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(54) Lathe apparatus and method

(57) In one form, the disclosure describes a lathe apparatus and method for manufacturing a product with a non-axisymmetric shape from a workpiece, such as a toric contact lens, comprises a spindle for rotating the workpiece about an axis of rotation, a cutting tool, a two-axis bed for supporting the cutting tool and for moving the cutting tool along a predetermined path adjacent the workpiece as the spindle rotates the workpiece, and a mechanism for oscillating the cutting tool along an oscillating axis as the two-axis bed moves the cutting tool

along the predetermined path, wherein the oscillation axis is oriented at a non-zero angle with respect to the axis of rotation. Preferably, the non-zero angle is about 45°. In a second form, a lathe apparatus comprises a rotary bed for arcuately moving a cutting tool adjacent a workpiece and a mechanism for translationally reciprocating the cutting tool as the cutting tool is arcuately moved adjacent the workpiece.

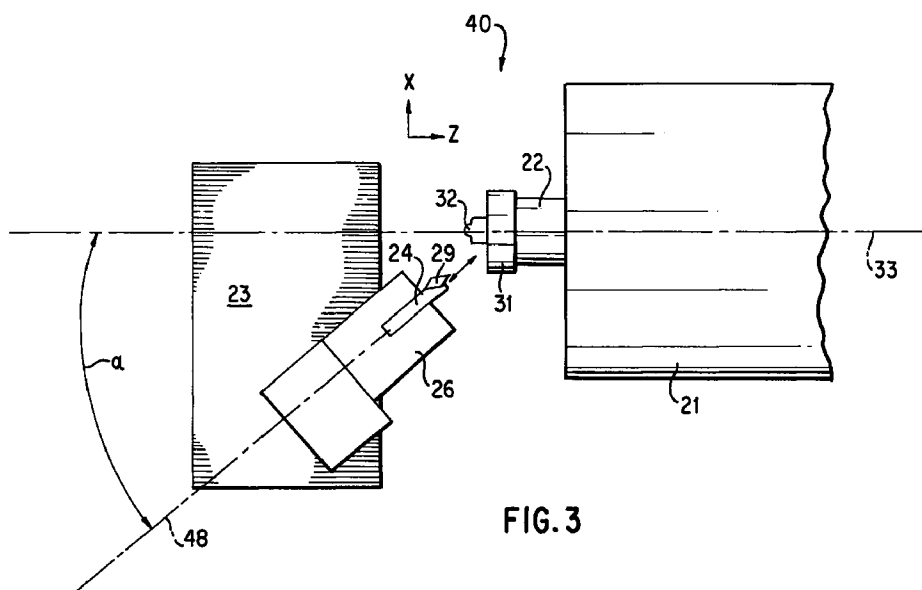


FIG. 3

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Description

The present invention relates generally to the field of machining three-dimensional surfaces on workpieces and in particular relates to a lathe apparatus and method for machining non-axisymmetric surfaces on workpieces, such as contact lenses.

Some people are lucky enough to have near-perfect vision which requires no optical correction. However, a great many people suffer from one or more visual impairments. For example, some people suffer from hypermetropia (farsightedness) in which light images nearer than a certain distance cannot be focused properly on the retina, but instead are focused behind it. Other people suffer from myopia or nearsightedness. The visual impairments just described typically can be corrected using contact lenses having spherical surfaces. However, a good many other visual impairments require contact lenses which have aspherical surfaces. For example, astigmatism, a common malady, requires the use of non-axisymmetric lens surfaces. Astigmatism is a refractive defect in which the curvature of the eye is different in one direction than it is in another direction. To correct this then, a contact lens is required having surfaces with different curvature radii in order to compensate for the astigmatism. Oftentimes, the astigmatism is coupled with nearsightedness or farsightedness so that the contact lenses required need to correct both conditions.

In the past, one way of providing contact lenses with both spherical surfaces and spherical surfaces has been to machine and polish a spherical correction onto a concave inner surface of a lens and thereafter to crimp the lens in a holding device to oblate the lens. The thus-oblated lens is then machined and polished on the convex outer surface. After the lens is released from the crimping device, the lens returns to its uncrimped configuration, leaving a toric surface on the outer surface of the lens. This process is labor-intensive and requires great precision in the crimping.

It has been recognized in the art that the crimping process is less than desirable and efforts have been made to provide for the manufacture of toric lenses without crimping. For example, U.S. Patent No. 4,680,998 describes a lathe apparatus in which a lens blank is chucked to a spindle and the spindle rotated. A cutting tool is supported on a rotary quadrant whose rotational swing moves the cutting tool arcuately across the face of the lens blank. In this way, the cutting tool is moved through a predetermined tool path in order to cut the lens as the spindle rotates. One disadvantage of this arrangement is that the useful magnitude (useful stroke) of the cutting tool's oscillations is severely limited because as the magnitude of the oscillations increases, the position of the cutting tool varies relative to the lens blank. This tends to limit the lenses that can be made with this arrangement.

