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(54) Title: BEARING ARRANGEMENT

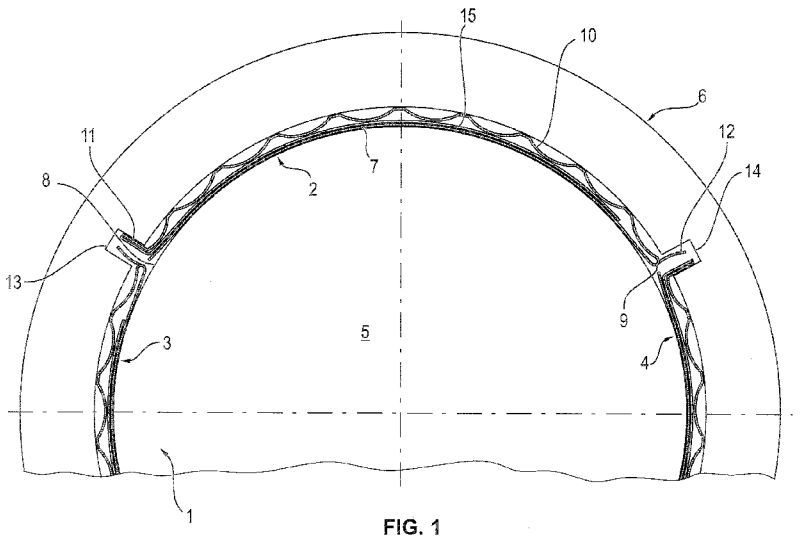

FIG. 1

(57) Abstract: The present invention relates to a bearing arrangement (28) having at least one radial air bearing (1) and/or having an axial air bearing (15'), wherein the radial air bearing (1) has an inner annular bearing plate (7) and a spring plate (10) which surrounds the bearing plate (7) at the outside, said bearing plate and spring plate being formed as a single-piece component.

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BEARING ARRANGEMENT

DESCRIPTION

The invention relates to a bearing arrangement as per the preamble of claim 1.

Bearing arrangements of said type having at least one radial air bearing and/or one axial air bearing are used in particular with rotating parts which have very high rotational speeds.

One known bearing arrangement has for this purpose a radial air bearing which has an inner slotted bearing plate which can for example be arranged around a shaft.

On the outer side of the bearing plate there is provided a separate spring plate which surrounds said bearing plate and which, in the rest state, the bearing plate presses against the outer surface of the shaft.

When the shaft starts to rotate, an air cushion begins to build up between the outer surface of the shaft and the inner surface of the bearing plate, such that the bearing plate is lifted from the shaft counter to the pressure of the spring plate and the shaft is thus mounted in a virtually wear-free manner by means of the air cushion. Here, the bearing plate and the spring plate may be arranged for example in an outer bearing sleeve or, such as is the case for example in turbochargers, directly in the bearing housing without the provision of an additional bearing sleeve.

It is an object of the present invention to provide a bearing arrangement of the type specified in the preamble of claim 1 which is of simpler construction and is simpler to assemble.

Said object is achieved by means of the features of claim 1.

According to the principles of the present invention, therefore, it is provided that the bearing plate and the spring plate of the radial air bearing are formed as a single-piece component. For this purpose, it is for example possible for an elongate plate strip to be bent, wherein that plate strip portion which is then at the outside has imparted to it a corrugated structure in order to form the spring plate.

Subclaims 2 to 6 relate to advantageous refinements of the invention.

Claims 8 and 10 define a radial air bearing and an axial air bearing in each case as independently marketable objects.

Further details, features and advantages of the invention will emerge from the following description of exemplary embodiments on the basis of the drawing, in which:

Figure 1 shows a schematically slightly simplified partial view of a radial air bearing according to the invention, which in the example is divided into three plate portions,

Figure 2 shows a perspective illustration of one of the plate portions from Figure 1,

Figure 3 shows a perspective illustration of an axial air bearing according to the invention,

Figures 4-8 show possible uses for a bearing arrangement according to the invention, and

Figures 9-11 show illustrations of a further embodiment of an axial air bearing.

Figure 1 shows a partial view of a radial air bearing 1 according to the invention, said radial air bearing being composed, in the example, of three plate portions 2, 3 and 4 which, in the assembled state of the air bearing 1 illustrated in Figure 1, form a bearing ring which, in the example, is arranged around a shaft 5 and is guided in a bearing bush or in a bearing housing 6.

Since the plate portions 2, 3 and 4 are in each case of identical construction, reference will be made below only to the plate portion 2 as a representative for all of the plate portions 2 to 4. As shown in Figure 1, the plate portion 2 has an inner bearing plate 7 which is of bent form corresponding to the diameter of the shaft 5, such that, in the assembled state shown in Figure 1, said inner bearing plate can rest against the outer circumference 8 of the shaft 5 when the latter is not rotating. The bearing plate 7 is connected via a bent connecting portion 9 to an outer spring plate 10, such that the bearing plate 7 and the spring plate 10 form a single-piece component. Said design can also be seen from the detail illustration of Figure 2.

Viewing Figures 1 and 2 together, it can be seen that the plate portion 2 is provided, at its end regions, with in each case one retaining lug 11 and 12 respectively which project outwards and thus point away from the shaft 5. Here, the retaining lug 11 is a plate strip which is bent away from the spring plate 10, whereas the retaining lug 12 is formed by punching out a part of the spring plate in the region of the connecting portion 9, said part likewise being bent outward after being punched out.

Figure 1 shows that said retaining lugs 11 and 12 engage into recesses 13 and 14 respectively in order to fix the position of the plate strip 2. Said recesses 13 and 14 are arranged in the bearing bush or in the surrounding bearing housing 6.

As is also shown in Figures 1 and 2, the spring plate 10 is provided with a corrugation in order to be able to generate the spring action by means of which the bearing plate 7 is pressed against the outer circumference 8 of the shaft 5 when the latter is in the rest state.

In the particularly preferred embodiment illustrated in Figure 1, there is also provided an intermediate layer 15, the bend of which corresponds to the bend of the bearing plate 7 and which is arranged between the bearing plate 7 and the spring plate

10 in order to prevent the corrugation of the spring plate 10 from being pressed into the bearing plate 7. Furthermore, the intermediate layer 15, by generating friction, serves for bearing damping.

