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(71) Applicant: **Schneider GmbH & Co. KG**
35112 Fronhausen (DE)

(72) Inventors:
• **Geist, Nadine**
35606 Solms (DE)
• **Link, Hans-Joachim**
35216 Biedenkopf (DE)

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(74) Representative: **Von Rohr Patentanwälte Partnerschaft mbB**
Rüttenscheider Straße 62
45130 Essen (DE)

(54) **POLISHING TOOL AND DEVICE FOR POLISHING A WORKPIECE**

(57) A polishing tool and a device for polishing a workpiece with a corresponding polishing tool are proposed, the polishing tool having an elastic intermediate layer with two portions/parts of different hardness, the

portion/part close to the processing surface being softer than the portion/part of the intermediate layer remote from the processing surface.

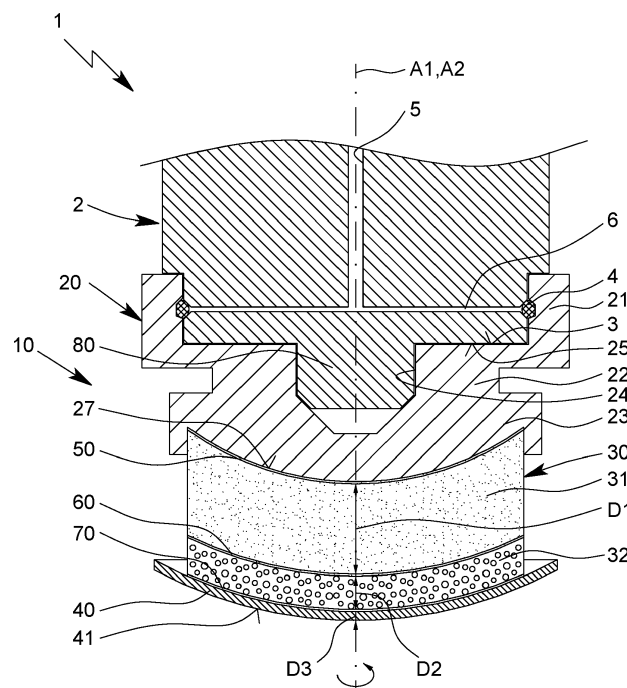


Fig. 1

EP 3 766 635 A1

Description

[0001] The present invention relates to a polishing tool according to the preamble of claim 1. The present invention further relates to a device for polishing a workpiece, in particular a lens, according to the preamble of claim 10.

[0002] A polishing tool of this type is known from DE 10 2014 015 052 A1. The polishing tool of this type has a base with a two-part foam carrier applied to its curved front surface, which in turn carries a polishing foil. The two-part foam carrier is softer adjacent to the base and harder adjacent to the polishing foil.

[0003] Such a polishing tool is used in particular for polishing optical workpieces such as lenses. Since the harder portion is much thinner than the softer portion, the polishing foil can adapt well to the geometry of the surface to be polished due to the comparatively thick softer portion. At the same time, a comparatively high removal rate can be achieved due to the comparatively thin harder area. Therefore, it shall be possible to polish ophthalmic lenses in a range from 0 to 14 diopters with a single tool with a constant curvature of the surface of the base. Basically, the number of polishing tools required for operating in the diopter range of the ophthalmic lenses to be polished shall be reduced. However, such a polishing tool does not meet the requirements for the most exact, deterministic polishing with a particularly accurate polishing result.

[0004] Furthermore, numerous polishing tools with a one-piece elastic intermediate layer are known in the state of the art. In particular when combined with a polishing spindle with spherical/ball head, the problem arises that when compressing the intermediate layer during the polishing process, the polishing tool or tool axis is (too) strongly deflected or tilted away from the center axis and/or drive axis (center offset). This leads to polishing errors because the polishing tool is not guided centrally and/or the tool axis is not guided perpendicular to the surface to be polished (processing surface / target surface), but off-center/eccentric and/or offset and/or at an angle / inclined to said surface.

[0005] The object of the present invention is to improve and/or further develop a polishing tool of the known type as well as a device of the known type in such a way that a particularly precise polishing of a workpiece, such as a lens or an ophthalmic lens, is made possible, in particular with small radial deflection of the polishing tool and/or reduced center offset during the polishing process.

[0006] The solution to this problem is a polishing tool with the features of claim 1 and a device with the features of claim 10.

[0007] A first independent aspect of the present invention is that the polishing tool according to the invention comprises a base, a polishing foil and/or polishing pad and a two-part or multi-part elastic intermediate layer, preferably made of foam, in particular a foam carrier, wherein the intermediate layer is designed to be harder and/or stiffer (against compression) in the (immediate)

vicinity of the base and softer and/or more elastic and/or more yielding in the (immediate) vicinity of the polishing foil. Thus, a strong radial deflection of the polishing tool according to the invention during the polishing process is at least reduced.

[0008] It is provided that the intermediate layer / foam carrier has a (first) portion/part in particular of foam material which (directly) adjoins the base and/or is remote from the processing surface and a (second) portion/part in particular of foam material which (directly) adjoins the polishing foil and/or is arranged between the polishing foil and the first portion/part and/or is close to the processing surface, wherein the first portion/part is thicker, harder / less elastic, stiffer and/or denser than the second portion/part.

[0009] Due to the softer/second portion/part, the polishing foil can adapt particularly well to the surface of the workpiece even at high rotational speeds of the polishing tool. In particular for workpieces or lenses with surfaces which are not rotationally symmetric, such as toric lenses or free-form lenses, the arrangement according to the invention of the portions/parts of the intermediate layer / foam carrier - in contrast to the state of the art - enables the polishing foil to dynamically adapt or snuggle against the surface so that the polishing foil always lies on the workpiece/lens with its (entire) surface.

[0010] Due to the harder/first portion/part, the polishing tool and/or the polishing foil can yield both in the axial direction / the direction of the tool axis and in the radial direction / transversely to the drive axis, in particular to allow adaptation to height differences and/or to radii of curvature of the workpiece varying in the circumferential direction, as in the case of toric lenses, and/or to be able to process workpieces with different radii of curvature with the same polishing tool.

[0011] A second independent aspect of the present invention is that a device for polishing according to the invention comprises a - rotatably driven - tool carrier, in particular a tool spindle / polishing spindle, which is (directly) connected to the base of the polishing tool according to the invention by means of an optional coupling element and/or is embodied for detachable and/or exchangeable holding of the polishing tool according to the invention, wherein the tool carrier, in particular the coupling element, is either at least substantially rigid / joint-free, in particular ball-head-free, or has an elastic flexure bearing / elastic flexure joint.

[0012] Thus, in particular, the tool carrier and/or the coupling element do/does not have a ball head / spherical head which would lead to an excessive center offset of the polishing tool when the polishing tool is pressed against the workpiece and can lead to tilting during polishing in the edge area of the workpiece.

[0013] The known devices with ball head have a fixed and relatively large distance between the joint / joint axis / tilt axis and the polishing surface. It is therefore a constraining/coercive mechanism which, even with small transverse forces, leads to a large center offset of the

polishing tool relative to the spindle axis / drive axis due to the large distance.

[0014] In contrast, the rigid and/or joint-free device according to the invention does not have a fixed joint axis / tilt axis.

[0015] As already explained, tilting of the polishing tool is (exclusively) caused by bending of the polishing tool, in particular of the intermediate layer / foam carrier. In other words, the polishing tool, in particular the intermediate layer/ foam carrier, preferably forms a flexure bearing, in particular with a virtual joint axis, with a reduced distance to the polishing surface compared to known devices with ball head, so that transverse forces of the same magnitude lead to a smaller center offset.

[0016] The polishing tool according to the invention, in particular the first/harder portion/part of the intermediate layer, can therefore take over the compensating functions of the known ball head and enables - in particular due to the smaller distance between the first portion/part and the polishing foil - a better guidance over/on the workpiece.

[0017] In addition, the rigid and/or joint-free device according to the invention prevents the risk of the polishing tool lifting off the workpiece in the edge area of the workpiece.

[0018] A basic idea according to the invention is thus to connect the polishing tool according to the invention, in particular directly and/or without a ball head, to a tool carrier, in particular a polishing spindle. This at least reduces the center offset. In particular, the center offset can no longer be influenced by the tilting of the ball head.

[0019] A major contribution to this effect according to the invention is that the polishing tool according to the invention in the vicinity of the tool carrier and/or coupling element, in particular the first portion of the intermediate layer, is designed to be stiffer and/or harder than in the state of the art in order to be able to contribute to a reduction of the center offset.

[0020] The above-mentioned aspects and features as well as the aspects and features of the present invention resulting from the claims and the following description can in principle be realized independently of each other, but also in any combination.