U.S. Patent Nos. 4,884,482 and 4,947,715 relate to

method and apparatus for cutting an aspheric surface on a workpiece. The apparatus and method described in the '482 and '715 patents is quite similar to that described in the '998 patent. However, in the '482 and '715 patents, instead of oscillating the cutting tool as is described in the '998 patent, the workpiece is oscillated (by oscillating the spindle) in an effort to improve the effective useful stroke of the oscillations between the cutting tool and the workpiece. However, oscillating the workpiece is somewhat problematic.

Accordingly, it can be seen that a need yet remains for a lathe apparatus and method which allows the production of non-axisymmetric surfaces on lenses and which provides a greater effective stroke over known apparatus and techniques. It is to the provision of such a lathe apparatus and method that the present invention is primarily directed.

Briefly described, in a first preferred form the present invention comprises a lathe for manufacturing a product with a non-axisymmetric shape from a workpiece. The lathe is particularly well-suited for making contact lenses with toric surfaces. The lathe comprises a spindle for rotating the workpiece about an axis of rotation and a cutting tool for cutting the workpiece. The lathe also includes a movable bed means for supporting the cutting tool in a fixed angular orientation relative to the axis of rotation and for moving the cutting tool along a predetermined path adjacent the workpiece as the spindle rotates the workpiece. Also, means are provided for oscillating the cutting tool along an oscillation axis as the movable bed means moves the cutting tool along the predetermined path. The oscillation axis is oriented at a fixed, non-zero angle with respect to the axis of rotation.

The apparatus and method according to the present invention offers substantial advantages over known apparatus and methods. In some of the known prior art, the effective stroke of the oscillation is limited due to the fact that the oscillations occur parallel to the axis of rotation, while much of the surface of a lens to be machined is oriented such that the axis of rotation is not perpendicular to the surface at that point. In other of the known prior art, the effective stroke is limited by the rotary nature of the oscillations of the cutting tool. By contrast, the present invention obtains a greater effective use of the limited actual stroke of the known oscillation mechanisms by swinging the oscillation axis out to an angle relative to the axis of rotation and/or by oscillating the cutting tool with a translational movement.

The invention allows the manufacture of a wider range of contact lenses, including contact lenses with greater asymmetry than previously possible. Accordingly, it is a primary object of the present invention to provide a lathe apparatus and method which is capable of producing a wide range of non-axisymmetric lenses. It is another object of the present invention to provide a lathe apparatus and method which is capable of producing lenses with greater non-axisymmetry. It is another

object of the present invention to provide a lathe apparatus and method which provides a greater effective oscillation stroke using known oscillation mechanisms. It is another object of the present invention to provide a lathe apparatus and method for producing non-axisymmetric lenses which is simple in its construction, durable in operation, and economical to manufacture and use.

Fig. 1A is a front side view of a non-axisymmetric lens which can be manufactured according to the apparatus and method of the present invention;

Fig. 1B is a left side view of the non-axisymmetric lens of Fig. 1A;

Fig. 1C is a side view of another non-axisymmetric lens which can be manufactured according to the apparatus and method of the present invention;

Fig. 2 is a schematic, plan view of a prior art lathe apparatus for making nonaxisymmetric lenses;

Fig. 3 is a schematic plan view of a lathe apparatus according to a preferred form of the invention for manufacturing non-axisymmetric lenses;

Fig. 4 is a schematic side view of a portion of a non-axisymmetric lens made according to the present invention;

Fig. 5 is a perspective, schematic view of a lathe apparatus according to another preferred form of the invention;

Fig. 6 is a schematic, sectional view of an oscillation mechanism portion of the lathe apparatus of Fig. 5.

Referring now in detail to the drawing figures, wherein like reference numerals depict like parts throughout the several views, Fig. 1A through 1C depict examples of non-axisymmetric lens shapes which can be constructed using the present invention. It should be noted that these lens shapes themselves are not new and that they have been made in the past, albeit at greater cost and with greater difficulty than using the principles of the present invention.

Fig. 1A and Fig. 1B show front and left side views, respectively of a toric lens 10 having a spherical portion 11 and an aspherical portion 12. As can be seen by comparing Fig. 1A and 1B, the aspherical portion 12 has a first radius of curvature r_1 in one direction and a second, quite different radius of curvature r_2 when viewed from a direction perpendicular thereto.

