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(54) Benævnelse: **STEMPELRING TIL EN STEMPELKOMPRESSOR SÅVEL SOM STEMPELKOMPRESSOR**

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PISTON RING FOR A PISTON COMPRESSOR AND PISTON COMPRESSOR

Description

The invention relates to a piston ring for a piston compressor according to the preamble of claim 1. The invention also relates to a piston compressor.

Prior art

Piston compressors comprising a cylinder and a piston linearly movable therein are known. In one possible embodiment, a piston ring is arranged on the piston, wherein the piston ring slides along the cylinder wall so that the piston ring seals the compression space delimited by the cylinder and the movable piston. WO 98/55783A1 discloses a dry-running piston compressor having a piston ring arranged on the piston and rubbing against the cylinder wall. This dry-running piston compressor is well suited, for example, for compressing hydrogen to a final pressure of up to 200 bar. However, there is an increasing need to compress fluids to even higher final pressures. The known piston ring, however, is only suitable to a limited extent for use at high pressure differences, since it exhibits pronounced cold flow under load, which results in rapid wear of the piston ring. The known piston ring is therefore only suitable to a limited degree for compressors with a high final pressure of over 200 bar.

Description of the invention

The object of the invention is to design a piston ring and a piston compressor having more advantageous operating properties.

This object is achieved with a piston ring having the features of claim 1. The dependent claims 2 to 8 relate to further, advantageous embodiments of the invention. The object is further achieved with a piston compressor having the features of claim 9. Dependent claims 10 to 12 relate to further advantageous embodiments. The object is further achieved with a use of the piston ring according to the invention in a piston compressor for compressing a fluid to a pressure of more than 500 bar.

The object is achieved in particular with a piston ring comprising an endless base ring and a sealing ring, wherein the base ring has a radially outwardly directed base ring face, and wherein the sealing ring has a radially outwardly directed sealing face and a radially inwardly directed, circular sealing ring inner side, wherein the sealing ring has three tangential cuts, which extend tangentially with respect to the sealing ring inner side, with the result that the sealing ring comprises three sealing ring segments, which are arranged in succession in a circumferential direction and which are separated by the tangential cut, wherein the endless base ring and the sealing ring are arranged in succession in a longitudinal direction perpendicular to the circumferential direction, wherein a top ring is arranged so as to adjoin the sealing ring in the longitudinal direction, wherein the top ring has a radially outwardly directed top ring outer side and a radially inwardly directed top ring inner side,

wherein the top ring has, on the side facing away from the sealing ring, at least one radially extending return flow channel, which extends in the radial direction along the entire width of the top ring, wherein the sealing face protrudes in the radial direction beyond the top ring outer side and the base ring face, and wherein the base ring and the top ring have a higher tensile strength than the sealing ring.

In a preferred embodiment, the tensile strength of the base ring and of the top ring is at least 1.5 times higher than the tensile strength of the sealing ring.

The piston ring according to the invention is designed as a so-called sandwich piston ring and comprises a sealing ring as well as support rings arranged on both sides in the axial direction, namely the base ring and the top ring, which rest on the sealing ring, wherein the support rings are preferably planar. In comparison to the base and top ring, the sealing ring consists of a softer material with preferably good conformability, in particular good conformability in the radial direction. The sealing ring thus has a lower tensile strength compared to the base and top ring. In the axial direction, the piston ring encompasses the base ring on one side and the top ring on the other side, wherein the base ring and the top ring form the two support rings so that the sealing ring rests on each side against one of the named rings and is held by them. The base ring and preferably also the top ring are designed to be endless and consist of a relatively solid material, that is to say a material with a higher tensile strength than the sealing ring. The sealing ring made of a relatively soft material or a material with lower tensile strength is held well and securely between the base ring and the top ring and has a good conformability in the radial direction, so that it lies tightly against the inner wall of the piston and thus prevents or reduces any leakage that may occur.

In the piston ring according to the invention, the sealing ring is designed as a friction sealing element in that the sealing ring slides along the inner wall of the cylinder, wherein the piston ring can be operated in a dry-running or lubricated manner. The piston ring according to the invention is preferably suitable in combination with piston compressors whose compression chamber has a high pressure load of preferably more than 500 bar and/or a high temperature load.

The sealing ring particularly preferably has a narrow structural height in the axial direction, preferably a structural height in the range from 1 to 6 mm. The piston ring according to the invention is mounted in the piston compressor in such a way that both the base ring and the top ring, at least in the cold state, have a small gap between the radially outwardly directed side and the inside of the cylinder, for example a gap of a few tenths of a millimeter to a few hundredths of a millimeter. The sealing ring, on the other hand, projects in the radial direction over the base ring and the top ring and touches the inside of the cylinder. In an advantageous embodiment, the base ring and the top ring do not come into contact with the inside of the cylinder during operation and thus do not form any friction rings. In this embodiment, both the base ring and the top ring do not have to have any dry-running properties.

In contrast to the base ring, which is arranged on the side facing away from the compression chamber, the top ring also has at least one return flow groove on the side facing the compression chamber, which enables the pressure to be reduced in the compression chamber during the return expansion. The base ring and the top ring, which are arranged on both sides of the sealing ring, thus prevent the sealing ring on both sides from being destroyed by the dynamically acting compressive forces acting in both directions of the direction of movement of the piston. The return expansion comes about as described below. The leakages between the individual sealing elements of a sealing system also result in pressure differences in the direction of the compression chamber when exposed to a pressure curve that changes over time. During the compression phase, the pressure in the sealing element chambers immediately following the compression chamber rises to values above the suction pressure level and can – depending on the state of wear of the sealing elements – almost reach the final compression pressure. If the pressure in the cylinder then falls again in the direction of the suction pressure during the expansion phase, the pressure is relieved back into the compression chamber, i.e. the direction of load on the sealing elements near the compression chamber is reversed.

The piston ring according to the invention thus has the advantage that the sealing ring cut by tangential cuts is supported on the one hand by the base ring during the compression process and is supported by the top ring during the expansion process, so that the cut sealing ring is protected both during the compression process and in particular during the expansion process from aggressive forces and thus from damage.

The sandwich design of the piston ring according to the invention makes it possible to design the sealing ring from a plastics material which intrinsically in a “self-supporting” embodiment, i.e. without support rings, would not be suitable for sealing high pressure differences. The piston ring according to the invention can be operated in a dry-running or oil-lubricated manner, depending on its configuration. In the case of a dry-running piston ring, at least the sealing ring must have dry-running properties. If the base and/or top ring also slide along the inner wall of the cylinder during operation, these support rings should also have dry-running properties. The sealing ring is preferably formed from a PTFE material or a polymer blend, with high-temperature polymers also being used in the case of very high pressure differences. Dry-running sealing rings are also filled with an inorganic filler such as carbon, graphite, glass fibres, MoS2 or bronze. The base and top ring are advantageously made of high-temperature polymer, fibre composite material and, in the case of very high pressure differences, of metal, such as bronze.