[0021] Further aspects, advantages, features, properties and advantageous further developments of the present invention result from the sub-claims and the following description of preferred embodiments with reference to the figures. They show in schematic, not to scale views:

Fig. 1 a schematic section of a device according to the invention with a tool carrier only partially shown and a polishing tool according to the invention according to a first embodiment;

Fig. 2 a schematic section of the device according to Fig. 1 with the tool carrier only partially shown and the polishing tool according to the

invention according to a second embodiment;

Fig. 3A a schematic section of the device according to Fig. 2 in a position moved away from a workpiece;

Fig. 3B a schematic section of the device according to Fig. 3A in a position pressed against the workpiece and/or in a central processing position;

Fig. 3C a schematic section of the device according to Fig. 3B in an eccentric and/or deflected processing position;

Fig. 3D a schematic section of the device according to Fig. 3C with a workpiece rotated by 90°; and

Fig. 4 a schematic diagram of the processing positions of the polishing tool relative to the workpiece in a top view.

[0022] In the partly not to scale, only schematic figures, the same reference signs are used for the same, identical or similar parts and components, wherein corresponding or comparable properties, characteristics and advantages are achieved, even if a repeated description is omitted.

[0023] Fig. 1 and Fig. 2 each show a preferred embodiment of a proposed device 1 for polishing a workpiece L, not shown in Fig. 1 and 2, in particular a lens or a spectacle/eyeglass lens.

[0024] The device 1 has a tool carrier 2, preferably rotatably driven about a spindle axis and/or drive axis A1, in particular a tool spindle and/or polishing spindle, and a polishing tool 10 for polishing the workpiece L.

[0025] The polishing tool 10 is attached or attachable to the tool carrier 2, preferably at least substantially rigid and/or immovable and/or joint-free.

[0026] In particular, the polishing tool 10 is detachably and/or interchangeably attached or attachable to the tool carrier 2 so that the polishing tool 10 preferably manually can be removed from the tool carrier 2 after one or more polishing processes and replaced by a new polishing tool 10.

[0027] In the embodiments shown, the polishing tool 10 according to the invention has a base 20, an intermediate layer / foam carrier 30 and a polishing pad / polishing film / polishing foil 40.

[0028] The polishing foil 40 preferably forms a (first) axial and/or free end of the device 1 and/or the polishing tool 10. In particular, the polishing foil 40 is in direct contact with the workpiece L when polishing the workpiece L.

[0029] Preferably, the polishing foil 40 has an in particular (concave or convex) curved, particularly preferably spherical, polishing surface 41, wherein the polishing surface 41 forms a front surface of the polishing tool 10.

[0030] The intermediate layer 30 is preferably arranged between the base 20 and the polishing foil 40. In

particular, the polishing foil 40 is connected to the base 20 by means of the intermediate layer 30.

[0031] The base 20 preferably forms a (second) axial end of the polishing tool 10 and/or is (directly) connected or connectable to the tool carrier 2, as explained in more detail below.

[0032] The polishing tool 10, in particular the base 20 and/or the intermediate layer / foam carrier 30, are/is preferably at least substantially cylindrical and/or (each) designed as a (circular) cylinder.

[0033] Particularly preferably, the polishing tool 10 and/or the base 20 and/or the intermediate layer 30 are/is at least essentially rotationally symmetrical.

[0034] The tool carrier 2 is preferably rotatable about the drive axis A1, preferably wherein the drive axis A1 runs centrally through the at least substantially cylindrical tool carrier 2.

[0035] The polishing tool 10, in particular the polishing foil 40, preferably has a tool axis A2, in particular wherein the tool axis A2 forms a longitudinal axis, symmetry axis, central axis and/or rotational axis of the preferably elongated and/or rotationally symmetrical polishing tool 10 and/or of the preferably circular polishing foil 40.

[0036] Usually the tool axis A2 corresponds to / coincides with / is the same as the drive axis A1. However, it is also possible to incline or tilt the polishing tool 10, in particular the polishing foil 40, relative to the base 20 and/or tool carrier 2 so that the tool axis A2 is inclined to the drive axis A1, thus creating a center offset.

[0037] The spatial allocations, arrangements and/or alignments, in particular the terms "radial" and/or "axial" used in the context of the present invention, preferably refer to the drive axis A1 and/or tool axis A2, unless otherwise indicated.

[0038] Preferably, the base 20 has a base part 21, a connecting part 22 and/or a head part 23, in particular wherein the base part 21 is connected to the head part 23 by means of the connecting part 22.

[0039] The base part 21 is preferably arranged on a side of the base 20 facing the tool carrier 2 and the head part 23 on a side of the base 20 facing away from the tool carrier 2.

[0040] Preferably, the polishing tool 10 is attachable or attached (directly) to the tool carrier 2 by means of the base 20, in particular the base part 21.

[0041] In the embodiments shown, the base 20 and/or the base part 21 is designed to at least partially receive the tool carrier 2. However, solutions are also possible in which the tool carrier 2 is designed to receive the base 20 and/or the base part 21. For example, the tool carrier 2 may have a bore hole to receive polishing tool 10.

[0042] Preferably, the tool carrier 2 is designed as a (tool-carrying) motor spindle and/or tool spindle and/or formed by a shaft with a tool interface at an axial and/or free end.

[0043] Preferably the tool carrier 2, in particular the tool interface, has a coupling element / pin 80 for torque transmission.

[0044] The base 20, in particular the base part 21, preferably has a receiving region 24 for receiving and/or centering the tool carrier 2, in particular the coupling element / pin 80 of the tool carrier / tool spindle 2.

[0045] The polishing tool 10, in particular the base 20, is connected or connectable, preferably detachably, with the tool carrier 2, in particular the coupling element / pin 80, by form-fit, force-fit and/or adhering/bonding.

[0046] As already explained at the beginning, the tool carrier 2 / tool spindle 2 is rotatably driven, preferably around the drive axis A1, for example by means of an electric motor (not shown).

[0047] Preferably, by means of the coupling element / pin 80 of the tool carrier 2, a torque and/or a rotary movement is transmittable from the tool carrier 2 to the polishing tool 10.

[0048] For this purpose, the coupling element / pin 80 and the receiving region 24 preferably have profiles for torque transmission that are complementary to each other, for example polygonal profiles, so that a form-fit is created between the tool carrier 2 and the polishing tool 10 in the direction of rotation when the coupling element / pin 80 is inserted into the receiving region 24, as shown in Figs. 1 and 2.

[0049] Preferably, the base 20, in particular the base part 21, lies axially - and optionally also radially - against the tool carrier 2 with its surface.

[0050] Preferably, the base 20, in particular the base part 21, has a base part surface 25, which lies axially and/or radially against a corresponding support surface 3 of the tool carrier 2.

[0051] As already explained, the polishing tool 10 is detachably connected or connectable to the tool carrier 2. Preferably, the device 1 and/or tool carrier 2 has a coupling for detachably connecting the polishing tool 10 to tool carrier 2.

[0052] In the embodiment shown in Fig. 1, the device 1 and/or the tool carrier 2 is equipped with a pneumatically actuated coupling, in which a sealing ring 4 can be acted upon with pressurized air via a central and/or axially running supply line 5 and one or more radially running pressure lines 6 in such a way that the sealing ring 4 can be pressed radially against the polishing tool 10 and/or the base 20. In this way, a frictional / force-fit connection is produced between the tool carrier 2 and the polishing tool 10.

[0053] In the embodiment shown in Fig. 2, the device 1 and/or tool carrier 2 is equipped with a magnetic coupling to magnetically connect the polishing tool 10 to tool carrier 2. For this purpose, the polishing tool 10 has one or more magnets 26 which are embedded in the base 20 and/or the base part 21 to allow magnetic adhesion to the preferably metallic tool carrier 2.

[0054] Preferably, the base 20 is designed to be rigid and/or harder, stiffer and/or less elastic than the intermediate layer 30 and/or the polishing foil 40, in particular to give the polishing tool 10 the necessary stability and/or to allow/enable attachment to the tool carrier 2.

[0055] The base 20 is preferably designed/constructed in one piece and/or made of a suitable plastic material, e.g. rigid PVC (PVC-U), in a manner known per se, in particular (injection-)molded.

[0056] The base 20, in particular the head part 23, is preferably designed to hold the intermediate layer / foam carrier 30, in particular in such a way that the rotary movement and/or the torques can be transmitted to the intermediate layer / foam carrier 30.

[0057] For this purpose, the intermediate layer / foam carrier 30 is connected to the base 20, in particular the head part 23, by form-fit, force-fit and/or adhering/bonding.

[0058] In the embodiments shown, the intermediate layer / foam carrier 30 and the base 20 are adhered together as indicated by a bonded/adhesive seam and/or an adhesive layer 50.

[0059] The base 20, in particular the head part 23, has a front surface 27 facing the intermediate layer / foam carrier 30, preferably wherein the intermediate layer / foam carrier 30 is adhered to the front surface 27.

[0060] As already explained, the polishing tool 10 and/or polishing foil 40 has the polishing surface 41, by means of which the workpiece L and/or the target surface / processing surface LF of the workpiece L can be polished.

[0061] The polishing surface 41 is preferably curved, especially preferably convex or concave, in particular spherical, preferably to process/machine the correspondingly curved processing surface LF of the workpiece L.