Fig. 1C shows another type of non-axisymmetry in which a toric lens 15 includes a generally spherical upper portion 16, an aspherical central portion 17 and a ballast portion 18. As can be seen in Fig. 1C, the ballast portion 18 has a thickness t_2 which is substantially greater than the thickness t_1 of the upper portion 16.

Fig. 2 shows a prior art lathe apparatus for making toric lenses of a general type made by Rank Pneumo and known in the art. Prior art lathe apparatus 20 includes an unshown base and a spindle housing 21 supported thereupon. The spindle housing 21 houses

and supports a rotatable spindle 22 driven by an unshown motor means. As is already known in the art, the lathe apparatus 20 also includes sensor means for detecting the instantaneous angular position of the spindle for coordinating the movements of the cutting tool.

The prior art lathe apparatus 20 also includes a two-axis movable bed or quadrant 23. A tool holder 24 is supported by a tool holder support housing 26 which in turn is mounted to the quadrant 23. The tool holder support housing 26 houses internal (unshown) oscillation means for oscillating the tool holder back and forth in the direction of doubleheaded direction arrow 27 along oscillation axis 28. In this way, a cutting tool 29, which is mounted to the tool holder 24, is oscillated back and forth along the oscillation axis 28.

A chuck 31 is mounted at the end of the spindle 22 for supporting a lens blank or workpiece 32. A spindle 22 rotates the workpiece 32 about rotation axis 33. As the workpiece 32 rotates about the rotation axis 33, the quadrant 23 moves through a predetermined path using conventional CNC (Computer Numerical Control) principles. In doing so, the quadrant moves in the X and Z axes.

The prior art apparatus just described and shown in Fig. 2 uses dual piezoelectric actuators with a motion amplifying lever mechanism for oscillating the tool holder 24 and the cutting tool 29. The range of motion of the oscillation is 0.4 mm (less as the rate of oscillation increases). This 0.4 mm stroke limitation acts to limit the types of non-axisymmetric toric lenses that can be manufactured using such an arrangement because in many instances a stroke greater than 0.4 mm would be required in order to provide the desired asymmetry.

Fig. 3 shows the novel lathe apparatus 40 according to a preferred form of the present invention. The lathe apparatus 40 is similar in many respects to the prior art lathe apparatus 20 depicted in Fig. 2. For example, the novel lathe apparatus 40 includes an unshown base, a spindle housing 21 and a spindle 22. The lathe apparatus 40 also includes a quadrant or movable bed 23 for moving in the X and Z directions. The novel lathe apparatus 40 also includes a chuck 31 for supporting a workpiece or lens blank 32. A tool holder 24 supports a cutting tool 29 and in turn is supported by a tool holder support housing 26. Note that the angular orientation of the cutting tool 29 relative to the tool holder 24 preferably is shifted (see Fig. 3) from what is shown in Fig. 2 in order to effect an appropriate presentation of the cutting tool to the workpiece. The tool holder support housing 26 also includes the internally mounted oscillation mechanism for oscillating the tool holder (and therefore the cutting tool 29) back and forth. In this regard, the dual piezoelectric actuators preferably are used, or alternatively, a motor can be used to oscillate the tool holder as taught in U.S. Patent No. 4,680,998. Alternatively, there may be other arrangements for oscillating the tool holder and the cutting tool.

As can be readily seen from Fig. 3, an important

distinction between the novel lathe apparatus 40 and what is shown in the prior art configuration depicted in Fig. 2 is that the oscillation axis 48 according to the present invention is no longer oriented to be parallel to the rotation axis 33. Rather, the oscillation axis 48 is oriented at an oblique angle α with respect to the oscillation axis. Preferably, the oblique angle α is between about 20° and 70° with respect to the rotation axis 33. More preferably, the oblique angle α is between 30° and 60° with respect to the rotation axis. Most preferably, the oblique angle is about 45°.

Fig. 4 is useful in understanding the significance of repositioning the oscillation axis to the oblique angle α . In Fig. 4, a portion of a lens L is shown in relation to the rotation axis 33. The lens L has a spherical portion 51 and an aspherical portion 52. In the aspherical portion 52, the non-axisymmetry is depicted by dash line 53. If one were to use the prior art lathe apparatus of Fig. 2 to try to produce this non-axisymmetry, the stroke of oscillation of the cutting tool would have to be greater than the distance d_2 in order to achieve the desired depth. However, the maximum stroke of the oscillation is less than the distance d_2 in many instances. By having the oscillation axis 48 be offset by an angle α from the rotation axis, to achieve the same profile, the distance d_1 corresponds to the necessary stroke required to achieve the profile. Simply put, the oscillation axis ideally is swung to an angle where it is perpendicular to the surface of the lens where the non-axisymmetry is required. In this way, the rather limited actual stroke of the known oscillation mechanism is more effectively utilized to achieve a desired non-axisymmetric profile. With the tool holder being held in a fixed orientation relative to the axis of rotation, the perpendicularity is not maintained over the entirety of the surface. It is possible to construct an arrangement in which the tool holder orientation is varied during use in order to maintain true perpendicularity at all points along the surface, but at the expense of added mechanical complexity and added computational complexity.