Below are examples of material combinations of the base ring, sealing ring and top ring. As already mentioned, a prerequisite is that the base ring and the top ring have a higher tensile strength than the sealing ring. Depending on the final pressure to be achieved, the following material combinations could, for example, be suitable, with details relating to the materials used being given in connection with the table:

	Piston ring 1	**Piston ring 2**	**Piston ring 3**	**Piston ring 4**
Top ring	High-temperature polymer	High-temperature polymer	Fibre composite material	Copper alloy (bronze)
Sealing ring	mod PTFE or filled PTFE	Polymer blend	High-temperature polymer	High-temperature polymer
Base ring	High-temperature polymer	High-temperature polymer	Fibre composite material	Copper alloy (bronze)

Table 1, examples of material combinations for the piston rings

Below are details of the materials used in Table 1, the filled materials specified below being required in particular for dry-running rings.

Pure or filled PEEK, pure or filled polyimide, pure or filled PPS, or pure or filled epoxy, for example, are suitable as **high-temperature polymers**.

As **PTFE,** a modified PTFE, also referred to as “mod PTFE”, or a filled PTFE filled with inorganic fillers such as carbon, graphite, glass fibres, MoS2 and/or bronze for example, is suitable.

As the **polymer blend,** a mixture of at least two organic plastics such as PTFE, PEEK, PPS is suitable, wherein the polymer blend can also be filled with an inorganic filler such as carbon, graphite, glass fibres, MoS_2 and/or bronze.

Carbon fibres in a matrix of, for example, PEEK or epoxy are suitable as **fibre composite material**.

Bronze materials such as aluminium, lead or tin bronze and a material such as brass are suitable as **copper alloy**.

A plastic that is very suitable for the sealing ring is polytetrafluoroethylene (PTFE), to which mostly inorganic fillers such as carbon, graphite, glass fibres, etc. are added to improve its physical, mechanical and/or tribological properties, in particular to impart dry-running properties. Despite these fillers, the use of previously known sealing rings made of PTFE was limited to low pressure differentials due to the pronounced cold flow tendency of PTFE. The piston ring according to the invention has the advantage that a sealing ring consisting of PTFE can be operated reliably even at higher pressure differences. This is explained using the following example of a dry-running "piston ring 1".

The exemplary piston ring 1 comprises a sealing ring made of filled PTFE, the PTFE being filled with carbon or graphite. Such a sealing ring has a tensile strength of 10MPa at a temperature of 20°C. The base and top ring are made of filled PEEK. Such a base or top ring has a tensile strength of 18MPa at a temperature of 250°C. In this embodiment, the piston ring according to the invention can be operated in dry run mode at 250°C without any problems, although the sealing ring has an extremely low tensile strength at this temperature, since the sealing ring is held in the axial direction between the support rings, i.e. between the base and top ring, and it is not possible for the sealing ring to escape in the radial direction, since it rests against the inner wall of the cylinder in the radial direction. The distance between the base or top ring and the inner wall of the cylinder is preferably a few tenths to a few hundredths of a millimeter.

The exemplary "piston ring 1" can also be used in an oil-lubricated piston compressor to seal the compression chamber. The sealing ring could, for example, consist of modified PTFE and the base and top ring, for example, of pure PEEK. The base and top ring could, for example, also consist of a filled PEEK, the PEEK being filled with carbon fibres (10% by weight), PTFE (10% by weight) and graphite (10% by weight).

For a piston with high pressure and/or temperature load, as shown using the example with "piston ring 3" and "piston ring 4" above, a piston ring comprising a sealing ring consisting of a high-temperature polymer such as polyether ether ketone (PEEK) or polyimide (PI) and comprising a top and base ring consisting of a fibre composite material such as carbon fibres in a matrix of PEEK or carbon fibres in a matrix of epoxy could be used.

Especially with oil-lubricated piston compressors, pressure differences can also assume very high values of over 1000 bar, so that, as shown above with “piston ring 4”, piston rings comprising a base and top ring made of a one-piece metal ring can also be used, especially in such piston compressors.
The invention will be further described in detail hereinafter by means of exemplary embodiments.

Brief description of the drawings

The drawings used to explain the exemplary embodiments show the following:

Fig. 1 shows a longitudinal section of a sealing arrangement arranged on a piston;
Fig. 2 shows a plan view of a top ring;
Fig. 3 shows a plan view of a sealing ring with a clamping ring;
Fig. 4 shows a plan view of a base ring;
Fig. 5 shows a longitudinal section through a second exemplary embodiment of a sealing arrangement;
Fig. 6 shows a side view of a piston with a plurality of sealing arrangements;
Fig. 7 shows a longitudinal section through a third exemplary embodiment of a sealing arrangement;
Fig. 8 shows a plan view of a top ring.

In principle, the same parts are provided with the same reference signs in the drawings.

Embodiments of the invention

Fig. 1 shows a longitudinal section through a piston compressor comprising a cylinder 10, a piston 12 and at least one piston ring 1 arranged in the piston 12. The piston 12 is designed as its constructed piston and comprises a plurality of piston bodies 11 arranged successively in a longitudinal direction L, wherein each piston body 11 has a chamber disk 11a which forms an interior space 11b. A piston ring 1 is arranged in the interior 11b.
In Figure 1, the compression chamber 13 of the piston compressor is arranged above, and the crankcase or the low-pressure part 14 is arranged below. The piston ring 1 comprises a sealing ring 3, a clamping ring 4, a top ring 2 and a base ring 5. The piston ring 1 is spaced apart in the radial direction to the longitudinal axis L with the formation of an inner gap 8 with respect to the chamber disk 11a. The inner gap 8 is connected in a fluid-conducting manner via a radial return flow channel 2a and the outer gap 6 arranged at the top is connected to a space that is not visible in the view shown above.
Figure 2 shows a plan view of the top ring 2 from the direction from the compression

chamber 13. The top ring 2 comprises a radially outwardly directed top ring outer side 2c and a circular, radially inwardly directed top ring inner side 2d. The top ring 2 is designed as an endless ring and comprises a plurality of radial return flow channels 2a that are distributed in the circumferential direction and run in the radial direction along the entire width of the top ring 2.

Figure 3 shows a plan view of the sealing ring 3 from the direction from the compression chamber 13. The sealing ring 3 has a radially outwardly directed sealing face 3e and a radially inwardly directed, circular sealing ring inner side 3f, wherein the sealing ring 3 has three tangential cuts 3d, which extend tangentially with respect to the sealing ring inner side 3f, with the result that the sealing ring 3 comprises three sealing ring segments 3a, 3b, 3c arranged in succession in a circumferential direction U and separated by the tangential cut 3d. A clamping ring 4 having a clamping ring gap 4a is advantageously arranged adjacent to the sealing ring inner side 3f. The clamping ring 4 resting along the inside of the sealing ring 3f causes a radially outwardly directed force on the sealing ring inner side 3f. The clamping ring 4 could also be dispensed with, in which case a fluid located in the interior 11b could cause a radially outwardly directed force on the sealing ring inner side 3f.