[0062] Preferably, the surface and/or front surface 27 of the base 20 is curved, particularly preferably convex or concave, in particular spherical, preferably in order to bend/curve the intermediate layer / foam carrier 30 and/or to create the curvature of the polishing surface 41 in this way. In this way, it is possible to dispense with a relatively expensive adaptation of the intermediate layer / foam carrier 30 and to use plate-shaped parts.

[0063] Preferably the radius of curvature of the front surface 27 of the base 20 is at least 75 mm and/or at most 1000 mm, particularly preferably at least substantially 150 mm or 600 mm.

[0064] Preferably, the radius of curvature of the polishing surface 41 is larger than the radius of curvature of the front surface 27, preferably by at least 100 mm, depending on the thickness and material properties of the intermediate layer / foam carrier 30 and the polishing foil 40.

[0065] In comparison to the state of the art, larger radii of curvature of the front surface 27 and/or the polishing surface 41 have proven to be effective in order to be able to process larger processing surfaces LF and/or to increase the removal during polishing.

[0066] Particularly preferably, the radius of curvature of the polishing surface 41 is larger than the (largest) radius of curvature of the workpiece L in order to create an annular contact surface when pressing the polishing

tool 10 onto the workpiece L. This is an advantageous way to increase the removal rate in comparison with punctiform contact surfaces and/or small radii of curvature of the polishing surface 41.

[0067] As already explained at the beginning, the intermediate layer / foam carrier 30 is made up of multiple parts and/or layers and/or is formed by a plurality of portions and/or parts.

[0068] The intermediate layer / foam carrier 30 has two parts/layers in the embodiments shown. However, solutions are also possible in which the intermediate layer / foam carrier 30 is composed of more than two portions and/or parts and/or layers.

[0069] Preferably, the intermediate layer / foam carrier 30 has a first portion/part 31 and a second portion/part 32.

[0070] The first portion/part 31 adjoins (directly and/or axially) the base 20. In particular, the first portion/part 31 is (directly) attached to the base 20 and/or adhesively bonded with the base 20 and/or (axially) arranged between the second portion/part 32 and the base 20.

[0071] The second portion/part 32 adjoins (directly and/or axially) the polishing foil 40. In particular, the polishing foil 40 is (directly) attached to and/or adhesively bonded with the second portion/part 32 and/or the second portion/part 32 is (axially) arranged between the first portion/part 31 and the polishing foil 40.

[0072] Preferably, the material properties and/or the geometry and/or the structural design of the portions/parts 31 and/or 32 differ from each other.

[0073] The essential aspect of the invention is that the first portion/part 31 and/or the portion/part 31 facing the base 20 is harder and/or less elastic and/or stiffer (than the second portion/part 32) and that the second portion/part 32 and/or the portion/part 32 facing the polishing foil 40 is softer and/or more elastic and/or more pliable and/or more flexible (than the first portion/part 31).

[0074] According to the invention, these properties/characteristics are preferably to be understood in such a way that the static and/or dynamic modulus of elasticity is higher in the vicinity of the base 20 than in the vicinity of the polishing foil 40 and/or, conversely, that the static and/or dynamic modulus of elasticity is lower in the vicinity of the polishing foil 40 than in the vicinity of the base 20.

[0075] Thus, preferably, the - static and/or dynamic - modulus of elasticity of the first/harder portion/part 31 is greater than the - static and/or dynamic - modulus of elasticity of the softer/second portion/part 32, preferably by at least a factor of 1.2 or 1.5 or 2.

[0076] Preferably, the first/harder portion/part 31 has a (static) modulus of elasticity of more than 0.4 N/mm², particularly preferably more than 0.75 N/mm², and/or less than 2 N/mm², particularly preferably less than 1.75 N/mm².

[0077] Preferably, the softer/second portion/part 32 has a (static) modulus of elasticity of more than 0.05 N/mm² or 0.075 N/mm², in particular more than 0.1 N/mm², and/or less than 1 N/mm² or 0.9 N/mm², in par-

ticalar less than 0.8 N/mm^2 or 0.6 N/mm^2 .

[0078] The modulus of elasticity is preferably a material characteristic value for the relationship between stress and strain and/or pressure and compression when a (test) piece made of this material is deformed.

[0079] A material with a low modulus of elasticity is softer and/or more elastic and/or easier to compress than a material with a higher modulus of elasticity.

[0080] The terms "hard" and/or "soft" are to be understood as a material property which can be used as a measure of the force required to compress or squeeze the material by a certain length value.

[0081] In other words, the "hardness" and/or "softness" and/or "stiffness" is the mechanical resistance that a material and/or substance has against (elastic) deformation/compression.

[0082] A hard material is preferably less elastic and/or less easy to compress than a soft material.

[0083] The term "elasticity" and/or "elastic" in the sense of the present invention is preferably understood to mean the property of a material to change its shape elastically, i.e. not plastically, under the action of force and to return to its original shape - without permanent deformation - when the acting force is removed.

[0084] To determine the (static) modulus of elasticity, a predefined pressure is preferably applied to a surface of a cuboidal, in particular a cube-shaped, test piece and the compression of the test piece in the direction of pressure/force is measured.

[0085] The modulus of elasticity is preferably the quotient of pressure in $[\text{N/mm}^2]$ and compression in $[\text{mm}]$ multiplied by the original length/width in $[\text{mm}]$ of the test piece in the direction of pressure/force.

[0086] Preferably, the above values for the modulus of elasticity refer to a test piece in which the ratio of the pressurized surface to the lateral surface (shape factor / form factor) is three and to which a pressure of 0.01 N/mm^2 or 0.035 N/mm^2 or 0.055 N/mm^2 or 0.1 N/mm^2 or 0.2 N/mm^2 is applied.

[0087] Preferably, the first/harder portion/part 31 has a greater compression hardness than the second/softer portion/part 32, in particular by at least a factor of two, three or four.

[0088] Preferably, the compression hardness of the first/harder portion/part 31 is at least 0.05 N/mm^2 , 0.1 N/mm^2 or 0.12 N/mm^2 and/or at most 0.3 N/mm^2 or 0.2 N/mm^2 .

[0089] Preferably, the compression hardness of the first/harder portion/part 31 is at least essentially 0.15 N/mm^2 .

[0090] Preferably, the compression hardness of the second/softer portion/part 32 is at least 0.01 N/mm^2 or 0.02 N/mm^2 and/or at most 0.1 N/mm^2 or 0.08 N/mm^2 .

[0091] Preferably, the compression hardness of the second/softer portion/part 32 is at least essentially 0.031 N/mm^2 or 0.047 N/mm^2 .

[0092] The compression hardness is preferably a material characteristic value that indicates the force required

to compress a test piece by a certain length.

[0093] The above values for the compression hardness preferably refer to a cuboidal, in particular a cube-shaped, test piece in which the ratio of the pressurized surface to the lateral surface (shape factor / form factor) is three and which has been compressed by 10 % relative to its original size.

[0094] Additionally or alternatively, the geometry and/or structural design of the first portion/part 31 may differ from the second portion/part 32, in particular to achieve different stiffness.

[0095] For example, the second portion/part 32 can be provided with recesses, such as slots, holes, bores or the like. In this way, the stiffness of the second portion/part 32 can be reduced - even with otherwise identical material properties - compared to the first portion/part 31.

[0096] The intermediate layer / foam carrier 30 is preferably (exclusively) formed by or made of foam, in particular polyurethane foam.

[0097] The first/harder portion/part 31 is preferably (exclusively) made of a closed-cell foam, in particular a closed-cell polyurethane foam.

[0098] The softer/second portion/part 32 is preferably (exclusively) made of an open-cell, mixed-cell or closed-cell foam, in particular an open-cell, mixed-cell or closed-cell polyurethane foam.

[0099] In the case of closed-cell foams, the walls between the individual cells of the foam are - at least substantially - closed, in particular in such a way that there is no exchange of liquid between the cells and/or the foam cannot absorb liquid. Preferably, a closed-cell foam has more than 80 % or 90 % closed cells and/or less than 20 % or 10 % open cells.

[0100] In the case of open-cell foams, the walls between the individual cells of the foam are at least partially open or not closed, in particular in such a way that a liquid exchange can take place between the cells and/or the foam can absorb liquid. Preferably, an open-cell foam has more than 70 % or 80 % open cells and/or less than 30 % or 20 % closed cells.

[0101] In the case of mixed-cell foams, the walls between the individual cells of the foam are partially open and partially closed. In particular, a mixed-cell foam is a mixture of a closed-cell foam and an open-cell foam. Preferably, the amount of open and/or closed cells in a mixed-cell foam lies between the amount for a closed-cell foam and an open-cell foam.

[0102] Usually, closed-cell foams are harder than open-cell and/or mixed-cell foams. Against this background, closed-cell foams are preferred for the first portion/part 31 and open-cell and/or mixed-cell foams for the second portion/part 32. However, it is also possible to use a closed-cell foam for the second portion/part 32 if corresponding material properties are achieved as with an open-cell or mixed-cell foam.

[0103] The absorption of polishing agent can affect the material properties of the foam.

[0104] To prevent or at least reduce the influence of the polishing agent on the material properties, it is preferable to use a closed-cell or mixed-cell foam also for the softer/second portion/part 32.