Those skilled in the art will recognize that the software used to control the oscillations of prior art lathe apparatus must be modified to adjust for the angle α . However, the mathematical compensation required represents a straightforward trigonometric problem. Those skilled in the art will easily recognize that while the oscillation axis is shown in Fig. 3 to be on one side of the rotation axis, it could just as easily be positioned on the other side. Furthermore, in addition to being very useful for making contact lenses (among other products), the present invention is equally useful for producing molds and other tooling for making contact lenses.

Fig. 5 shows a lathe apparatus 110 according to a second preferred form of the present invention. The lathe apparatus 110 includes a spindle housing 121 and a driven spindle 122 for supporting and rotating a workpiece 132. The workpiece is rotated about an axis of rotation 133. The lathe apparatus 110 also includes a

rotary quadrant 123 supporting a housing 126. The housing 126 includes a mechanism (unshown in this figure) for reciprocating (oscillating 30 back and forth in a translational manner) a tool holder 124 which supports a cutting tool 129. In this way, the cutting tool 129 is reciprocated along movement axis 130. An upper portion of rotary quadrant 123 moves arcuately in the direction of arcuate direction arrow 140 to move the cutting tool 129 through a predetermined arcuate path adjacent the workpiece 132.

Fig. 6 shows one preferred mechanism for oscillating the cutting tool 129 in a reciprocal translational manner. The oscillation mechanism 150 includes guide means 151 and 152 for guiding the tool bar 124 to restrict its motion to a reciprocating, translational motion depicted by arrow 130. Also, additional (unshown) guide means can be provided on the sides of the tool bar 124 to further restrict the movement to a translational, reciprocating motion. The mechanism 150 is of the general type employed in the Rank Pneumo device described above.

The oscillation mechanism 150 also includes a pair of piezoelectric elements 156 and 157 for causing pivotal movement of a pendulum 158 about a pivot point 159. As the height of each of the piezoelectric elements 156 and 157 rises and falls with changing voltages applied thereto, this causes the pendulum 158 to pivot about the pivot point 159 and causes the lower end 161 of the pendulum to move through an arcuate path of movement depicted by direction arrow 160. A linkage or strut 162 is pivotally connected at one end thereof to the lower end 161 of the pendulum 158 and is pivotally connected at an opposite end thereof to a backside portion of the tool bar 124. In this way, pivotal motion of the lower end 161 of the pendulum 158 is converted into translational movement of the tool bar 124. With the cutting tool 129 being fixedly secured to an upper portion of the tool bar 124, a reciprocating, translational motion of the cutting tool is achieved.

The present invention has some notable advantages over the prior art lathe apparatus having oscillation mechanism. Firstly, for a given profile, it allows a smaller oscillation to be used to achieve the same asymmetric depth. The use of a smaller oscillation often allows the rate of oscillation to be increased, thereby allowing the spindle speed to be increased well. This increases the productive throughput or production rate of the lathe apparatus. Moreover, the present apparatus and method also allows greater effective use of the maximum stroke of the known oscillation mechanisms to increase the effective range of the oscillation mechanisms.

Furthermore, using a reciprocating translational oscillation mechanism (See Figs. 5 and 6) with a rotary quadrant greatly increases the utility of a rotary quadrant lathe. In other words, profiles that could not previously be made using known equipment can now be generated with the novel apparatus of the present

invention.