As already explained in the introduction, it is provided according to the invention that the radial air bearing 1 is constructed either by means of a single (then in the form of an open ring similar to a shaft seal) plate arrangement (spring plate 10, bearing plate 7 and if appropriate intermediate layer 15), or that the radial air bearing 1 is divided into at least two, preferably three plate portions 2, 3 and 4 as is provided and illustrated in the particularly preferred embodiment of Figure 1.

As explained in the introduction, the bearing plate 7 rests on the outer circumference 8 of the shaft 5 when the latter is in the rest position.

When the shaft 5 starts to rotate, an air cushion is built up between the bearing plate 7 and the outer circumference 8 of the shaft 5, such that the bearing plate 7 lifts up from the outer circumference 8 of the shaft 5 counter to the pressure of the spring plate 10, and as a result the shaft 5 is mounted by means of the air cushion built up between the outer circumference 8 and the bearing plate 7.

An axial air bearing has the same mode of operation, wherein a preferred embodiment of said axial air bearing according to the invention is illustrated in Figure 3 and is denoted by the reference symbol 15'.

The axial air bearing 15' has a carrier plate or a bearing plate 16 which is in the form of an annular disk and which is provided with a multiplicity of protuberances 17, 18, wherein of the multiplicity of protuberances, only the protuberances 17, 18 are visible in Figure 3. For this purpose, the bearing plate 16 has an inner annular region 16A and, concentrically surrounding the latter at the outside, an outer annular region 16B. To form the protuberances 17 and 18, the inner annular region 16A is milled out such that the protuberances 17 and 18 project as raised webs relative to the milled-out inner annular region 16A.

On the bearing plate 16 there rests a spring plate 19 which, in the example, is constructed from a multiplicity of spring plate portions, of which those spring plate portions which are visible in Figure 3 are denoted by the reference symbol 19'. The spring plate portions 19' are in turn connected via webs 20 to an inner ring 21.

As is also shown in the figure, the axial air bearing 15' has, in the example, three rotation prevention means arranged on the outer circumference, of which one is denoted, as a representative for all of the rotation prevention means, by the reference symbol 22. Said rotation prevention means 22 are in the form of recesses 23 which are open on one side and into each of which can engage a pin (not illustrated in any more detail).

The bearing plate 16 and the spring plate 19 self-evidently each have a central recess 24 through which the shaft to be mounted extends in the assembled state.

In the particularly preferred embodiment illustrated in Figure 4, there is arranged on the spring plate 19 a support plate 25 which has tongues projecting inwardly from an outer ring 25A, of which the tongues 25B to 25D are visible in Figure 3 and which partially overlap the spring plate 19 in order to build up a spring action and in order to introduce occurring loads as uniformly as possible into a cover plate 38. The spring plate 19 with its spring plate portion 19', the protuberances 17 and 18 and the support plate 25 consequently form an annular spring arrangement on which the cover plate 38 is arranged. Even though said spring arrangement which is formed by the above-explained components 17, 18, 19, 19' and 25 constitutes a particularly preferred embodiment, it is also possible for the spring arrangement to be designed in some other form, for example as a corrugated annular plate. It would be possible for the cover plate 38 to be mounted on said annular plate too.

The cover plate 38 has an outer ring 39 which, as shown in Figure 3, in the assembled state, covers the outer ring 25A which is connected via a connecting portion 25E to the tongues, as can be seen in detail from the illustration of Figure 3.

The outer ring 39 of the cover plate 38 is connected via connecting webs to an inner ring 41, wherein owing to the illustration selected in Figure 3, only one of said webs is visible, said web being denoted by the reference numeral 40.

The inner ring 41 is, as shown in Figure 3, provided with a spiral arrangement 42 which is constructed from a multiplicity of spiral channels. The design, shown in Figure 3, of said spiral channels of the spiral arrangement 42 yields, with a shaft assembly of the shaft to be mounted, which shaft assembly rests on the cover plate 38 in the assembled state, an air delivery means by which the air is forced radially outward, that is to say in the direction of the outer edge of the axial bearing 15', in order to build up an air cushion by means of which the shaft assembly of the shaft to be mounted is mounted as it rotates. The spiral channel arrangement illustrated in Figure 3 constitutes a particularly preferred embodiment of a device for building up an air pressure between the bearing plate 16 and the spring arrangement, which device, as the shaft mounted by means of the axial air bearing 15' rotates, sucks in air and builds up an air cushion between the bearing plate 16 and the spring arrangement, which air cushion, as a result of the abovementioned air pressure build-up, forms a cushion, which is stable during the rotation of the shaft, for mounting said shaft.

As an alternative to this, it would also be possible to provide an external air feed device such as for example in the form of a compressor which is arranged separately from the axial bearing 15' or of a compressor which pumps air from the

outside between the spring arrangement and the bearing plate 16 and thereby builds up said air cushion. An example of such an arrangement is the compressor wheel 36 to be explained in detail below on the basis of Figure 6, which can realize the external feed of air to the axial air bearing.

With regard to the illustration selected in Figure 3, it must be stated that the bearing plate 16, the spring plate 19, the support plate 25 and the cover plate 38 are self-evidently in each case closed rings, which are however only partially illustrated in Figure 3 in order to make it possible to illustrate the individual components.

With regard to the arrangement and design of the spiral arrangement 42, reference is hereby made explicitly to the diagrammatic illustration thereof in Figure 3, wherein it is basically also possible for said particularly preferred embodiment illustrated in Figure 3 to be modified if this is necessary in one or another usage situation. Instead of the protuberances 17, 18, it is also possible for plate strips to be provided which extend inward in the region of the spring plate portions 19' on the inner ring 21 and can be bent such that, in the bent state, they come to rest under the spring portions 19'. In this case, such bent webs would then, together with the other components 19, 19', 25, form the spring arrangement.

The axial air bearing 15' is, in the fully assembled state for guiding a shaft in both axial directions, self-evidently constructed from in each case two bearing plate/spring plate arrangements which are arranged on both sides of a shaft assembly, as will be explained in more detail below on the basis of the usage examples.

A diagrammatic circuit diagram for possible uses of the air bearing arrangement according to the invention is shown in Figure 4. In this regard, Figure 4 shows an electric machine 26 which may be in the form of an electric motor or generator. The shaft 27 of the electric machine 26 is mounted by means of the air bearing arrangement 28 according to the invention, which is symbolized by the two blocks.

If the arrangement is for example an air feed device, the shaft 27 of the electric machine 26 is coupled to a compressor 30 and drives the compressor wheel thereof in order to deliver air.