[0105] Preferably, the first/harder portion/part 31 and the second/softer portion/part 32 are connected with each other by adhering/bonding.

[0106] As indicated by a corresponding adhesive seam and/or adhesive layer 60, the portions/parts 31, 32 are adhered together in the embodiments shown. However, it is also possible to foam the two portions/parts 31, 32 together during production.

[0107] It is preferred - in contrast to the state of the art - that the harder portion/part 31 is (significantly) thicker than the softer portion/part 32, in particular to enable precise polishing by means of the polishing tool 10 and to reduce the center offset, as explained at the beginning.

[0108] Preferably, the first/harder portion/part 31 is at least by a factor of 1, 1.1 or 1.5 and/or at most by a factor of 3 or 2 thicker than the second/softer portion/part 32.

[0109] Preferably, the axial extension and/or thickness D1 of the first/harder portion/part 31 is at least 5 mm or 6 mm, particularly preferably at least 8 mm or 10 mm, and/or at most 20 mm or 18 mm, particularly preferably at most 16 mm or 14 mm.

[0110] Preferably, the axial extension and/or thickness D2 of the second/softer portion/part 32 is at least 2 mm or 4 mm, particularly preferably at least 6 mm, and/or at most 12 mm or 10 mm, particularly preferably at most 9 mm.

[0111] Preferably, the axial extension and/or thickness of the intermediate layer / foam carrier 30 in total is at least 12 mm or 14 mm, particularly preferably at least 15 mm, and/or at most 30 mm or 25 mm, particularly preferably at most 22 mm or 20 mm.

[0112] As already explained, the intermediate layer / foam carrier 30 is cylindrical and/or embodied as a (circular) cylinder. Preferably, the intermediate layer / foam carrier 30 has an at least essentially constant diameter along the tool axis A2 and/or in the axial direction.

[0113] Preferably, the diameter of the intermediate layer / foam carrier 30 is at least 35 mm and/or at most 60 mm.

[0114] Preferably, the diameter of the polishing foil 40 is larger than the diameter of the intermediate layer / foam carrier 30. In other words, the polishing foil 40 preferably protrudes at the edges beyond the intermediate layer / foam carrier 30.

[0115] Preferably, the polishing foil 40 is connected to the intermediate layer / foam carrier 30, in particular the second/softer portion/part 32, by bonding, in particular adhering, as indicated by a corresponding adhesive seam and/or adhesive layer 70 in the figures.

[0116] The polishing foil 40 preferably has a thickness D3 of at least 0.08 mm or 1 mm and/or at most 2 mm, particularly preferably at least substantially 1.2 mm.

[0117] The polishing foil 40 is preferably made of polyurethane.

[0118] As already explained, the device 1 and/or the polishing tool 10 is designed for (micro)cutting/machining/processing (of surfaces), in particular for fine processing and/or polishing, of the workpiece L and/or the processing surface LF of the workpiece L.

[0119] The processing/machining and/or the polishing process of the workpiece L will be explained in more detail below with reference to Fig. 3A to 3D and Fig. 4.

[0120] Fig. 3A shows the device 1 and/or polishing tool 10 in a position (moved) away from the workpiece L. Fig. 3B shows the device 1 and/or polishing tool 10 in a position pressed against the workpiece L and/or in a (central) processing position in which the polishing tool 10 and the workpiece L are arranged coaxially. Fig. 3C shows the device 1 and/or polishing tool 10 in an eccentric/off-center and/or deflected processing position. Fig. 3D shows the device 1 and/or polishing tool 10 in the eccentric/off-center and/or deflected processing position according to Fig. 3C with workpiece L rotated by 90° about a workpiece axis A3. Fig. 4 shows a schematic view/diagram of possible processing positions of the device 1 and/or polishing tool 10 relative to the workpiece L.

[0121] In the processing/machining position and/or during the polishing process, the polishing tool 10, in particular the polishing foil 40, and the workpiece L are in contact with each other. In particular, in the processing position and/or during the polishing process, the polishing surface 41 lies preferably with its (entire) surface on the workpiece L and/or the processing surface LF, as shown in Figs. 3B, 3C and 3D.

[0122] Preferably, a polishing force and/or polishing pressure and/or contact/surface pressure is applied to the workpiece L during the polishing process.

[0123] Preferably, the polishing pressure is kept at least essentially constant during a polishing process.

[0124] Preferably, during the polishing process, a polishing pressure of more than 0.01 N/mm² or 0.02 N/mm² and/or less than 1 N/mm² or 0.05 N/mm², in particular less than 0.1 N/mm², is generated and/or applied to the workpiece L.

[0125] In the processing position and/or during the polishing process, the polishing tool 10, in particular the intermediate layer / foam carrier 30, is compressed/squeezed, preferably wherein the second/softer portion/part 32 is compressed/squeezed more than the first/harder portion/part 31.

[0126] Particularly preferably, the intermediate layer / foam carrier 30 is compressed/squeezed by more than 5 % or 10 % and/or by less than 80 %, in particular less than 50 % or 25 % (based on the original thickness of the intermediate layer / foam carrier 30).

[0127] As already explained, the workpiece L is preferably a lens, in particular a spectacle lens.

[0128] Preferably, the workpiece L is round in a top view and/or designed as a (circular) cylinder.

[0129] In particular, the workpiece L has a workpiece axis A3, wherein the workpiece axis A3 forms a central axis and/or rotational axis of the workpiece L.

[0130] The workpiece L preferably has a larger diameter than the polishing tool 10 and/or the polishing foil 40, in particular by at least a factor of 1.2 or 1.5, particularly preferably by at least a factor of 2. However, it is also possible that the diameter of the workpiece L is at least substantially the same as the diameter of the polishing foil 40.

[0131] For the processing and/or the polishing process, the workpiece L is preferably fixed/attached to a workpiece carrier (not shown), in particular by means of a block piece (not shown).

[0132] Preferably, the workpiece L rotates during the processing and/or the polishing process and/or the workpiece carrier is rotatably driven, for example by means of an electric motor (not shown).

[0133] Preferably, the rotational speed of the polishing tool 10 and/or tool carrier 2 is greater than the rotational speed of the workpiece L and/or workpiece carrier, particularly preferably by at least a factor of 1.5 or 2. However, it is also possible that the rotational speed of the polishing tool 10 is at least substantially the same as the rotational speed of the workpiece L.

[0134] Preferably, the rotational speed of the polishing tool 10 and/or tool carrier 2 and/or workpiece L is more than 1000 min^{-1} or 1200 min^{-1} , in particular at least essentially 1500 min^{-1} or 2000 min^{-1} .

[0135] Preferably, the workpiece L rotates in the opposite direction to polishing tool 10, as indicated by the corresponding arrows in Fig. 4. However, a rotation of workpiece L and polishing tool 10 in the same direction is also possible.

[0136] A polishing process in the sense of the present invention means in particular the complete polishing of the processing surface LF to be polished of the workpiece L with the polishing tool 10.

[0137] Preferably, the duration of a (complete) polishing process is between 30 seconds and 120 seconds.

[0138] Particularly preferably, a plurality, in particular at least 100 or 150, of polishing processes can be carried out and/or of workpieces L can be processed with the polishing tool 10 before a change of the polishing tool 10 is necessary.

[0139] For the processing and/or the polishing process, the workpiece L and the polishing tool 10 are preferably (initially) aligned coaxially with each other and/or aligned with each other in such a way that the tool axis A2 corresponds to / coincides with / is the same as the workpiece axis A3 and/or that the polishing surface 41 is arranged directly opposite to and/or centrally on the processing surface LF of the workpiece L, as shown in Fig. 3A.

[0140] Then the polishing tool 10 and the workpiece L are pressed together, as shown in Fig. 3B.

[0141] During the (subsequent) processing and/or during the polishing process, the polishing tool 10 and the workpiece L are moved relative to each other - in particular radially and/or axially - in particular in order to process the entire processing surface LF of the (larger) work-

piece L with the (smaller) polishing tool 10.

[0142] Preferably, the polishing tool 10 and the workpiece L are moved radially relative to each other, in particular in such a way that the drive axis A1 and/or the tool axis A2 is (radially) offset and/or shifted and/or tilted relative to the workpiece axis A3.

[0143] The tool carrier 2 and thus the polishing tool 10 are preferably adjustable in an X-direction and/or along an X-axis, in particular by means of a slide (not shown) and an associated drive (not shown).

[0144] The X-axis is preferably designed as a controlled or feedback-controlled axis and/or as a CNC-axis or linear axis, so that precise positioning in the X-direction is made possible.

[0145] Preferably, the X-axis is transverse and/or perpendicular to the drive axis A1, the tool axis A2 and/or the workpiece axis A3.

[0146] It is further provided that the tool carrier 2 and thus the polishing tool 10 is pivotable about a swivel axis B, hereinafter referred to as B-axis, in particular about a swivel angle S, as shown in Fig. 3C.

[0147] The B-axis is preferably designed as a controlled or feedback-controlled swivel axis and/or CNC axis, also called rotary axis.