Claims

1. A lathe for manufacturing a product with a non-axisymmetric shape from a workpiece, such as a contact lens with one or more toric surfaces, said lathe comprising:
 - a spindle for rotating the workpiece about an axis of rotation;
 - a cutting tool;
 - movable bed means for supporting said cutting tool in a fixed angular orientation relative to said axis of rotation and for moving said cutting tool along a predetermined path adjacent the workpiece as said spindle rotates the workpiece, said movable bed means being capable of translational movement along at least a first axis and a second axis transverse to said first axis; and
 - means for oscillating said cutting tool along an oscillation axis as said movable bed means moves said cutting tool along said predetermined path, wherein said oscillation axis is oriented at a non-zero angle with respect to said axis of rotation.
2. A lathe as claimed in Claim 1 wherein said oscillation axis is oriented at an angle of between about 20° and 70° with respect to said axis of rotation.
3. A lathe as claimed in Claim 1 wherein said oscillation axis is oriented at an angle of between about 30° and 60° with respect to said axis of rotation.
4. A lathe as claimed in Claim 1 wherein said oscillation axis is oriented at an angle of about 45° with respect to said axis of rotation.
5. A lathe as claimed in Claim 1 wherein said non-zero angle is held constant and is non-varying.
6. A lathe as claimed in Claim 1 wherein said means for oscillating said cutting tool provides translational oscillating movement of said cutting tool.
7. A lathe for manufacturing a product with a non-axisymmetric shape, such as a toric contact lens, said lathe comprising a spindle for rotating a workpiece about a rotation axis, a cutting tool holder, a movable bed for supporting said cutting tool holder in a fixed angular orientation relative to the rotation axis and for moving said cutting tool holder in a fixed angular orientation relative to the rotation axis and for moving said cutting tool holder along a predetermined path as the spindle rotates said workpiece, and an oscillating device for oscillating the cutting tool holder along an oscillation axis, wherein said oscillating device is oriented such that the oscillation axis is oriented at an oblique angle with respect to the rotation axis.
8. The improvement of claim 7 wherein said oblique angle is between about 20° and 70°.
9. The improvement of claim 7 wherein said oblique angle is between about 30° and 60°.
10. The improvement of Claim 7 wherein said oblique angle is about 45°.
11. A method of manufacturing products having a non-axisymmetric shape from a workpiece, a method being carried out using a lathe with a cutting tool and comprising the steps of:
 - rotating the workpiece about a rotation axis;
 - moving the cutting tool along a predetermined path adjacent the workpiece as the workpiece is rotated, the step of moving the cutting tool along a predetermined path being carried out by translational movements of the cutting tool along at least two movement axes which are transverse to one another; and
 - as the cutting tool is moved along the predetermined path, oscillating the cutting tool along an oscillation axis which is oriented at an oblique, non-varying angle relative to the rotation axis.
12. The method of Claim 11 wherein said oblique angle is between about 20° and 70°.
13. The method of Claim 11 wherein said oblique angle is between about 30° and 60°.
14. The method of Claim 11 wherein said oblique angle is about 45°.
15. A lathe for manufacturing a product with a non-axisymmetric shape from a workpiece, such as a contact lens with one or more toric surfaces, said lathe comprising:
 - a spindle for rotating the workpiece about an axis of rotation;
 - a cutting tool;
 - rotary quadrant means for supporting said cutting tool and for moving said cutting tool arcuately along a predetermined path adjacent the workpiece as said spindle rotates the workpiece; and
 - means for oscillating said cutting tool translationally along an oscillation axis as said rotary quadrant means moves said cutting tool along said predetermined path, wherein said means

for oscillating is mounted adjacent said rotary quadrant.

16. A method of manufacturing products having a non-axisymmetric shape from a workpiece, the method being carried out using a lathe with a cutting tool and comprising the steps of:

rotating the workpiece about a rotation axis;
swinging the cutting tool arcuately along a predetermined path adjacent the workpiece as the workpiece is rotated; and
as the cutting tool is swung arcuately along the predetermined path, translationally oscillating the cutting tool relative to the workpiece.

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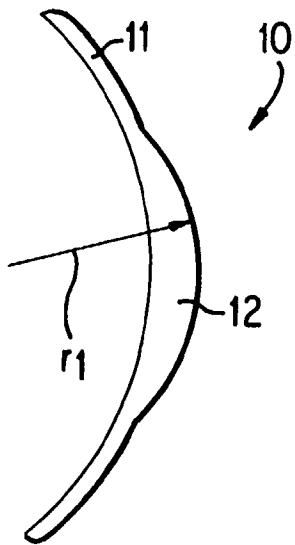