Optionally, the other end of the shaft 27 may be coupled to a turbine 31, the turbine wheel of which may for example be driven by the exhaust-gas flow of an engine or of some other combustion chamber.

The abovementioned basic principle can also be found in the embodiment as per Figure 5, which illustrates a so-called "range extender" which serves for increasing the range of vehicles, in particular automobiles, which are driven by means of electric motors.

In said example, too, an air bearing arrangement 28 according to the invention may be provided. As shown in Figure 5, in addition to the components explained with regard to Figure 4, the range extender is provided with a combustion chamber 32 in which fuel can be burned, which fuel can be supplied in the form of the combustion gases generated to the turbine 31 in order to drive the turbine wheel. In this case, the electric machine 29 is in the form of a generator and can be used for electrical power generation in order to charge the batteries by means of which the electric motor drive of the vehicle (not illustrated in Figure 5) can be used. In the embodiment illustrated in Figure 5, the generator 29 is furthermore connected to the compressor 30 which in turn supplies the compressed combustion air via a recuperator 33 to the combustion chamber 32.

Figure 6 shows structural details of one possibility for the practical realization of the diagrammatic illustrations of Figures 4 and 5.

From the illustration of Figure 6, it is clear that the bearing arrangement 28 according to the invention is provided, in the example, with two radial air bearings 1 according to the invention and one axial air bearing 15' according to the invention, the two disk packs of which are arranged, as explained above on the basis of Figure 3, on both sides of a shaft assembly 34 in order to be able to mount the shaft 27 in both axial directions by means thereof.

In the embodiment illustrated in Figure 6, it must be emphasized that the electric machine 26 is separated from the turbine 31 by the compressor 30, which yields the advantage that the high temperatures which inevitably prevail in the turbine 31 cannot be transmitted to the electric machine 26.

This yields an arrangement of a turbine wheel 35 and compressor wheel 36 of the turbine 31 and of the compressor 30 "back to back", as shown in detail in the illustration of Figure 6.

In said arrangement, the bearing arrangements 1 and 15' are arranged in the housing of the electric machine 26, as shown in Figure 6.

Further possible uses for the bearing arrangement 28 according to the invention with at least one radial air bearing 1 and one axial air bearing 15 are shown in Figures 7 and 8.

Here, Figure 7 shows a conventional exhaust-gas turbocharger 37 which may be provided either with two radial air bearings and one axial air bearing or else is only partially mounted by means of air bearings, because it is for example possible for two radial air bearings to be combined with one conventional axial bearing. Furthermore, according to the invention, it is likewise possible in principle for only one radial air bearing and one conventional radial bearing to be combined with one another. Said

bearing combinations could in turn be combined either with a conventional axial bearing or with an axial air bearing.

Figure 8 shows an electric machine 26 which is combined with a compressor 30 in order to drive the latter, such that the arrangement of Figure 8 yields an electric charger.

Also possible is the combination of an electric machine in the form of a generator with a turbine. Said arrangement may be arranged for example in the exhaust tract of a motor vehicle in order to utilize the energy of the exhaust gases which drive the turbine, which in turn drives the generator in order to generate electrical energy. Said arrangement may be provided in a conventional naturally-aspirated engine or else downstream of an exhaust-gas turbocharger in the exhaust tract.

Figures 9 to 11 show a further embodiment of an axial air bearing according to the invention, wherein said air bearing is illustrated without the conventional housing parts and is symbolized merely by a carrier plate 43 and a spring plate 55 visible in Figure 10. Said parts are, in the case of an axial air bearing, placed into a housing, wherein in each case two carrier plates and spring plates are arranged in associated housing parts which are arranged on both sides of a central disk connected rotationally conjointly to the shaft to be mounted, wherein the air cushion is built up between said disk and the carrier plate.

Viewing Figures 9 to 11 together, it can be seen that, in the particularly preferred embodiment illustrated in said figures, the carrier plate 43 has three injection and admission pressure regions, one of which is denoted by the reference symbol 44 and will be described below as a representative for all of said regions.

The injection and admission pressure region 44 has two sub-regions 44A and 44B which are recessed in relation to the plane of the annular carrier plate 43. The sub-regions 44A and 44B are in each case open, via openings 45 and 46, in the direction of a central recess 56.

Adjacent to the sub-region 44B there is provided a ramp 50 for generating a pumping effect and a pressure build-up. Here, the ramp is of curved form and is formed so as to be inclined relative to a circumferential direction U by an angle α which is greater than 90° and which is preferably in an angle range from 110° to 160°. Adjacent to the ramp 50 there is furthermore provided a slot 57 which is formed so as to be open on one side via an opening 58. Accordingly, the ramp 50 is arranged between the sub-region 44B and the slot 57.

On the outer circumference of the carrier plate 43 there are furthermore provided three rotation prevention means 47, 48 and 49 which interact with rotation

prevention pins (not illustrated in any more detail in the drawings) of the housing of the axial air bearing.

In the vicinity of said rotation prevention means 47 and 49 there are provided in each case air-cooling regions, of which one is denoted, as a representative for all of the air-cooling regions, by the reference symbol 51 in Figures 9 to 10. Said air-cooling regions lie approximately 0.5 mm lower than the surface regions 59 and 60, wherein the surface region 59 is situated between the ramp 50 and the sub-region 44B, and the surface region 60 adjoins the air-cooling region 51, as can be seen in detail from Figure 9.

Figure 10 furthermore shows the provision of a spring plate 55 with springs or spring regions 52 to 54, wherein said spring plate 55, in the illustration selected in Figure 10, is arranged under the carrier plate 43, that is to say under the plane of the drawing of Figure 10.

Accordingly, the rear side of the carrier plate 43 is of preferably planar form, in particular if the springs or spring regions 52 to 54 were so large as to project into the punched regions, in particular the sub-regions 44A and 44B.

The construction, illustrated in Figures 9 to 10, of the axial air bearing according to the invention preferably generates an air circulation which contributes to cooling of the bearing, because said air circulation makes it possible for heat to be dissipated into the surrounding housing.

Furthermore, the curved form of the ramp 50 yields an advantageously stable air pressure build-up and therefore a stable air cushion for mounting the shaft which is provided with the axial air bearing.

The arrangements as per Figures 6 to 11 may also be provided with a bearing arrangement according to the invention which comprises the above-explained possible combinations of radial and axial air bearings with or without conventional radial or axial bearings.