[0148] Preferably, the B-axis is transverse, in particular at least substantially perpendicular, to the X-axis, drive axis A1, tool axis A2 and/or workpiece axis A3, as indicated in Fig. 4.

[0149] By swiveling the polishing tool 10, it is possible to follow the curvature of the processing surface LF and/or to provide a large contact surface also in the edge area of the processing surface LF and thus a high removal rate.

[0150] In addition, by swiveling the polishing tool 10, the polishing force and/or polishing pressure is not or not significantly changed when the polishing tool 10 is guided/moved to the edge area of the processing surface LF.

[0151] It is thus preferable to move the (smaller) polishing tool 10 - in particular by shifting/moving it along the X-axis and/or swiveling it around the B axis - from the center to the edge of the (larger) workpiece L (or vice versa) in order to polish the entire processing surface LF, as indicated in Fig. 4.

[0152] As already explained, the polishing tool 10 and/or the polishing foil 40 can give way / yield in the radial direction and/or transverse to the drive axis A1, for example to allow adaptation to radii of curvature of the workpiece L that change in the circumferential direction, as in the case of toric lenses.

[0153] In Fig. 3D, the workpiece L is rotated by 90° about the workpiece axis A3 compared to Fig. 3C, the radius of curvature of the workpiece L in the sectional plane shown in Fig. 3D being smaller than that shown in Fig. 3C.

[0154] The smaller radius of curvature results in the polishing tool 10, in particular the intermediate layer 30, being more strongly compressed in the deflected and/or eccentric/off-center processing position at the edge of

workpiece L, in Fig. 3D on the right, than in the center of the workpiece L. This results in the workpiece axis A3 being tilted relative to the drive axis A1 and a center offset being created.

[0155] Due to the construction of the device 1 and/or the polishing tool 10 according to the invention and/or due to the rigid/stiff and/or joint-free construction of the device 1 and/or the polishing tool 10, it is possible to move the polishing tool 10 and/or the tool axis A2 up to or over the edge of the workpiece L without the polishing foil 40 lifting off the processing surface LF. On the contrary, known devices with a joint, such as a ball/spherical head, would tilt in a processing position in which the tool axis A2 is moved over the edge of the workpiece L in such a way that the polishing foil 40 would lose contact with the processing surface LF.

[0156] With the polishing tool 10 according to the invention, it is therefore possible to carry out surface polishing and/or polishing with a high removal rate even in the edge area of the workpiece L.

[0157] As can be seen from Figs. 1 and 2, a device 1 for polishing according to the invention has a tool carrier 2, in particular a polishing spindle, which is rigidly connected to the base 20 of the polishing tool 10 according to the invention, in particular by means of the coupling element 80, in particular by the coupling element 80 itself being rigid. The coupling element 80 thus has in particular no ball head which would contribute to an excessive center offset of the polishing tool 10 according to the invention. Rigid connections between a polishing tool 10 and a tool carrier 2 are known per se in the state of the art.

[0158] In an alternative embodiment (not shown), a device 1 for polishing according to the invention has a tool carrier 2, in particular a polishing spindle, which is elastically connected to the base 20 of the polishing tool 10 according to the invention by means of the coupling element 80, wherein the coupling element 80 is designed in the form of an elastic flexure bearing / elastic flexure joint. Such connections by means of elastic flexure bearings are known per se in the state of the art.

[0159] A basic idea according to the invention thus is to connect the polishing tool 10 according to the invention to the tool carrier 2, in particular a polishing spindle, joint-free / without a ball head. This at least reduces the center offset. In particular, the center offset can no longer be influenced by the tilting of a ball head.

[0160] A major contribution to this effect according to the invention is that the polishing tool 10 according to the invention in the vicinity of the coupling element 80 and/or the first portion/part 31 of the intermediate layer 30 is designed to be stiffer and/or harder and preferably also thicker than in the state of the art in order to be able to contribute to a reduction of the center offset.

[0161] Further aspects of the present invention which are realizable independently but also in combination with the aspects explained above are in particular:

1. Polishing tool, comprising:

a base (20),

an elastic intermediate layer (30), in particular a foam carrier, applied to the base (20),

a polishing foil (40) applied to the elastic intermediate layer (30),

wherein the elastic intermediate layer (30) has at least two portions (31, 32) of different hardness,

characterized

in that the portion (31) of the elastic intermediate layer (30) adjoining the base (20) is harder than the portion (32) of the elastic intermediate layer (30) adjoining the polishing foil (40).

2. Polishing tool according to aspect 1, characterized in that the harder portion (31) of the elastic intermediate layer (30) has a degree of deformation of 7 % to 75 % at a compressive load of 0.028 N/mm² to 1 N/mm².

3. Polishing tool according to aspect 1 or 2, characterized in that the ratio of the thickness (D1) of the harder portion (31) to the thickness (D2) of the softer portion (32) of the elastic intermediate layer (30) is 2:1 to 1:1, in particular 3:2 to 1:1.

4. Polishing tool according to one of the preceding aspects, characterized in that the harder portion (31) is made of a closed-cell foam.

5. Polishing tool according to aspect 4, characterized in that the harder portion (31) consists of a closed-cell polyetherurethane foam.

6. Polishing tool according to one of the preceding aspects, characterized in that the harder portion (31) has a compressive strength of up to 0.120 N/mm².

7. Polishing tool according to one of the preceding aspects, characterized in that the harder portion (31) has a static shear modulus of 0.07 N/mm² to 0.13 N/mm².

8. Polishing tool according to one of the preceding aspects, characterized in that the harder portion (31) has a dynamic shear modulus of 0.15 N/mm² to 0.18 N/mm².

9. Polishing tool according to one of the preceding aspects, characterized in that the harder portion (31) is adhered to the base (20) and/or the softer portion (32) is adhered to the polishing foil (40).

10. Device for polishing a workpiece, having a tool carrier, in particular a polishing spindle, which is connected by means of a coupling element to the base of a polishing tool (10) according to one of aspects 1 to 9, the coupling element (80) being either rigid or in the form of an elastic flexure bearing.

[0162] Individual aspects and features of the present invention can be realized independently of each other, but also in any combination.

List of reference signs

[0163]

1	Device
2	Tool Carrier
3	Support Surface
4	Sealing Ring
5	Supply Line
6	Pressure Line
10	Polishing Tool
20	Base
21	Base Part
22	Connecting Part
23	Head Part
24	Receiving Region
25	Base Part Surface
26	Magnet
27	Front Surface
30	Intermediate Layer / Foam Carrier
31	First / Harder Portion / Part
32	Second / Softer Portion / Part
40	Polishing Foil
41	Polishing Surface
50	Adhesive Seam between Base and Intermediate Layer
60	Adhesive Seam between First and Second Portion/Part
70	Adhesive Seam between Intermediate Layer and Polishing Foil
80	Coupling Element / Pin
A1	Drive Axis
A2	Tool Axis
A3	Workpiece Axis
B	Swivel Axis
D1	Thickness of the First/Harder Portion/Part
D2	Thickness of the Second/Softer Portion/Part
D3	Thickness of the Polishing Foil
L	Workpiece
LF	Processing Surface
S	Swivel Angle
X	Linear Axis

Claims

1. Polishing tool (10), comprising:

5 a base (20),
an elastic intermediate layer (30), in particular a foam carrier, applied to the base (20),
a polishing foil (40) applied to the intermediate layer (30),
10 wherein the intermediate layer (30) has at least two portions/parts (31, 32) of different hardness and/or stiffness,
characterized,
15 **in that** a first portion/part (31) of the intermediate layer (30) adjoining the base (20) is harder and/or stiffer than a second portion/part (32) of the intermediate layer (30) adjoining the polishing foil (40).

20 **2.** Polishing tool according to claim 1, **characterized in that** the modulus of elasticity of the harder/first portion/part (31) is greater than the modulus of elasticity of the softer/second portion/part (32).

25 **3.** Polishing tool according to claim 1 or 2, **characterized in that** the modulus of elasticity of the first/harder portion/part (31) is more than 0.4 N/mm² and/or less than 2 N/mm² and/or the modulus of elasticity of the second/softer portion/part (32) is more than 0.05 N/mm² and/or less than 1 N/mm².

30 **4.** Polishing tool according to one of the preceding claims, **characterized in that** the first/harder portion/part (31) is thicker than the second/softer part (32), preferably at least twice as thick, and/or **in that** the ratio of the thickness (D1) of the harder/first portion/part (31) to the thickness (D2) of the softer/second portion/part (32) of the intermediate layer (30) is at least 3:2, preferably 2:1, and/or at most 1:2, preferably 2:3.

35 **5.** Polishing tool according to one of the preceding claims, **characterized in that** the first/harder portion/part (31) consists and/or is made of a closed-cell foam, in particular polyetherurethane foam.

40 **6.** Polishing tool according to one of the preceding claims, **characterized in that** the second/softer portion/part (32) consists and/or is made of an open-, mixed- or closed-cell foam, in particular polyetherurethane foam.