FIG. 1A

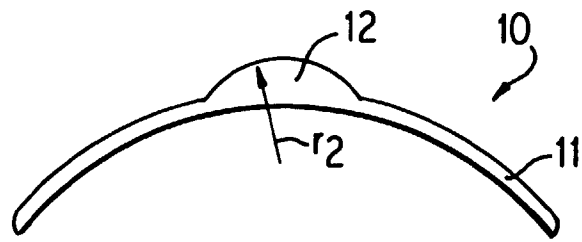


FIG. 1B

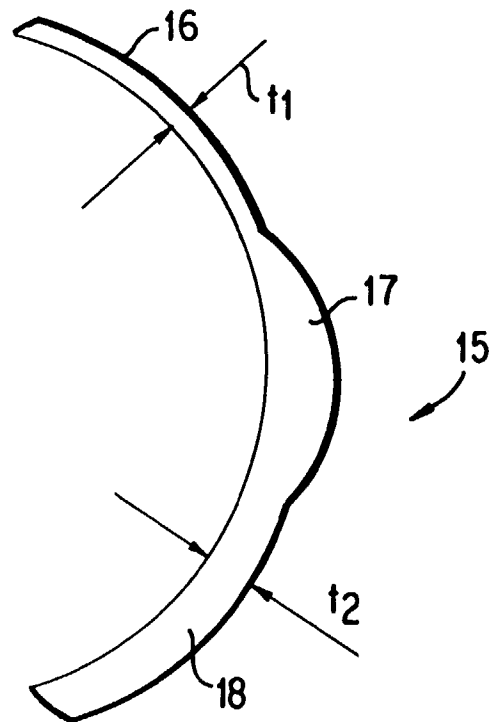