Figure 4 shows a plan view of the base ring 5, which has a radially outwardly directed base ring face 5a.

The endless base ring 5 and the sealing ring 3 are arranged in succession in a longitudinal direction L perpendicular to the circumferential direction U, wherein the endless top ring 2 is arranged adjacent to the sealing ring 3 in the longitudinal direction L, so that, as shown in Figure. 1, a piston ring 1 is formed which comprises the base ring 5, sealing ring 3 and top ring 2.

In the new state, i.e. before the sealing ring 3 is retracted for a certain period of time, the sealing ring 3 is designed in such a way that its sealing face 3e protrudes in the radial direction beyond the top ring outer side 2c and the base ring face 5a, as shown in Figure 1. So that the supporting and protective effect of top ring 2 and base ring 5 is as great as possible for the sealing ring 3, the play between top ring 2 and/or base ring 5 and the inner wall of the cylinder 10 or cylinder bore 10a is preferably kept to a minimum. In the exemplary embodiment shown in Figure 1, the outside diameter of at least the top ring 2 and/or the base ring 5 is only a few hundredths of a millimeter or a few tenths of a millimeter smaller than the inside diameter of the cylinder bore 10a. Due to the heating of the piston ring 1 during operation, it experiences thermal expansion. In an advantageous embodiment, the outside diameter of the top ring 2 and/or the base ring 5 increases to a diameter equal to or larger than the cylinder bore. If the outside diameter of the base ring 5 and/or top ring 2 were to grow to a diameter larger than the cylinder bore, this has the consequence that the top ring 2 and/or the base ring 5 are in contact with the inner wall of the cylinder 10a during a running-in phase, and material is removed from the top ring 2 and/or from the base ring 5 on the outside end face, so that the top ring 2 and/or the base ring 5 fit “without clearance” into the bore of the cylinder 10 in the warm operating state. So that the top ring 2 and/or base ring 5 does not jam during this running-in process, the end faces aligned with the inner wall of the cylinder 10 are preferably at least partially widened, preferably conically widened, so that the entire width of the top ring 2 and/or the base ring 5 does not have to be removed, but only the area which would otherwise protrude beyond the inner wall of the cylinder 10. During the running-in phase, material is also removed from the sealing ring 3 at its sealing face 3e, so that in a preferred embodiment and in the heated state, the sealing ring 3, the top ring 2 and the base ring 5 are arranged in the bore of the cylinder 10 without clearance.

However, as shown in Figure 5, it is also possible to dispense with a conical configuration of the top ring outer side 2c and/or of the base ring face 5a. Figure 5 shows a piston ring 1 in the run-in state and during operation, that is to say in the heated state. The top ring 2 and the base ring 5 have adapted to the inner wall of the cylinder 10a in such a way that they move back and forth in the direction of the longitudinal axis L without clearance in the warm operating state. In addition, the sealing ring 3 is adapted in such a way that it is displaceable outwardly in the radial direction or is arranged between the top ring 2 and the base ring 5 with a pretensioning force substantially determined by the clamping ring 4, and rests against the inner wall of the cylinder 10a by means of friction.

Figure 6 shows a side view of an exemplary embodiment of a piston 12 which, starting from the high-pressure side 13, has a plurality of sealing elements spaced from one another in the longitudinal direction L, namely four captive piston rings 15 on the left and then five piston rings 1 in the longitudinal direction L. In addition, a guide ring 15 is arranged on the right.

Figure 7 shows a longitudinal section of a third exemplary embodiment of a sealing arrangement 1. Figure 8 shows a plan view of the top ring 2 used in Figure 7. In contrast to the exemplary embodiment according to Figures 1 and 2, the top ring 2 has a radial cut 2e, and thus has a joint or a gap at this point. The top ring 2 is therefore no longer designed as an endless top ring 2 but as a cut top ring 2. In addition, in contrast to the exemplary embodiment according to Figures 1 and 2, the top ring 2 has an L-shaped cross section, with a first leg 2f extending radially to the longitudinal axis L and a second leg 2g extending in the direction of the longitudinal axis L. The sealing element 3 is arranged in the radial direction in front of the second leg 2g, the second leg 2g preferably resting against the sealing ring inner side 3f of the sealing element 3. The second leg 2g, which is arranged behind the sealing element 3 in the radial direction, also has the properties of a clamping ring or a spring, and thus assumes the function of a clamping ring or a spring. The force acting outwardly in the radial direction on the sealing element 3 is generated by spring properties of the top ring 2 and/or by the internal pressure acting on the top ring 2 in the inner gap 8. The top ring 2, which has a radial cut 2e, has particularly pronounced properties of a friction ring due to the radial cut 2e, the top ring 2 simultaneously causing a force acting outwardly in the radial direction on the sealing element 3 via the second leg 2g, so that a separate clamping ring 4, as shown in Figures 1 and 5, can be omitted.

STEMPELRING TIL EN STEMPELKOMPRESSOR SÅVEL SOM STEMPELKOMPRESSOR

PATENTKRAV

1. Stempelring, der omfatter en endeløs grundring (5) såvel som en tætningsring (3), hvor grundringen (5) har en grundringsforside (5a), der vender radialt udad, og hvor tætningsringen (3) har en tætningsringsforside (3e), der vender radialt udad, og en tætningsringsinderside (3f), der vender radialt indad og forløber i cirkelform,
hvor den endeløse grundring (5) og tætningsringen (3) er placeret følgende efter hinanden i en længderetning (L), der forløber vinkelret på omkredsretningen (U),
kendetegnet ved, at tætningsringen (3) har tre tangentielle snit (3d), der strækker sig tangentielt i forhold til tætningsringsindersiden (3f), således at tætningsringen (3) omfatter tre tætningsringssegmenter (3a, 3b, 3c), der er placeret følgende efter hinanden i en omkredsretning (U) og er adskilt af det tangentielle snit (3d),
at der i længderetningen (L) er placeret en dækring (2), der slutter sig til tætningsringen (3), at dækringen (2) har en dækringsyderside (2c), der vender radialt udad, og en dækringsinderside (2d), der vender radialt indad,
at dækringen (2) på den side, der vender væk fra tætningsringen (3), indeholder i det mindste én radialt forløbende returstrømskanal (2a), der strækker sig i radial retning langs hele dækringens (2) bredde,
at tætningsforsiden (3e) rager ud over dækringsydersiden (2c) og grundringsforsiden (5a) i radial retning,
og at grundringen (5) såvel som dækringen (2) har en højere trækstyrke end tætningsringen (3).