45 **7.** Polishing tool according to one of the preceding claims, **characterized in that** the base (20) has a curved front surface (27), the radius of curvature of the front surface (27) being at least 50 mm and/or at most 1000 mm.

8. Polishing tool according to one of the preceding claims, **characterized in that** the first/harder portion/part (31) is adhered - in particular directly - to the base (20), in particular the front surface (27) of the base (20), and/or the second/softer portion/part (32) is adhered - in particular directly - to the polishing foil (40). 5
9. Polishing tool according to one of the preceding claims, **characterized in that** the second/softer portion/part (32) has one or more recesses. 10
10. Device (1) for polishing a workpiece (L), having a rotatably driven tool carrier (2), in particular a polishing spindle, and a polishing tool (10), 15
wherein the polishing tool (10) is replaceably attached to the tool carrier (2), and
wherein the polishing tool (10) is formed according to one of the preceding claims. 20
11. Device according to claim 10, wherein the tool carrier (2) is either rigid and/or joint-free or has an elastic flexure bearing. 25

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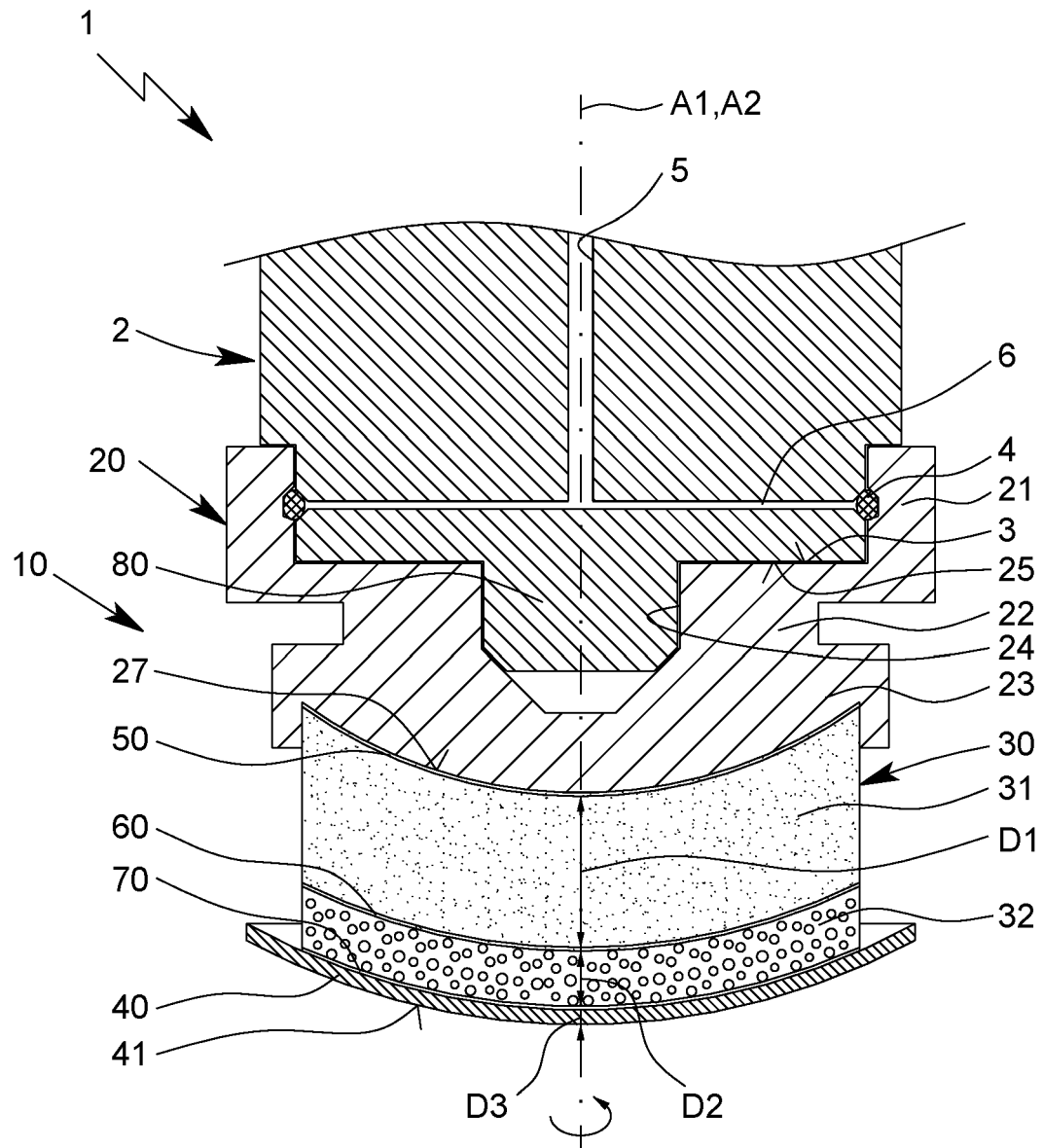