FIG. 1C

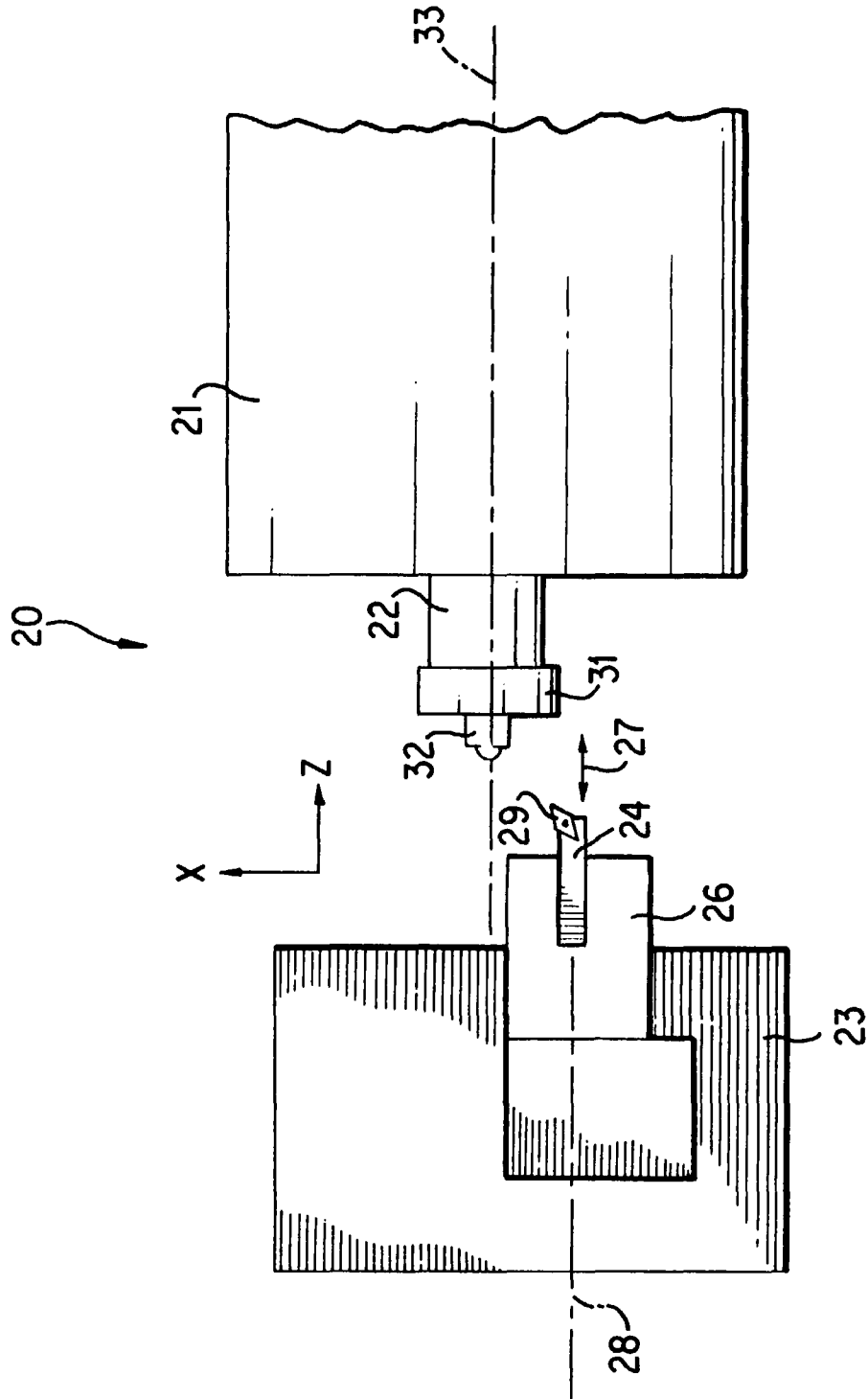
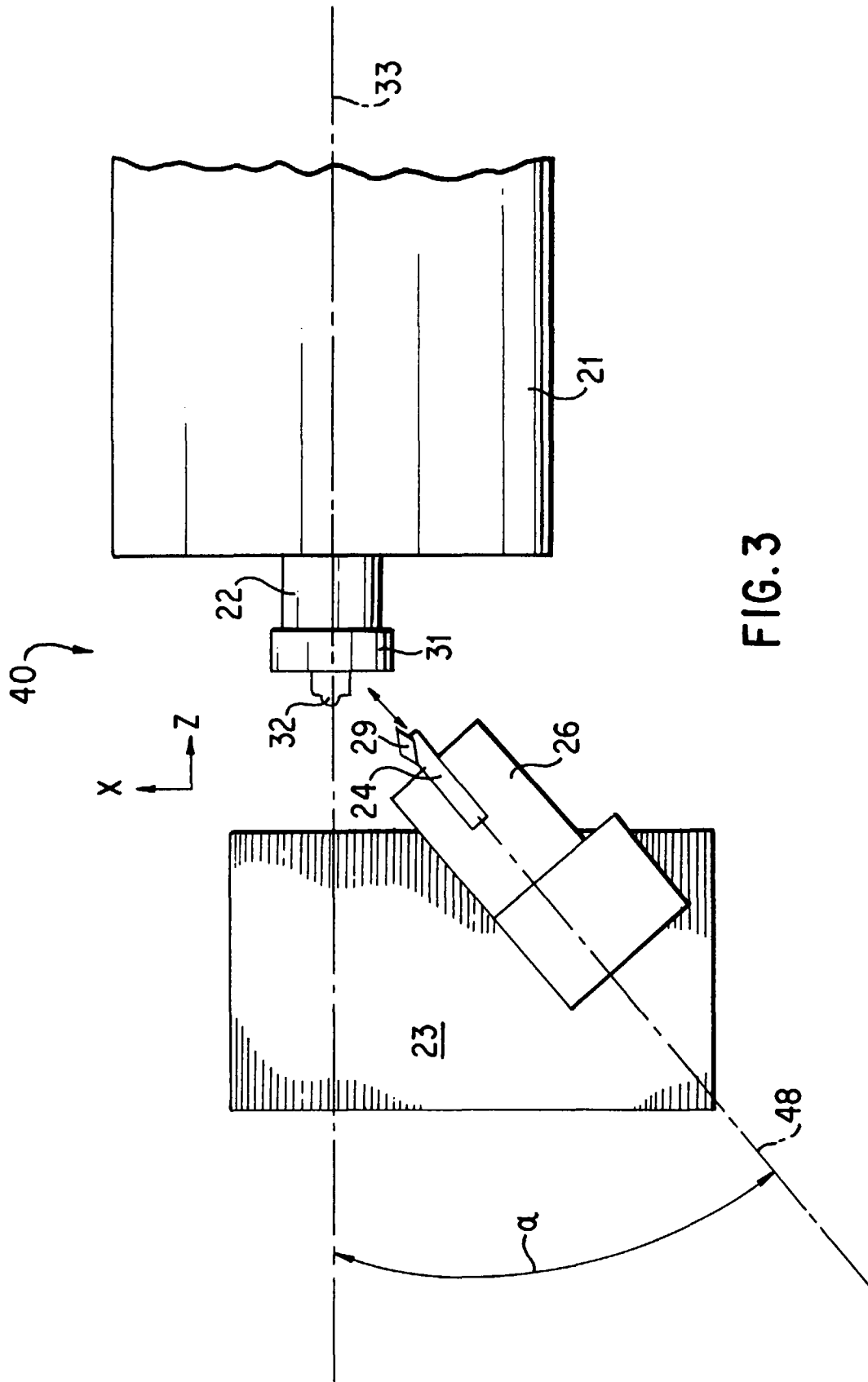