It must furthermore be emphasized that the arrangements as per Figures 6 to 11 each constitute separate articles according to the invention.

In addition to the above written disclosure of the invention, reference is hereby made explicitly to the diagrammatic illustration thereof in Figures 1 to 11.

LIST OF REFERENCE SYMBOLS

1	Radial air bearing
2, 3, 4	Plate portions
5	Shaft
6	Bearing bush or bearing housing
7	Bearing plate
8	Outer circumference of the shaft 5
9	Connecting portion
10	Spring plate
11, 12	Retaining lugs
13, 14	Recesses in the housing or in the bearing bush
15	Intermediate layer
15'	Axial air bearing
16	Axial bearing plate
16A	Inner ring region
16B	Outer ring region
17	Protuberance
18	Protuberance
19	Axial spring plate
19'	Spring plate portions
20	Connecting webs
21	Inner ring
22	Rotation prevention means
23	Recess
24	Recess of the bearing plate 16, of the spring plate 19, of the support plate 25 and of the cover plate 38
25	Support plate
25A	Outer ring
25B - 25D	Tongues
25E	Connecting region
26	Electric machine (electric motor and/or generator)
27	Shaft
28	Bearing arrangement
29	Generator
30	Compressor
31	Turbine

32	Combustion chamber
33	Recuperator
34	Shaft assembly
35	Turbine wheel
36	Compressor wheel
37	Exhaust-gas turbocharger
38	Cover plate
39	Outer ring
40	Web / connecting web
41	Inner ring
42	Spiral arrangement
43	Carrier plate
44	Injection and admission pressure region
45, 46	Inlet openings
47, 48, 49	Rotation prevention means
50	Ramp
51	Air-cooling region
52, 53, 54	Springs
55	Spring plate
56	Central recess
57	Slot
58	Opening
59, 60	Surface regions of the carrier plate 43

CLAIMS

1. A bearing arrangement (28)
- having at least one radial air bearing (1); and/or
- having an axial air bearing (15'),

characterized in that
- the radial air bearing (1) has an inner annular bearing plate (7) and a spring plate (10) which surrounds the bearing plate (7) at the outside, said bearing plate and spring plate being formed as a single-piece component.

2. The bearing arrangement as claimed in claim 1, characterized in that the single-piece component constructed from the bearing plate (7) and the spring plate (10) has at least one retaining lug (11, 12).

3. The bearing arrangement as claimed in claim 1 or 2, characterized in that the spring plate (10) is of corrugated form.

4. The bearing arrangement as claimed in one of claims 1 to 10, characterized in that the bearing plate (7) and the spring plate (10) are divided into at least two, preferably three plate portions (2, 3, 4) which can be assembled to form a bearing ring.

5. The bearing arrangement as claimed in one of claims 1 to 4, characterized in that an intermediate layer (15) is provided between the bearing plate (7) and the spring plate (10).

6. The bearing arrangement as claimed in one of claims 1 to 5, characterized in that the axial air bearing (15') has an annular bearing plate (16) and an annular spring arrangement (17, 18, 19, 19', 25) on which is arranged a cover plate (38) which is provided with a device (42) for building up air pressure between the bearing plate (16) and the spring arrangement (17, 18, 19, 19', 25).

7. The bearing arrangement as claimed in claim 1, characterized in that the axial air bearing has an annular carrier plate (43) on which is arranged a curved ramp (50) for building up air pressure.

8. A radial air bearing (1)
- having an inner annular bearing plate (7); and

- having a spring plate (10) which surrounds the bearing plate (7) at the outside,

characterized in that

- the bearing plate (7) and the spring plate (10) are formed in one piece.

9. The radial air bearing as claimed in claim 8, characterized by at least one of claims 2 to 5.

10. An axial air bearing (15')

- having an annular bearing plate (16) and
- having an annular spring arrangement (17, 18, 19, 19', 25) on which is arranged a cover plate (38) which is provided with a device (42) for building up air pressure between the bearing plate (16) and the spring arrangement (17, 18, 19, 19', 25).

11. The axial air bearing as claimed in claim 10, characterized in that the spring arrangement (17, 18, 19, 19', 25) is provided with a multiplicity of raised protuberances (17, 18) which are arranged on the bearing plate (16) and on which rest spring plate portions (19') of a spring plate (19).

12. The axial air bearing as claimed in claim 10 or 11, characterized by a rotation prevention means (22).

13. The axial air bearing as claimed in claim 12, characterized in that the rotation prevention means (22) has a multiplicity of spaced-apart, circumferentially arranged receiving recesses (23) for rotation prevention pins.

14. The axial air bearing as claimed in one of claims 10 to 13, characterized in that the device for building up air pressure is in the form of a spiral duct arrangement (42).

15. The axial air bearing as claimed in one of claims 10 to 13, characterized in that the device for building up air pressure is in the form of an external air feed device which pumps air from the outside between the spring arrangement (17, 18, 19, 19', 25) and the bearing plate (16).

16. The axial air bearing as claimed in one of claims 10 to 15, characterized in that a support plate (25) is arranged between the spring plate (19) and the cover plate (38).

17. An axial air bearing, characterized by an annular carrier plate (43) on which is arranged a curved ramp (50) for building up air pressure.

18. The axial air bearing as claimed in claim 17, characterized in that the curved ramp (50) is arranged so as to be inclined relative to a circumferential direction (U) of the support plate (43) by an angle (α) of $> 90°$, preferably of 110° to 160°.

19. The axial air bearing as claimed in claim 17 or 18, characterized in that a spring plate (55) is arranged on the carrier plate (43).

20. The axial air bearing as claimed in one of claims 17 to 19, characterized by at least one air-cooling region (51) arranged on the carrier plate (43).