2. Stempelring ifølge krav 1, kendetegnet ved, at dækringen (2) er udformet som endeløs dækring (2).

3. Stempelring ifølge krav 1 eller 2, kendetegnet ved, at en spændering (4) ligger op til tætningsringsindersiden (3f), og at spænderingen (4) udøver en kraft, der er rettet radialt udad, på tætningsringens inderside (3f).

4. Stempelring ifølge krav 1, kendetegnet ved, at dækringen (2) har et radialt snit (2e), at dækringen (2) har et L-formet tværsnit med et første ben (2f), der forløber

radialt i forhold til længdeaksen (L), og et andet ben (2g), der forløber i længdeaksens (L) retning, hvor tætningsringsindersiden (3f) på tætningsringen (3) er orienteret mod det andet ben (2g).

5. Stempelring ifølge et af de foregående krav, kendetegnet ved, at grundringens (5) og dækringens (2) trækstyrke er mindst 1,5 gange større end tætningsringens (3) trækstyrke.

6. Stempelring ifølge et af de foregående krav, kendetegnet ved, at tætningsringen (3) i længderetningen (L) har en højde inden for området 1 til 6 mm.

7. Stempelring ifølge et af de foregående krav, kendetegnet ved, at grundringsforsiden (5a) og/eller dækringsydersiden (2c) med udgangspunkt i tætningsringen (3) tilspidses i aksial retning (L).

8. Stempelring ifølge krav 7, kendetegnet ved, at grundringsforsiden (5a) og/eller dækringsydersiden (2c) tilspidses konisk i aksial retning (L).

9. Stempelkompressor, der omfatter en stempelring (1) ifølge et af de foregående krav.

10. Stempelkompressor ifølge krav 9, der omfatter et stempel (12) såvel som en cylinder (10) med en cylinderboring (10a), kendetegnet ved, at grundringen (5) og/eller dækringen (2) har en udvendig diameter, der er mindre end en tiendedel millimeter og fortrinsvis kun få hundreddele af en millimeter mindre end den indvendige diameter af cylinderboringen (10a).

11. Stempelkompressor ifølge krav 10, kendetegnet ved, at grundringen (5) og/eller dækringen (2) i kold tilstand har en sådan udvendig diameter, at grundringen (5) og/eller dækringen (2) i den opvarmede tilstand er placeret uden slør i cylinderen (10).

12. Stempelkompressor ifølge et af kravene 9 til 11, der omfatter et stempel (12) med et stempellegeme (11) og en flerhed af stempelringe (1), hvor stempellegemet (11) indeholder en flerhed af omkredsnoter (11b), som er placeret følgende efter hinanden i aksial retning (L), og i hvilke der i hvert enkelt tilfælde er placeret én stempelring (1), hvor

omkredsnotens (11b) samlede aksiale bredde er større end stempelringens (1) samlede aksiale bredde, og hvor stempelringen (1) på siden, der vender radialt indad, er placeret med en radial afstand i forhold til stempellegemet (11).

13. Anvendelse af stempelringen ifølge et af kravene 1 til 8 til komprimering af et fluid til et tryk på mellem 500 bar og 1000 bar.

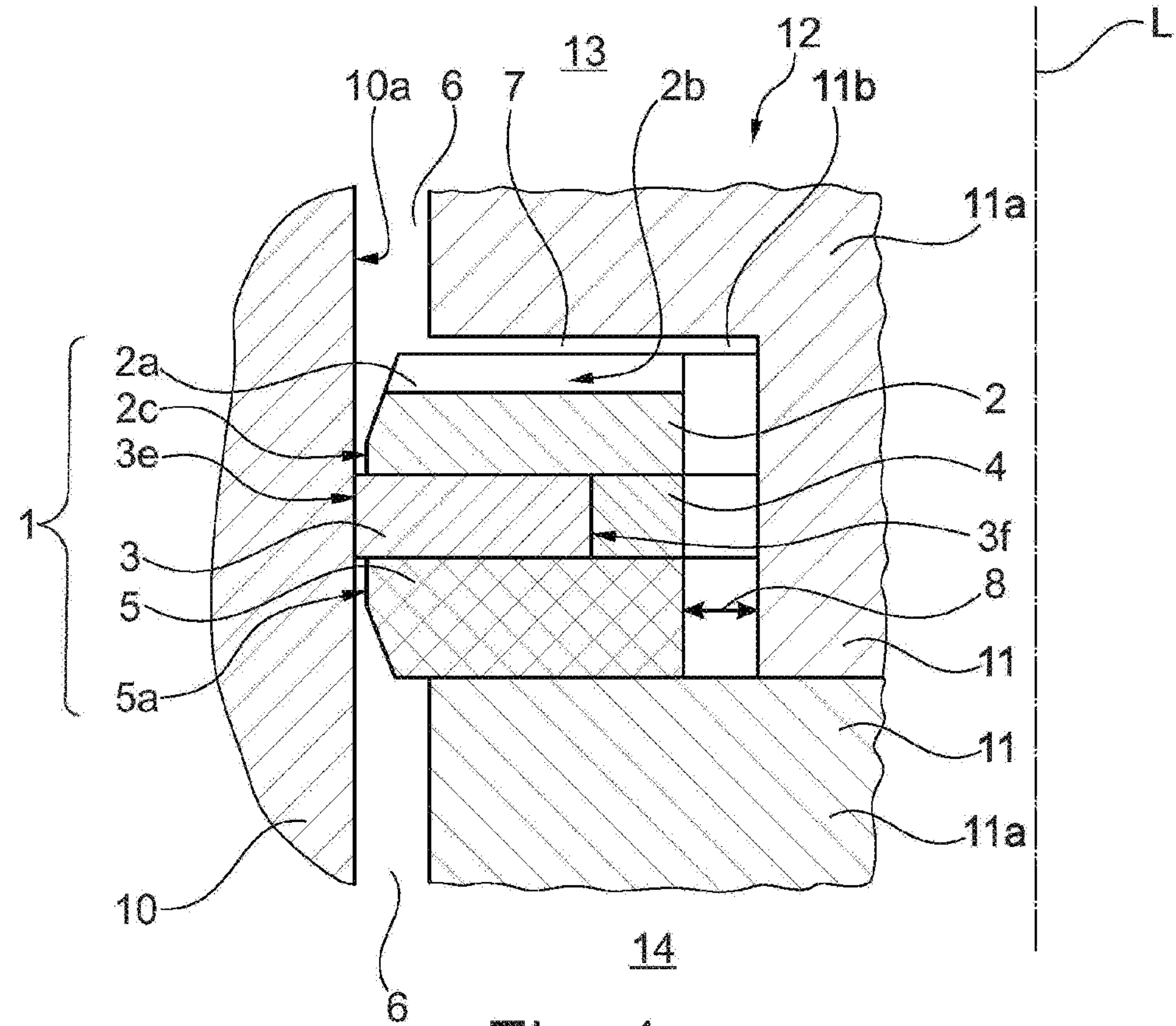
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Fig. 1