FIG. 2
(PRIOR ART)



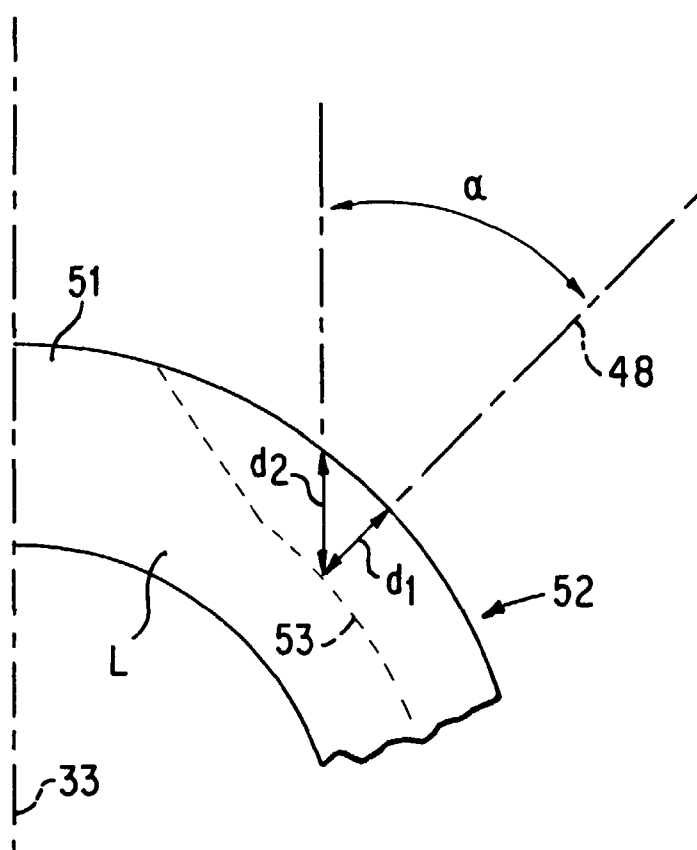


FIG. 4

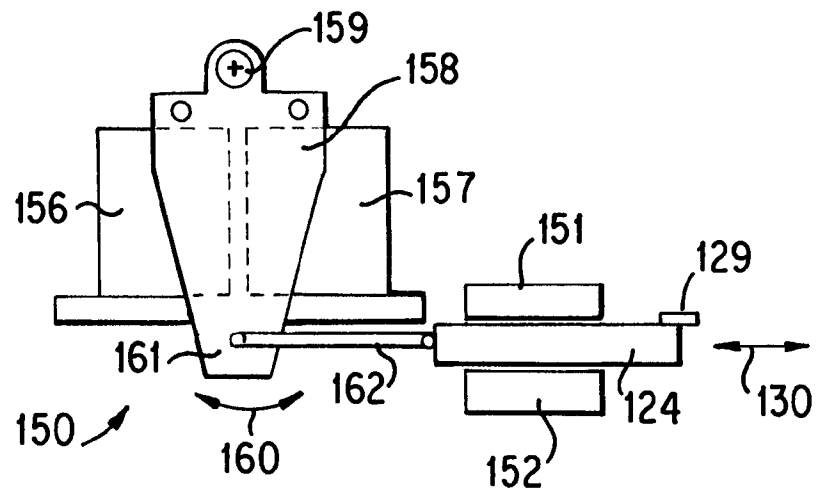


FIG. 6

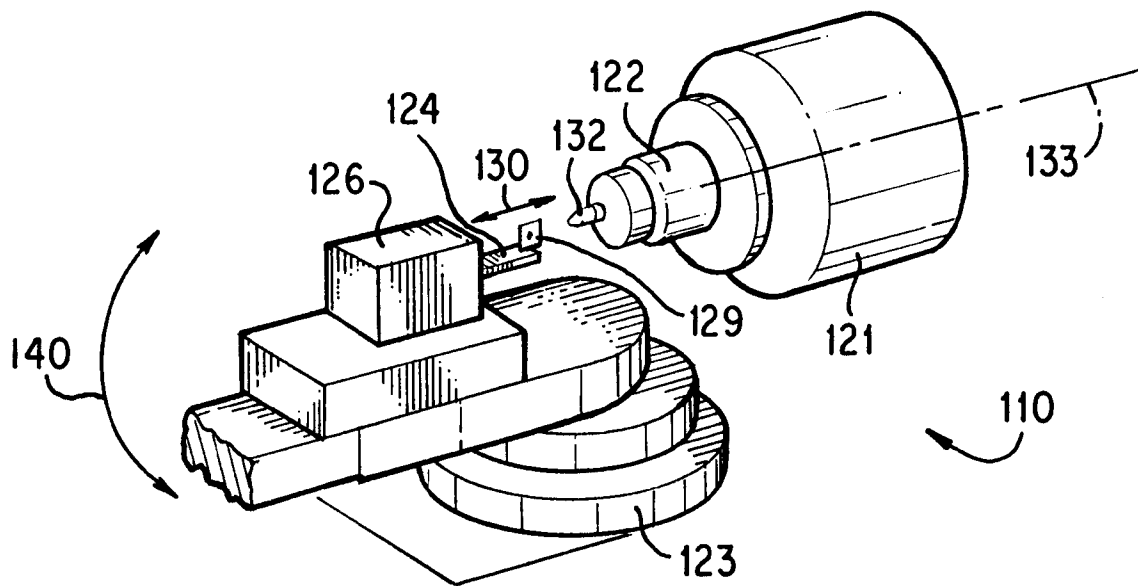


FIG. 5



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 98 10 6802

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 439 425 A (CIBA GEIGY AG) 31 July 1991 * claims; figure * -----	1,7,11, 15,16	B24B13/00 B24B13/04 B24B13/06
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			B24B
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 15 July 1998	Examiner Eschbach, D
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