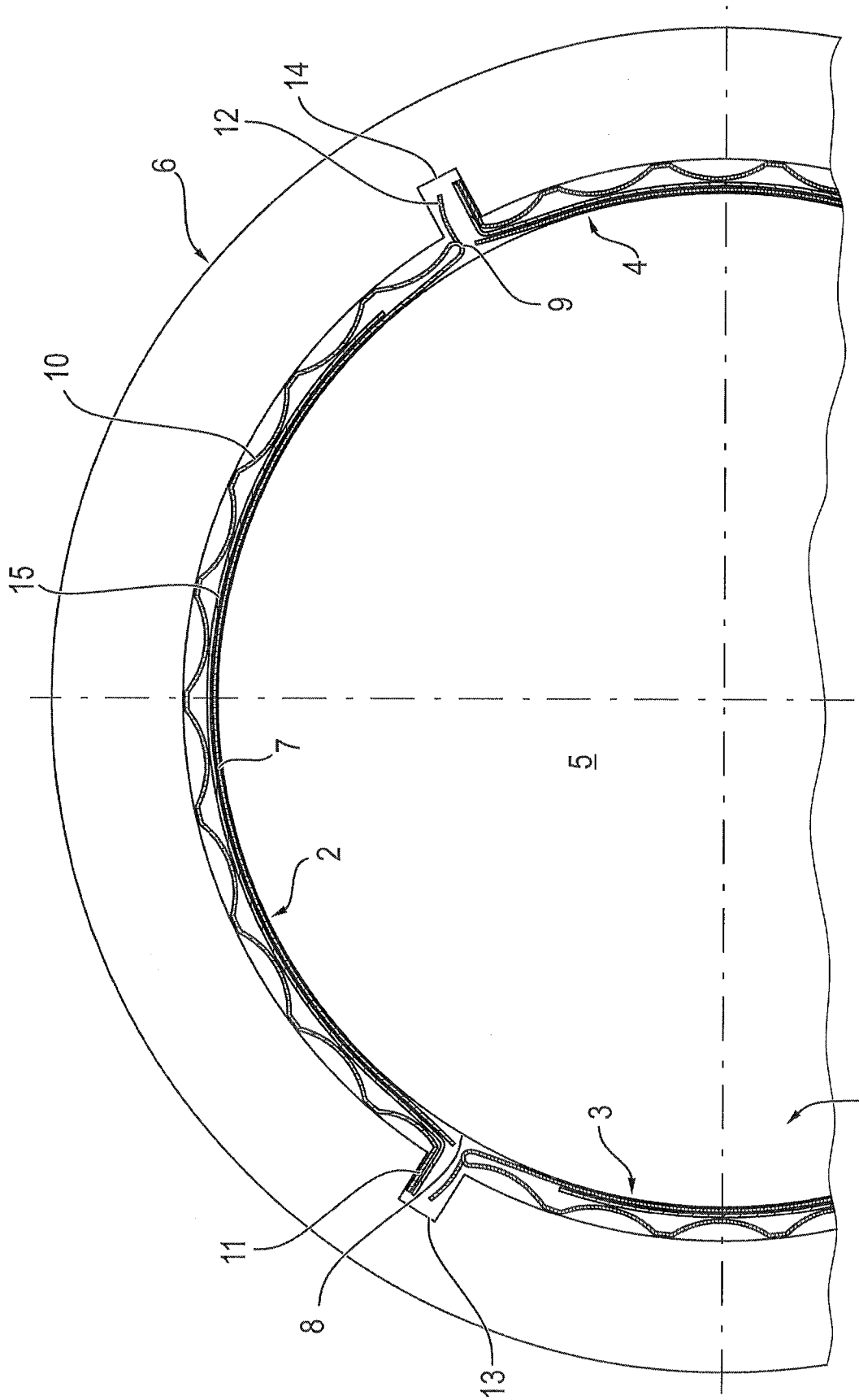


FIG. 1

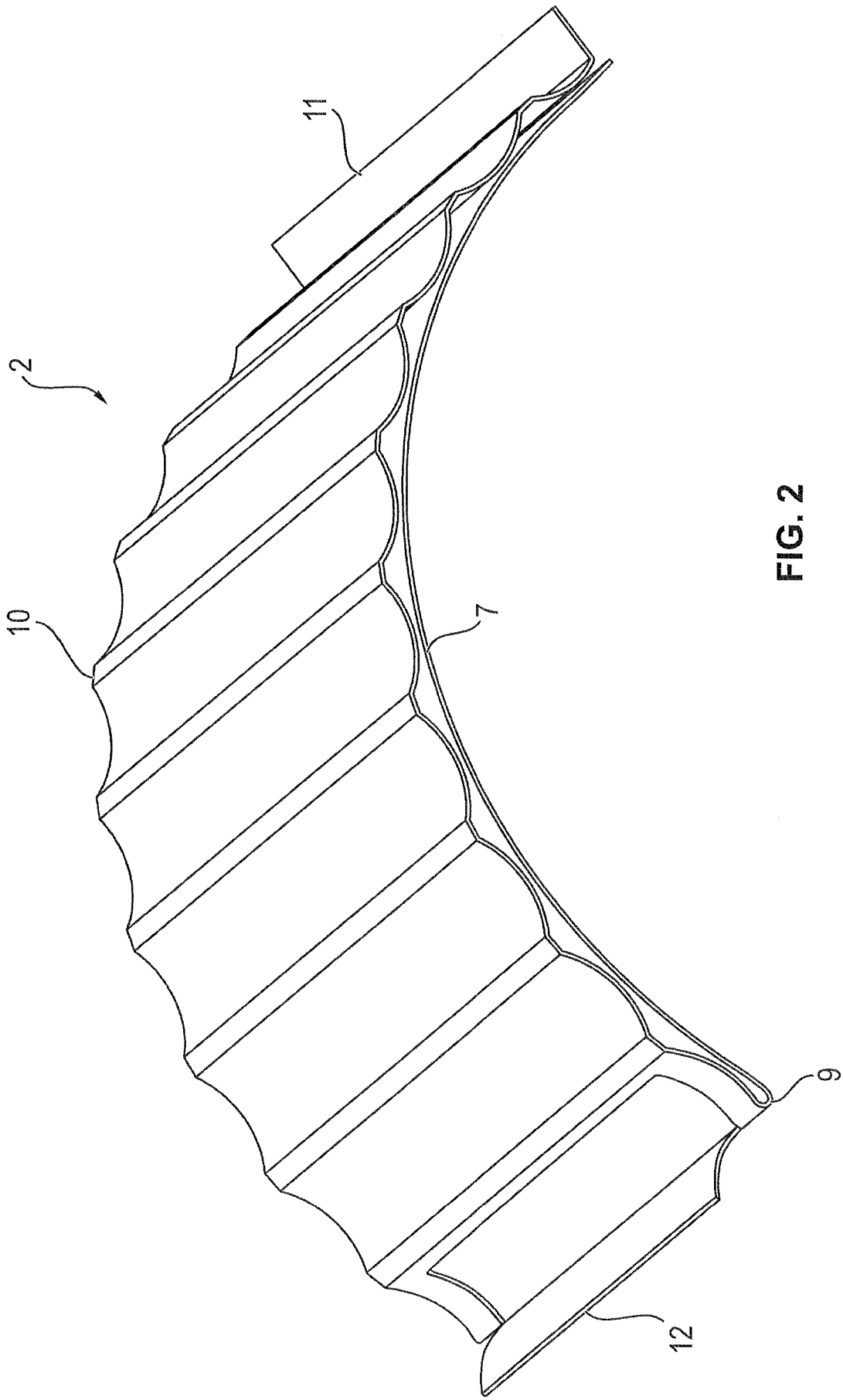
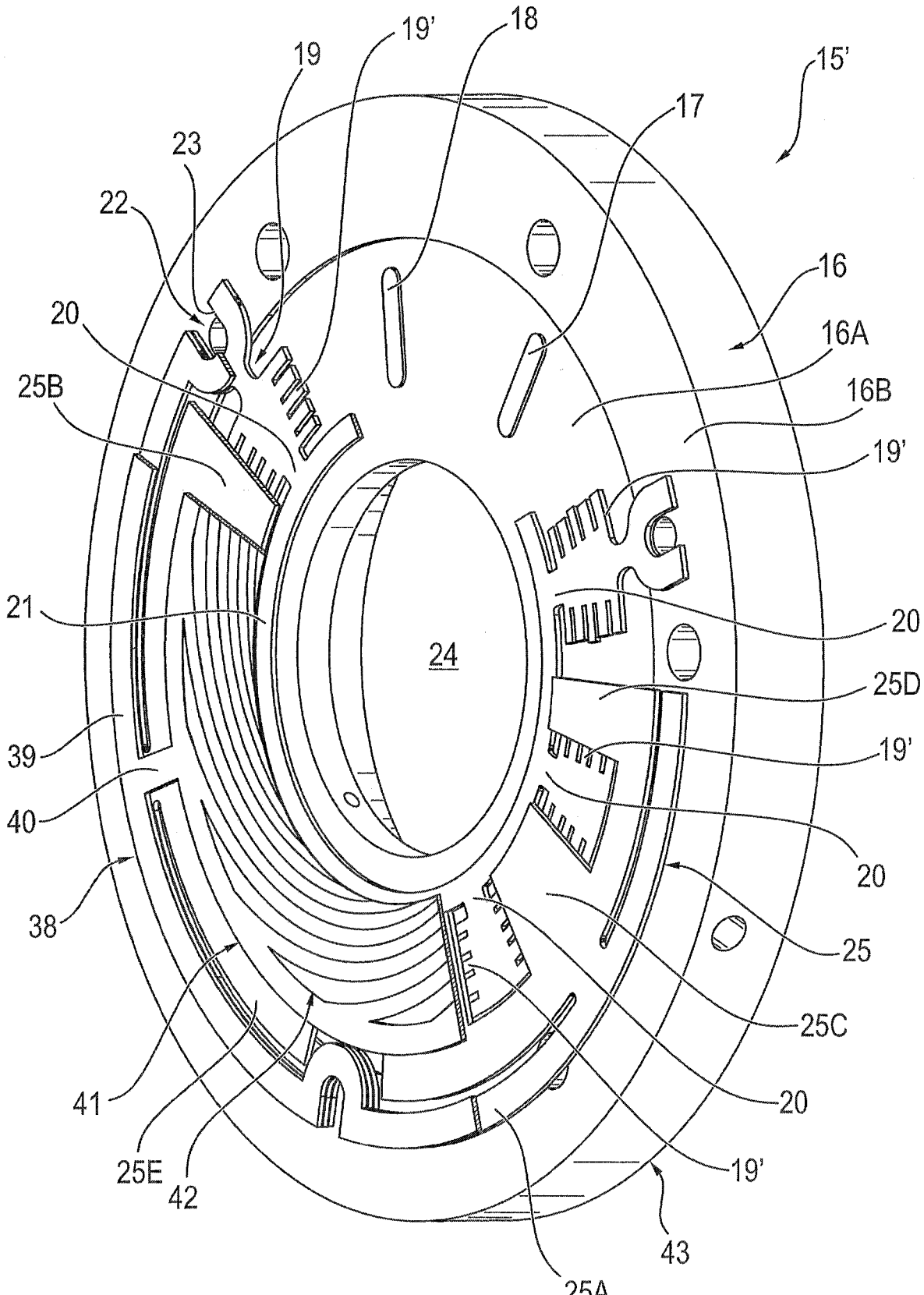


FIG. 2


19'
18
19
15'
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23
22
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16A
25B
16B
19'
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38
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25C
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25E
19'
42
43
25A