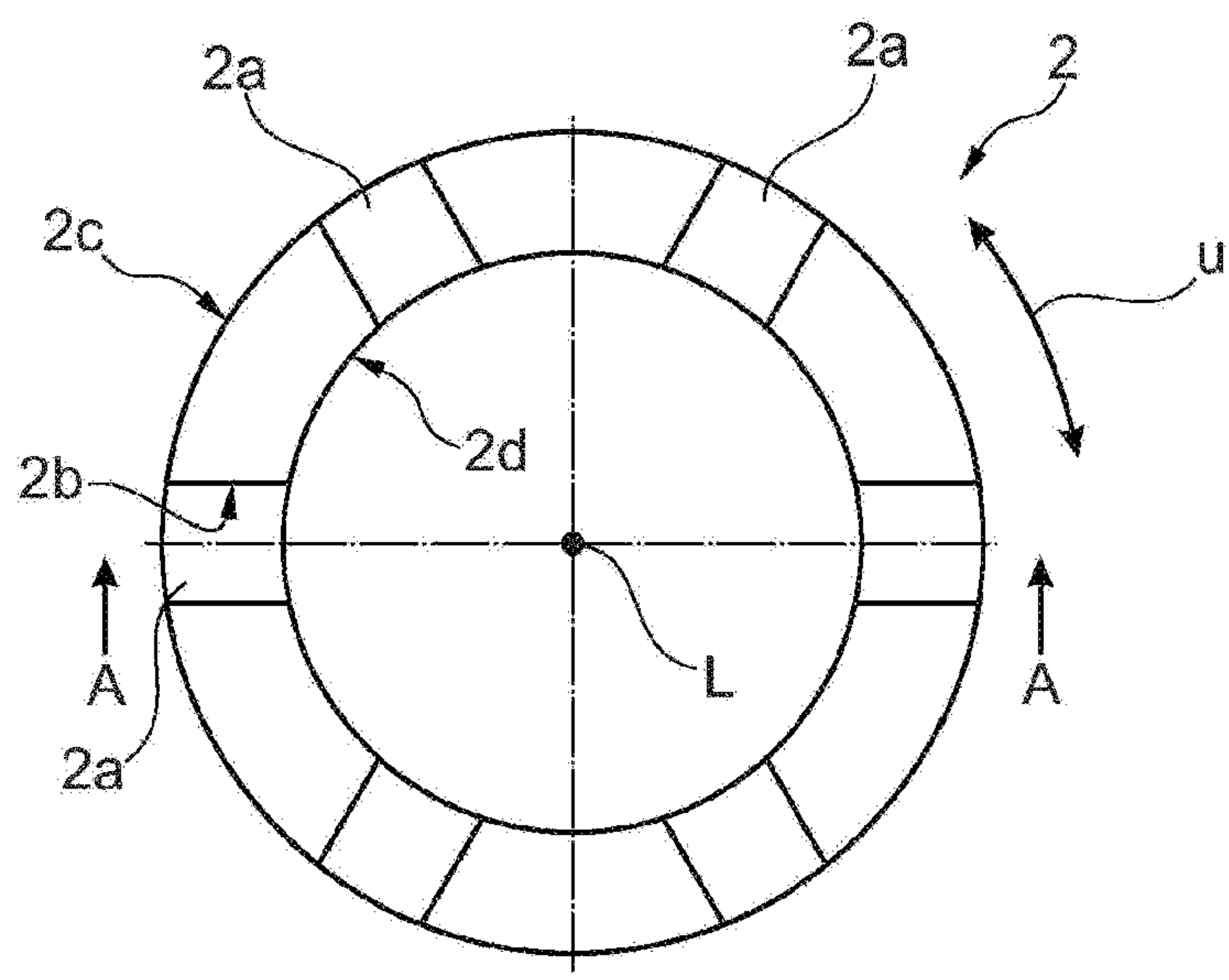
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Fig. 2

