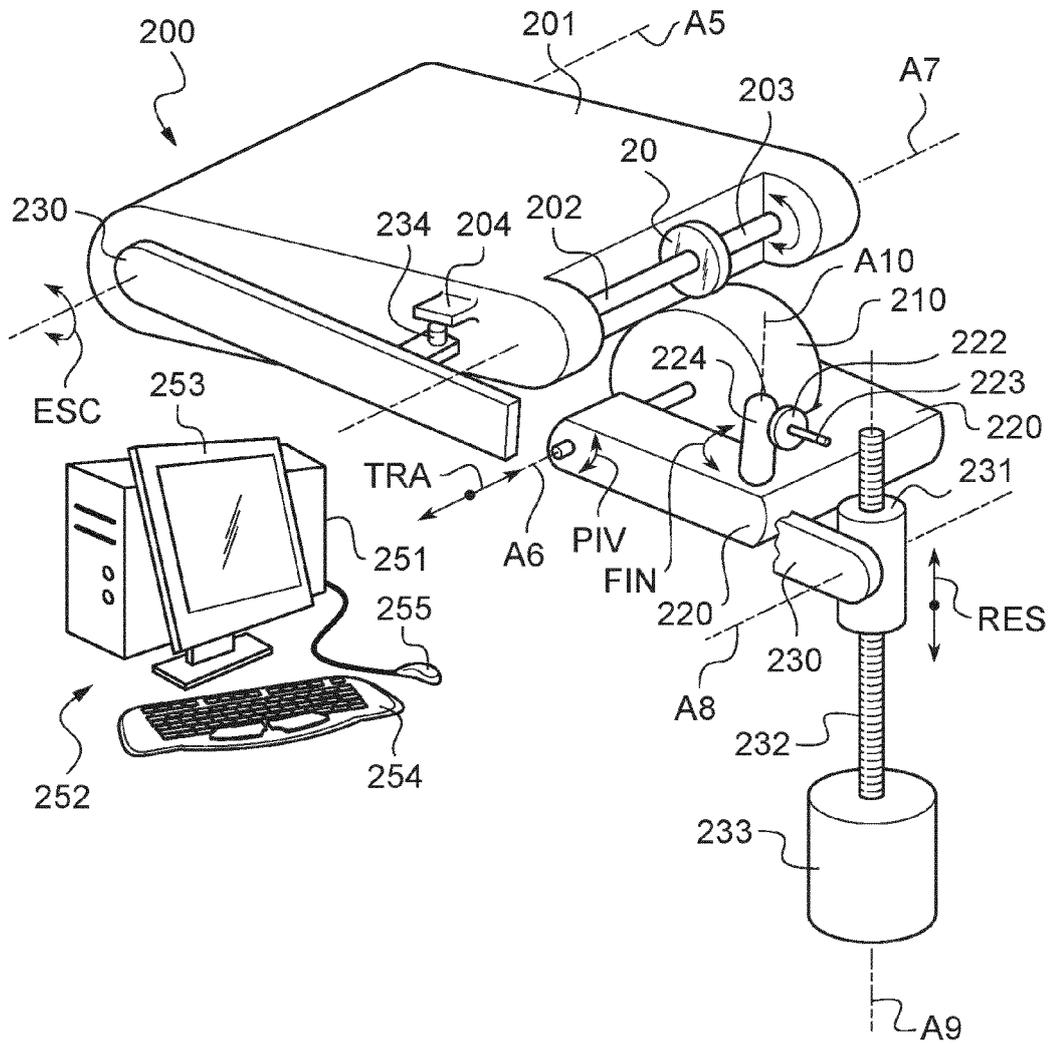
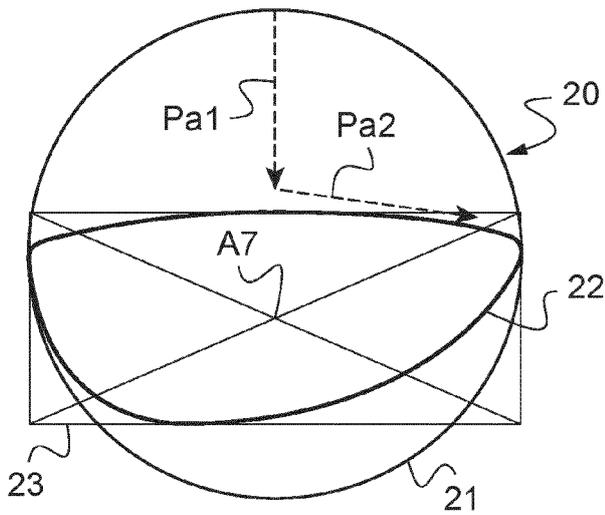
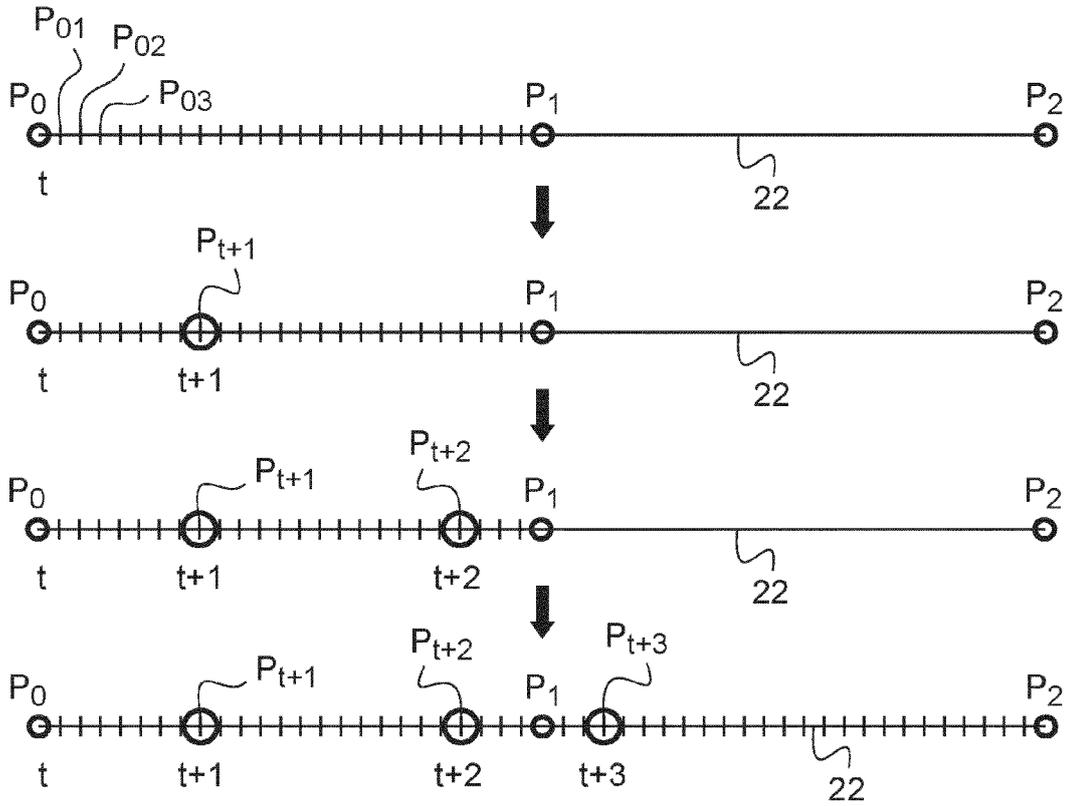