Fig. 1

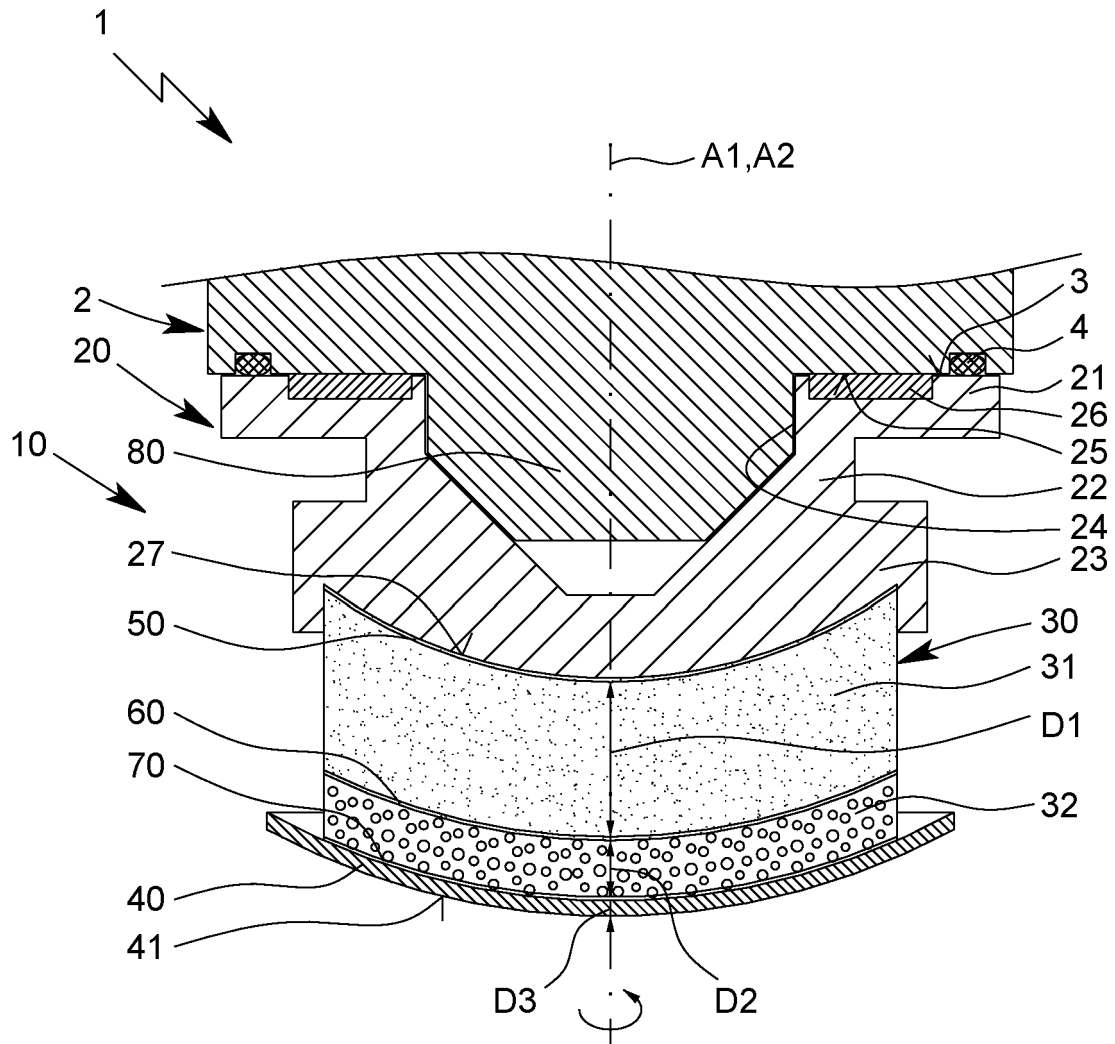


Fig. 2

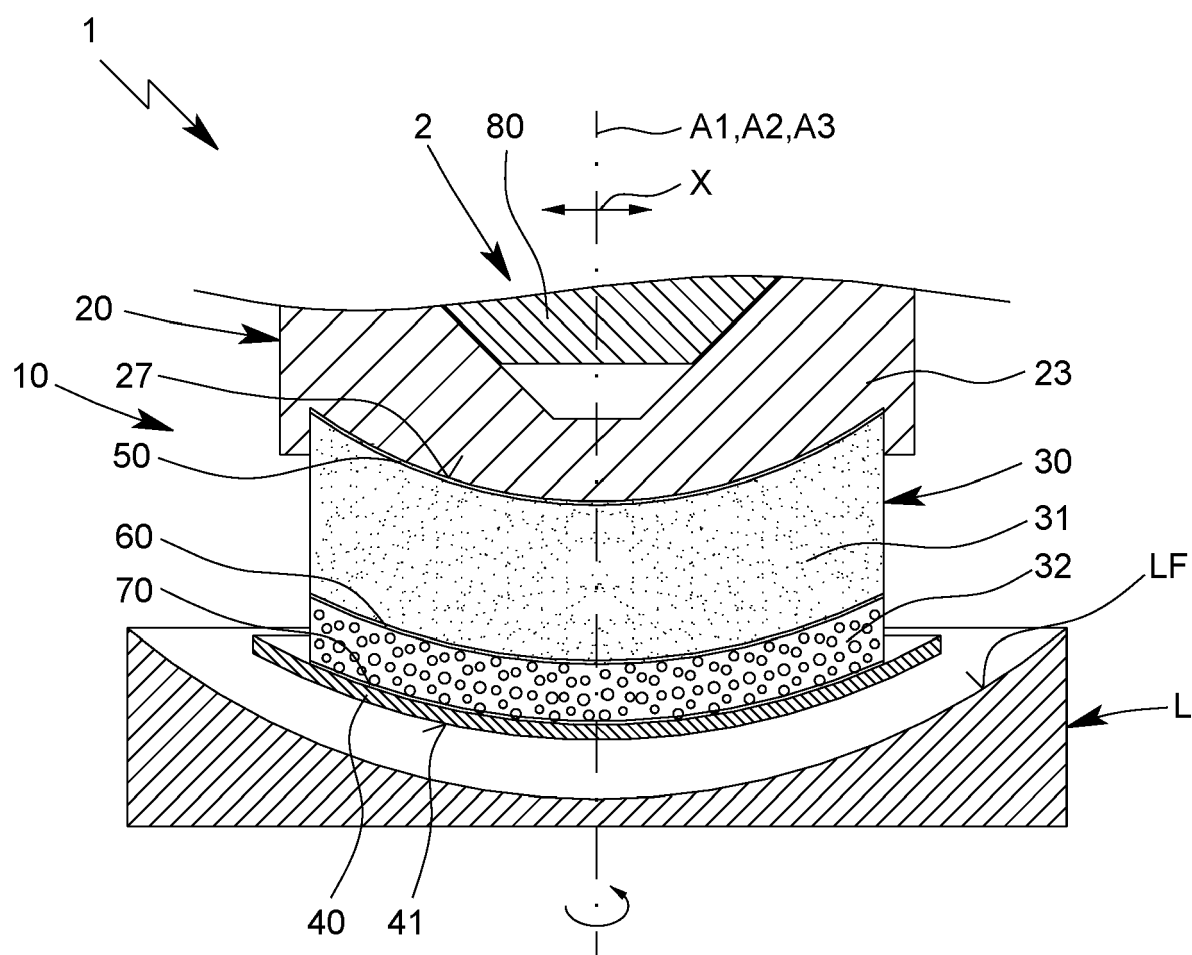


Fig. 3A

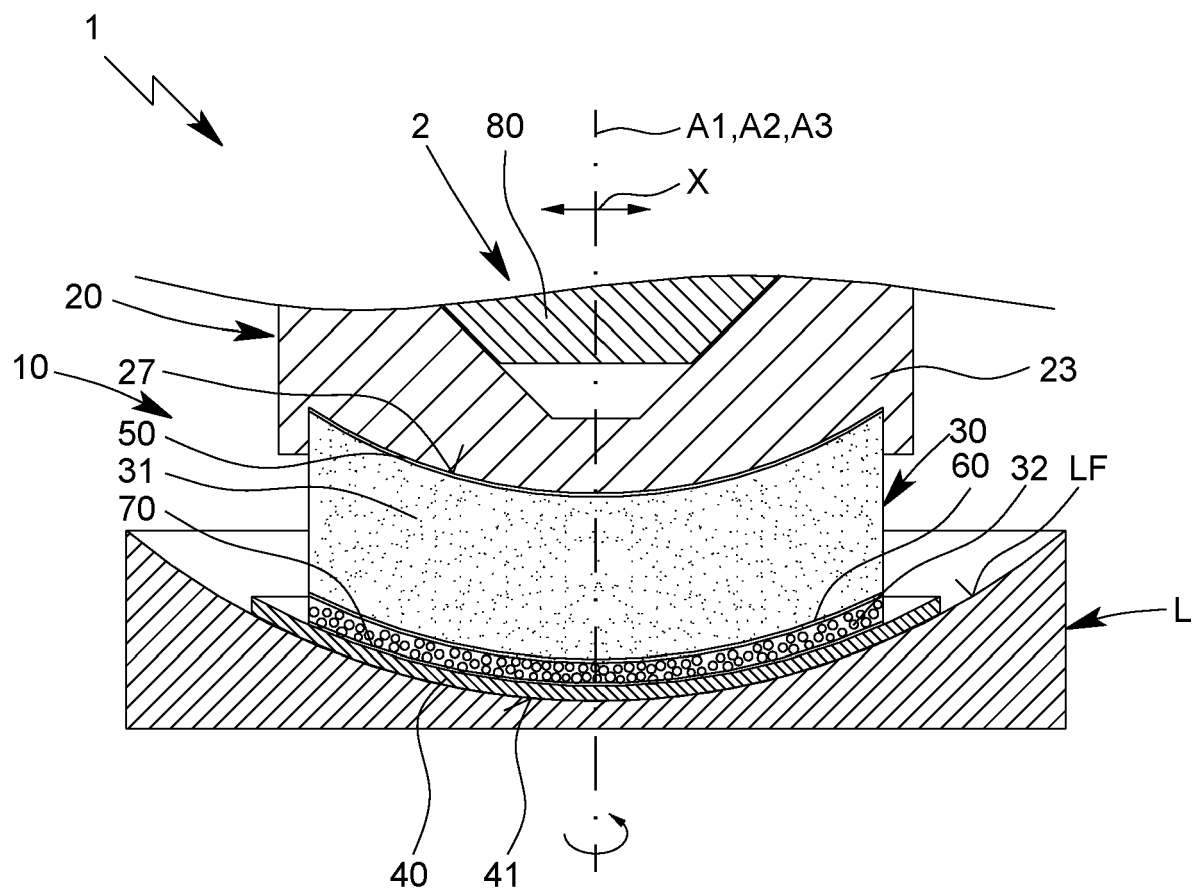


Fig. 3B

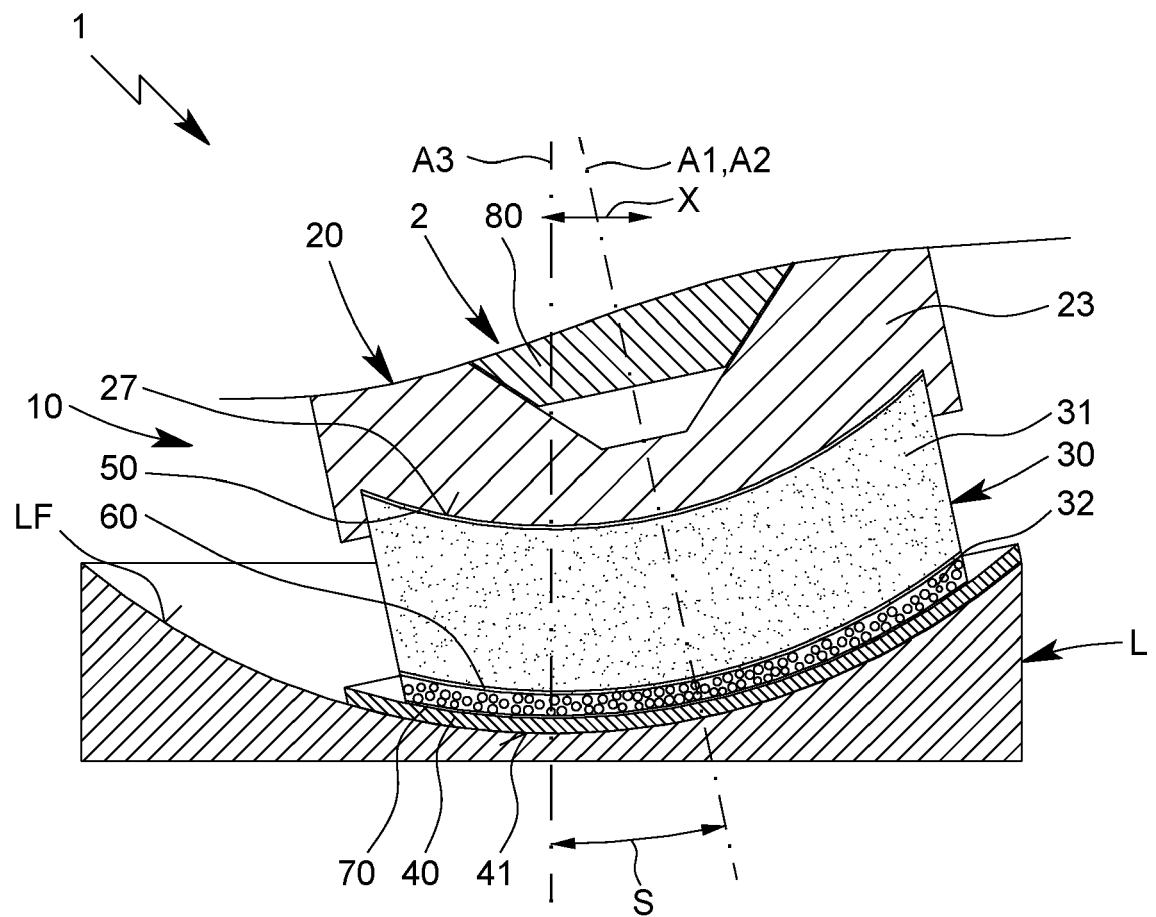


Fig. 3C

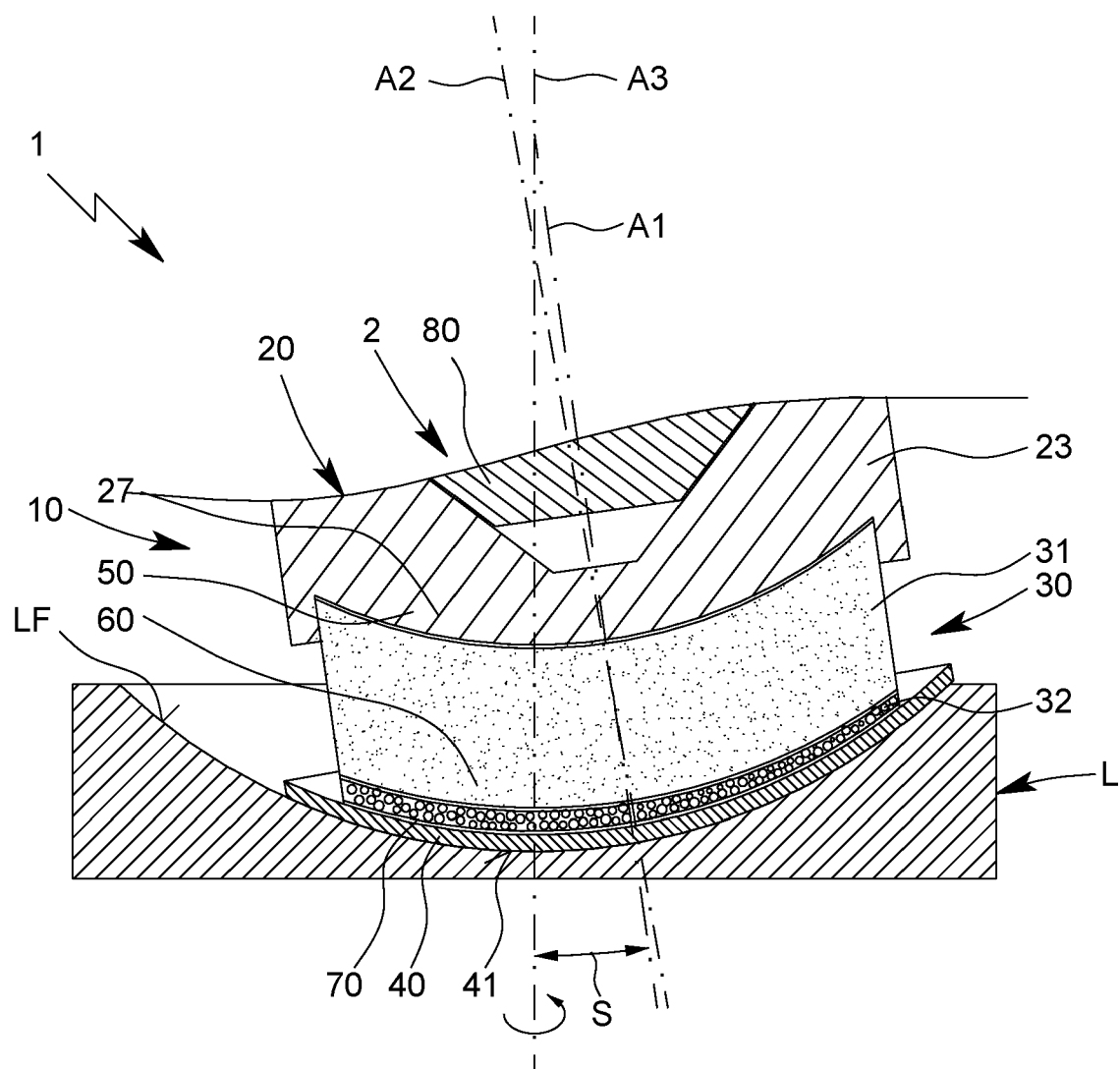


Fig. 3D