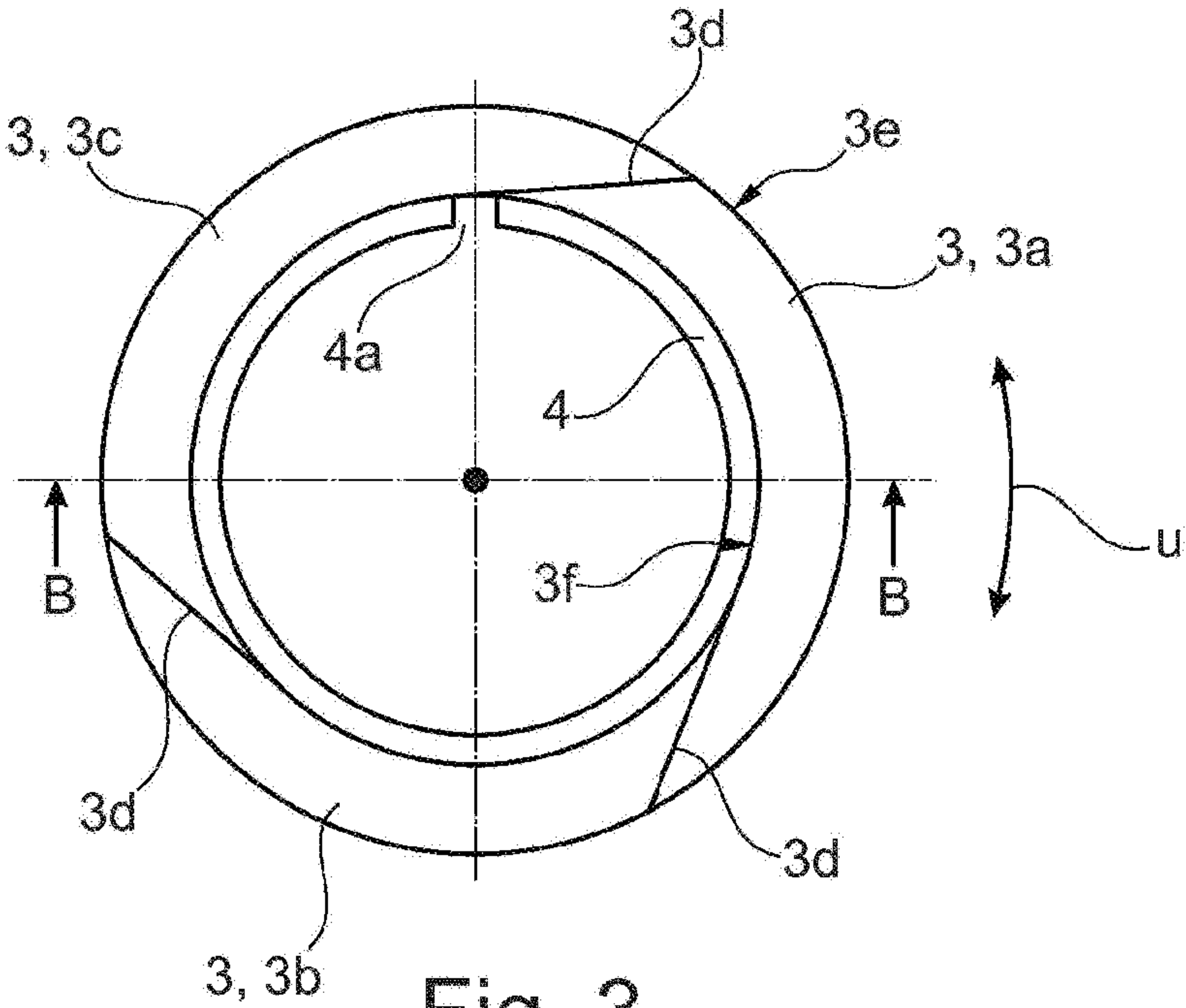


Fig. 3

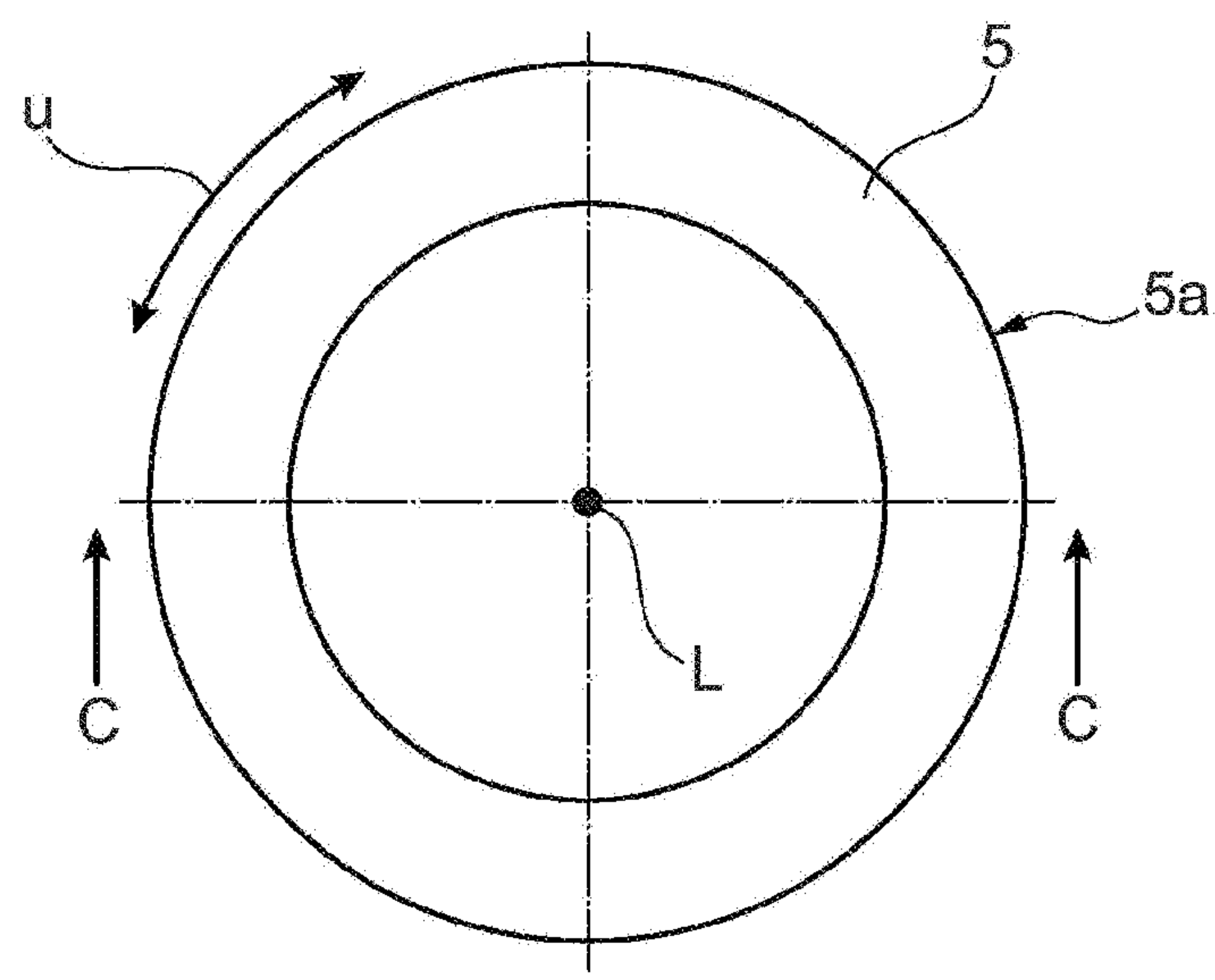


Fig. 4