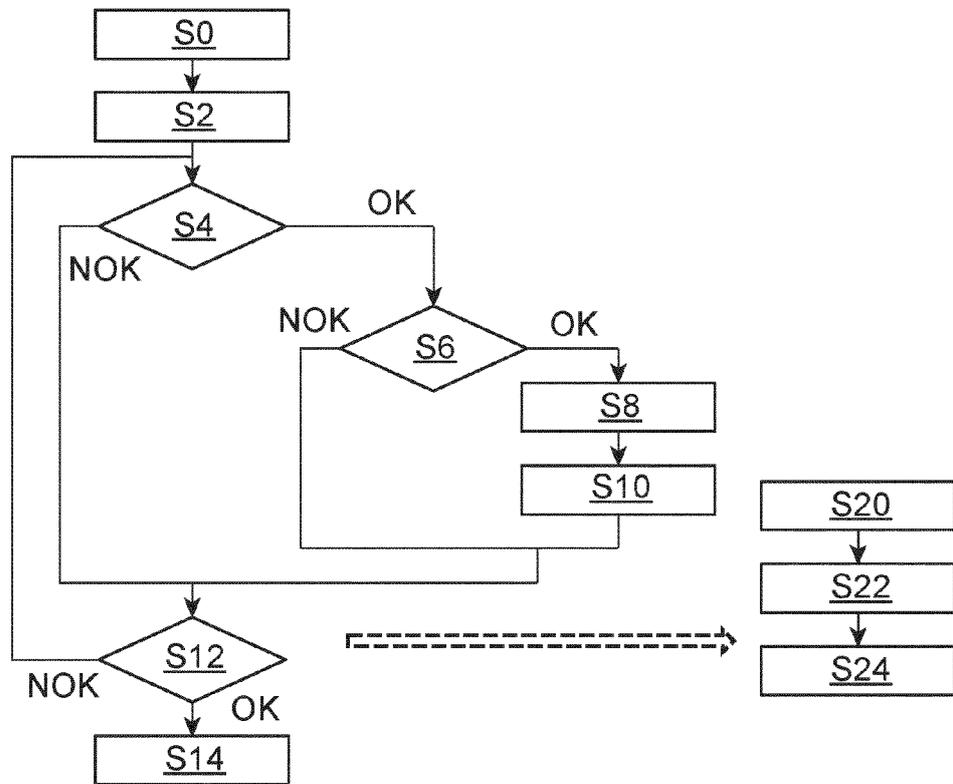
Fig.2



**Fig.3**



**Fig.4**





EUROPEAN SEARCH REPORT

Application Number  
EP 22 30 6407

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	<p>EP 2 623 261 A2 (NIDEK KK [JP])                      7 August 2013 (2013-08-07)                      * claims 1-8 *                      * paragraph [0032] *                      * paragraphs [0067] - [0068] *                      * figures 1, 6, 16 *                      -----</p>	1-13	<p>INV.                      B24B9/14                      B24B49/00                      B24B49/02                      B24B49/16                      B24B51/00</p>
			<p>TECHNICAL FIELDS SEARCHED (IPC)</p>
			<p>B24B</p>
<p>The present search report has been drawn up for all claims</p>			
Place of search		Date of completion of the search	Examiner
Munich		2 March 2023	Herrero Ramos, J
CATEGORY OF CITED DOCUMENTS		<p>T : theory or principle underlying the invention                      E : earlier patent document, but published on, or after the filing date                      D : document cited in the application                      L : document cited for other reasons                      .....                      &amp; : member of the same patent family, corresponding document</p>	
<p>X : particularly relevant if taken alone                      Y : particularly relevant if combined with another document of the same category                      A : technological background                      O : non-written disclosure                      P : intermediate document</p>			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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02-03-2023

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