FIG. 3

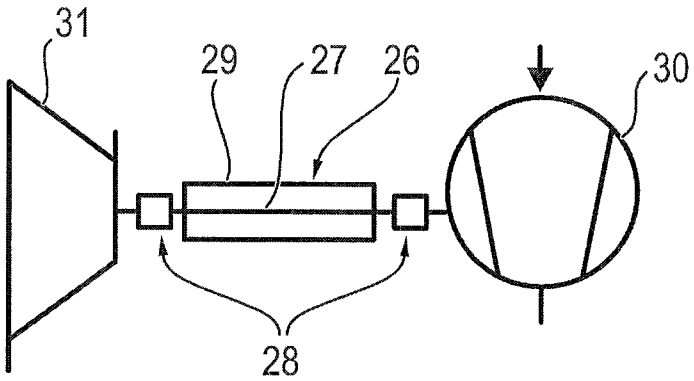


FIG. 4

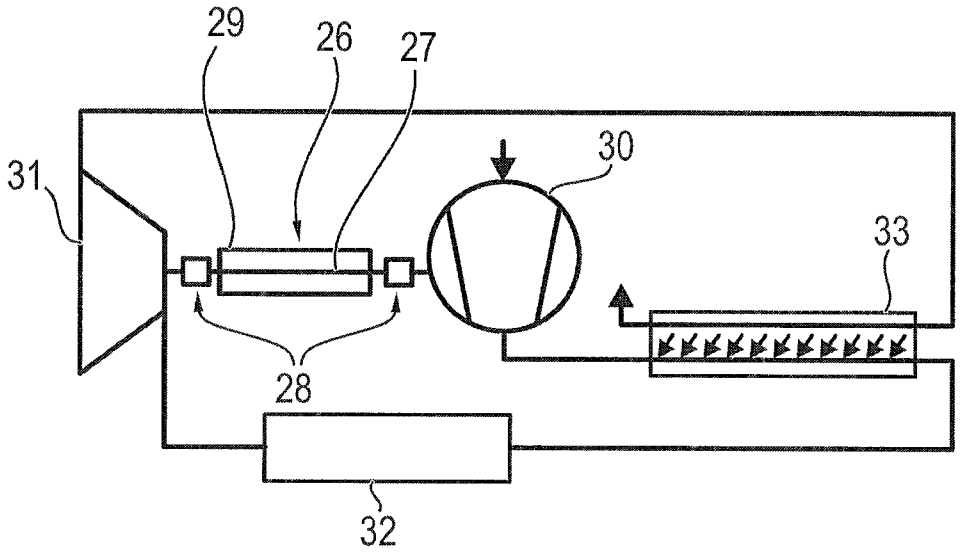


FIG. 5

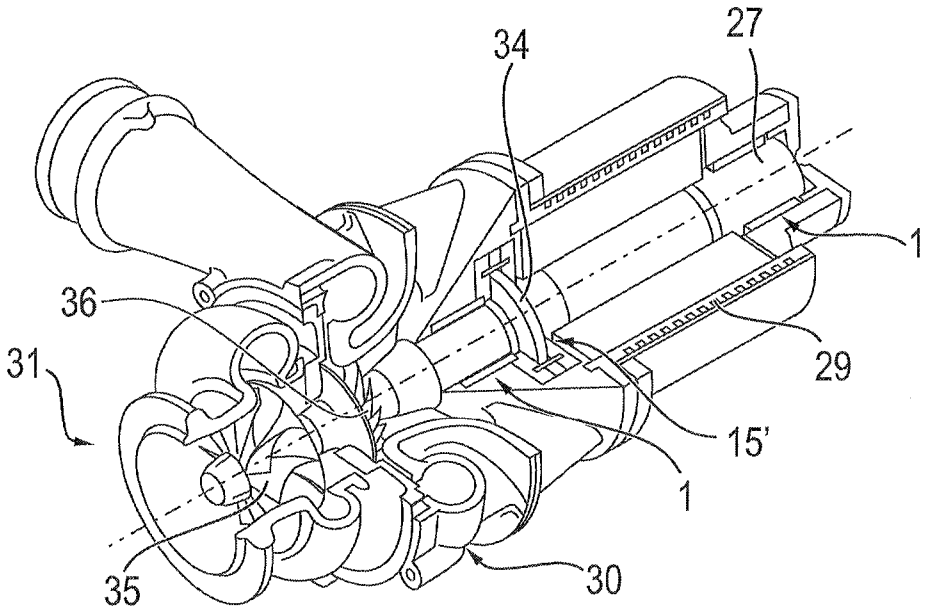


FIG. 6

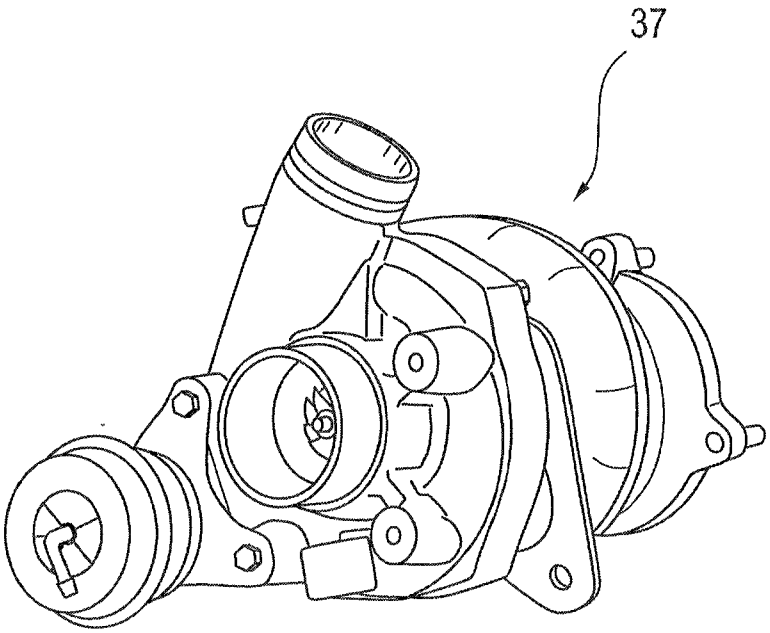


FIG. 7

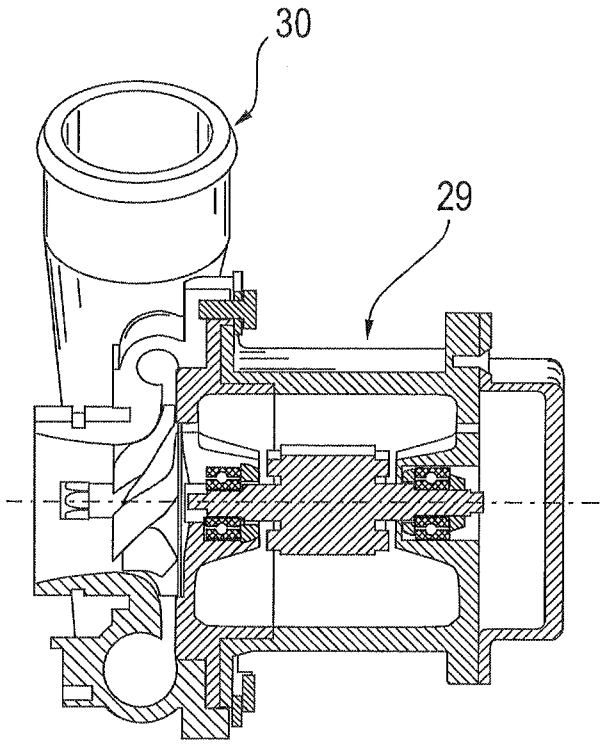


FIG. 8

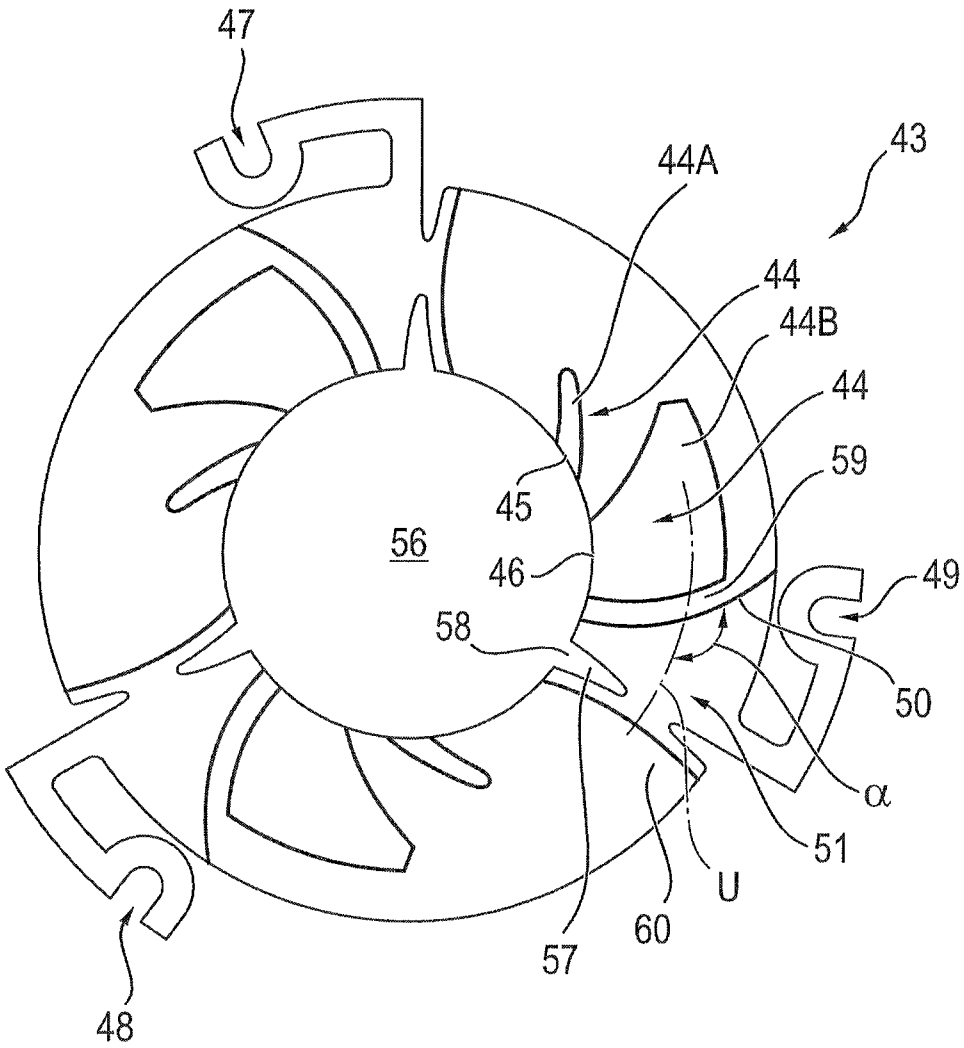