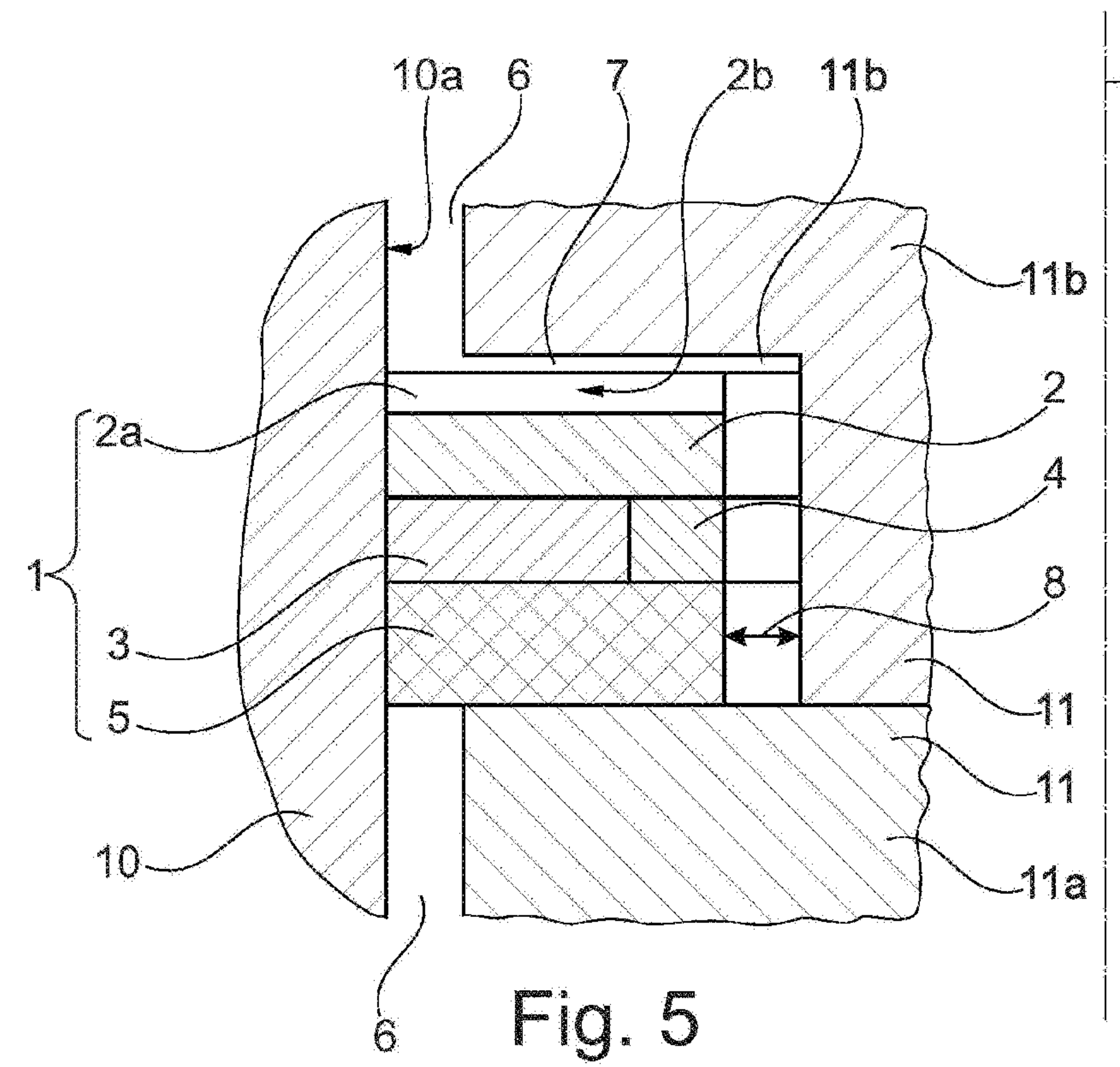


Fig. 5

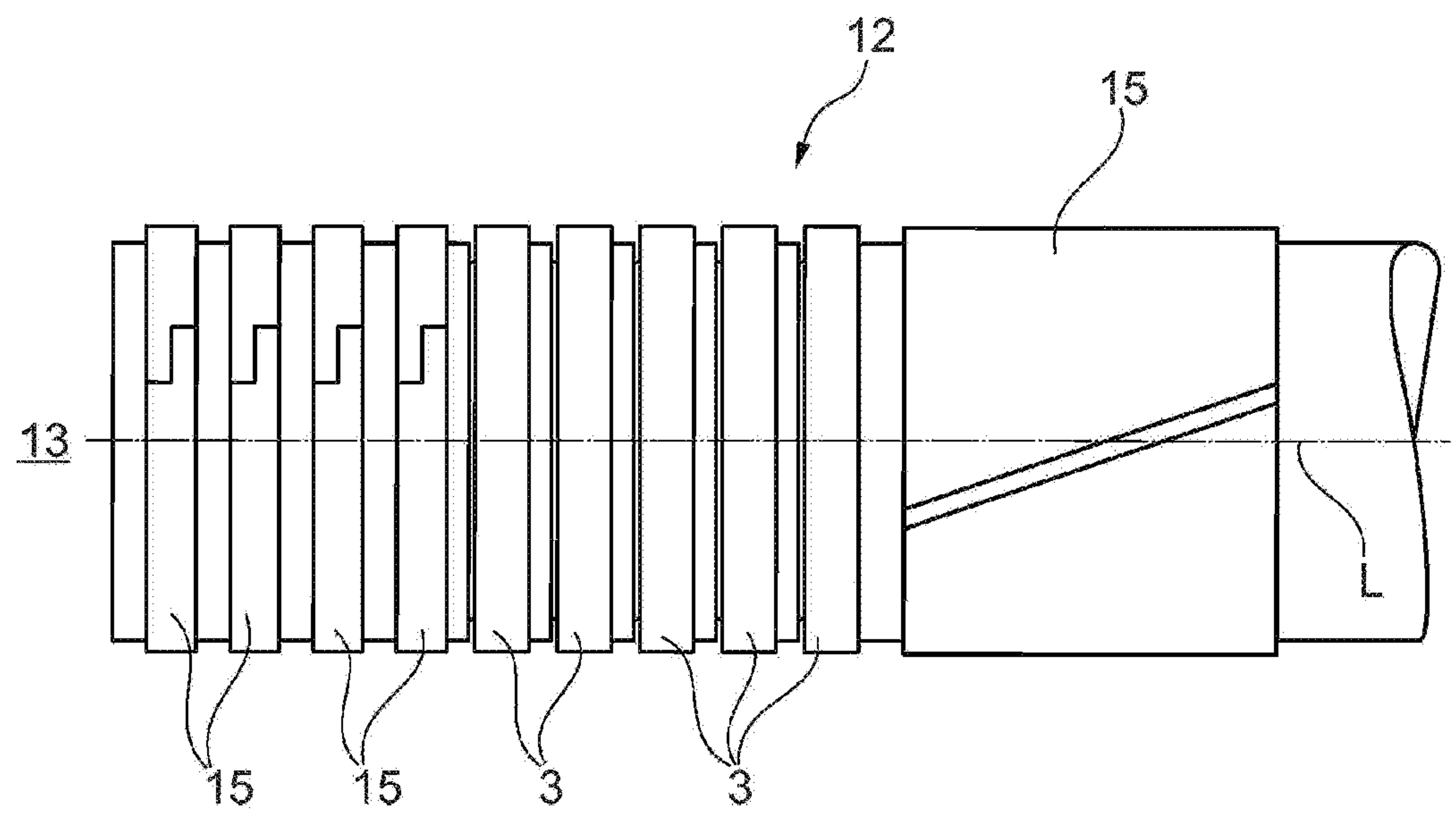
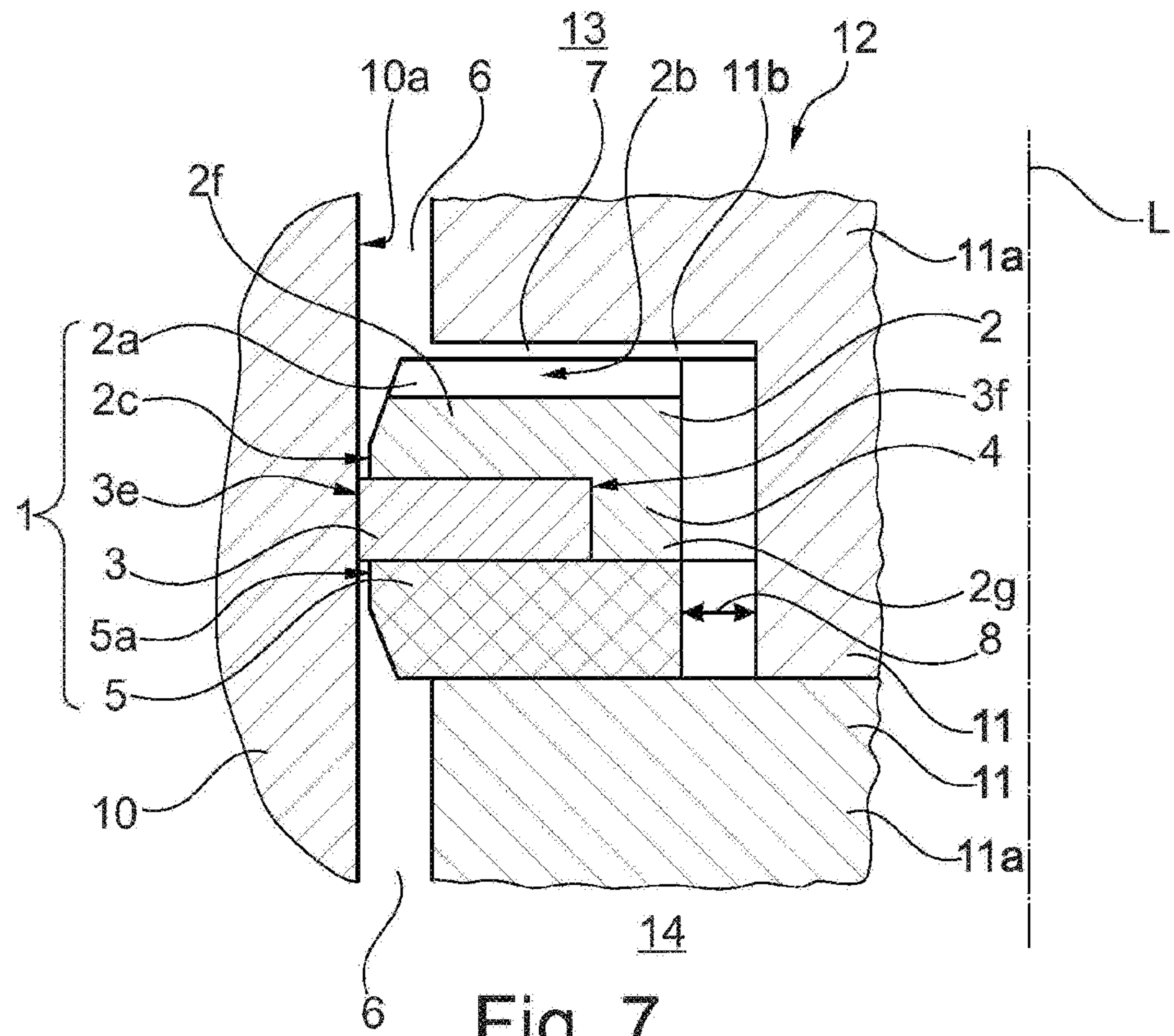