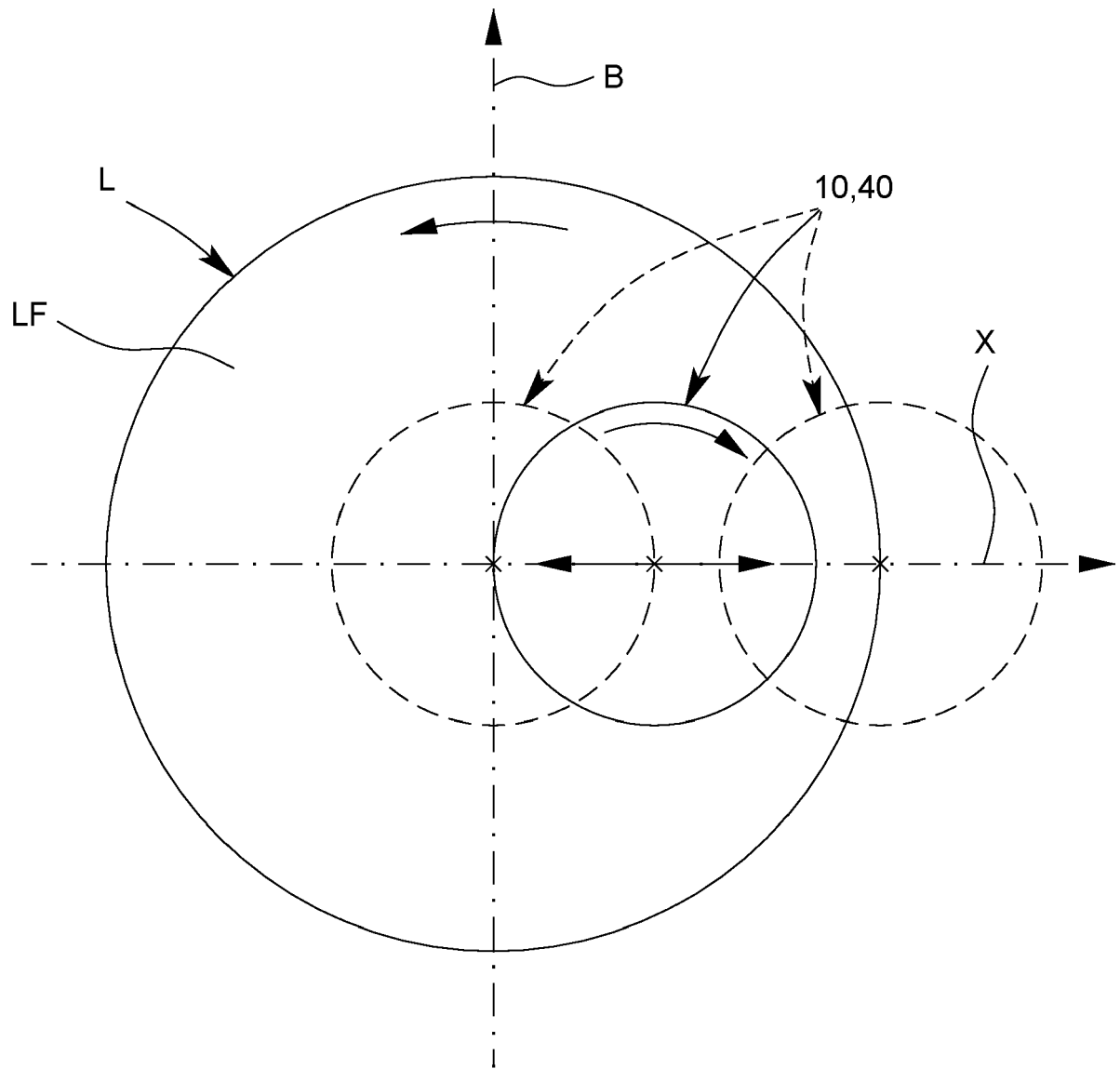


Fig. 4



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Place of search Munich		Date of completion of the search 23 November 2020	Examiner Herrero Ramos, J
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