Fig. 6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6

Fig. 7

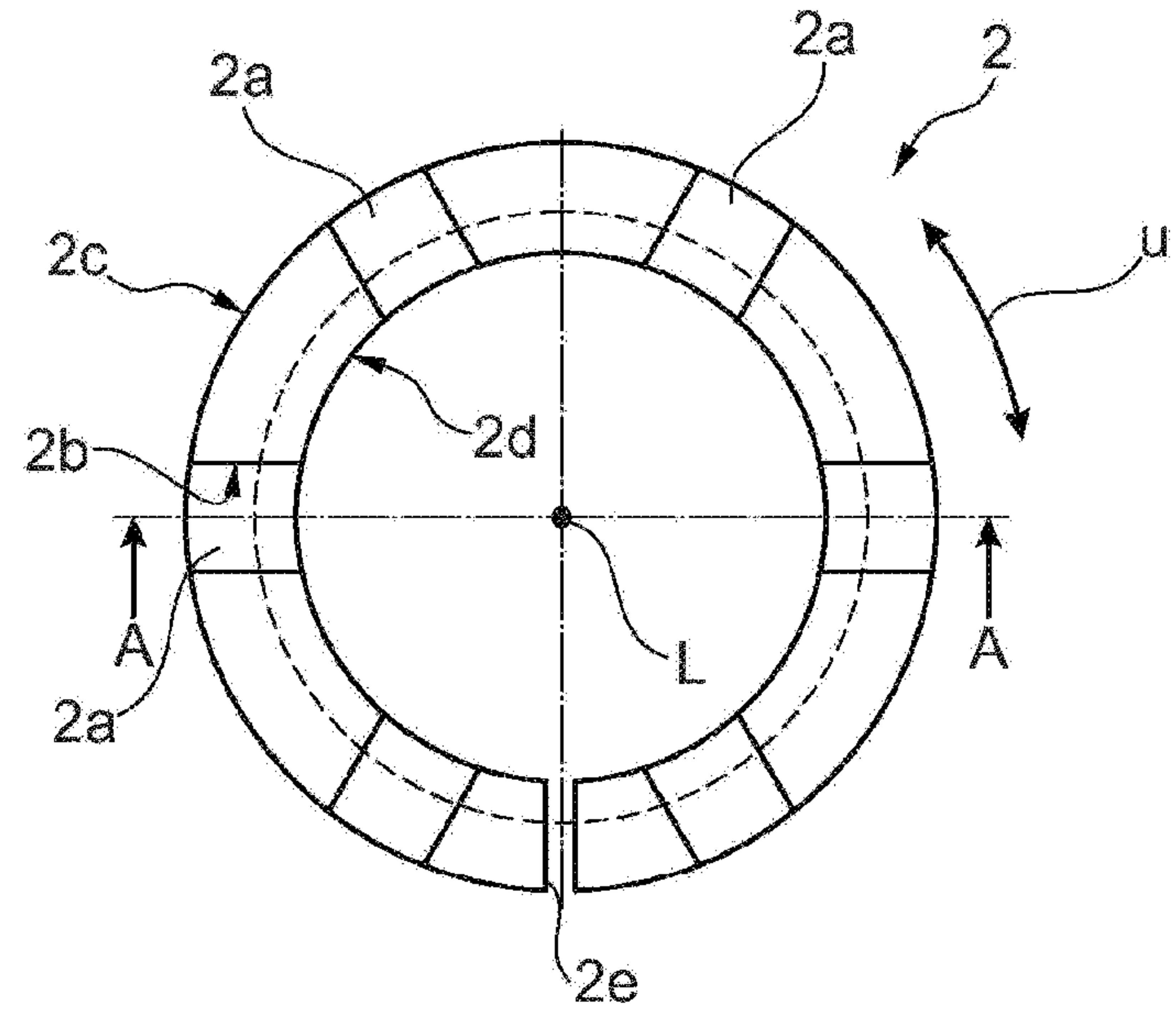
2a
2a
2
2c
u
2d
2b
A
A
L
2a
2e

Fig. 8