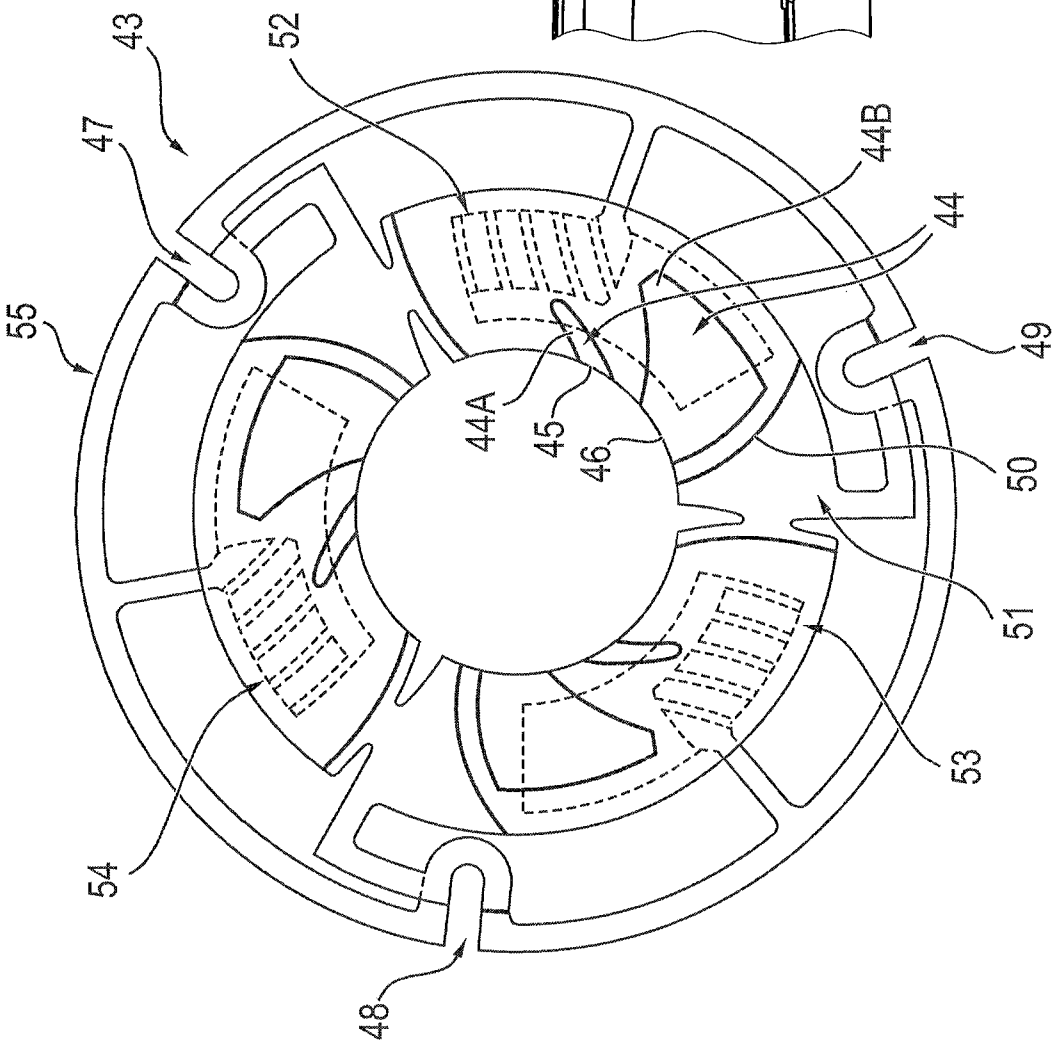


FIG. 9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47
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44B
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44A
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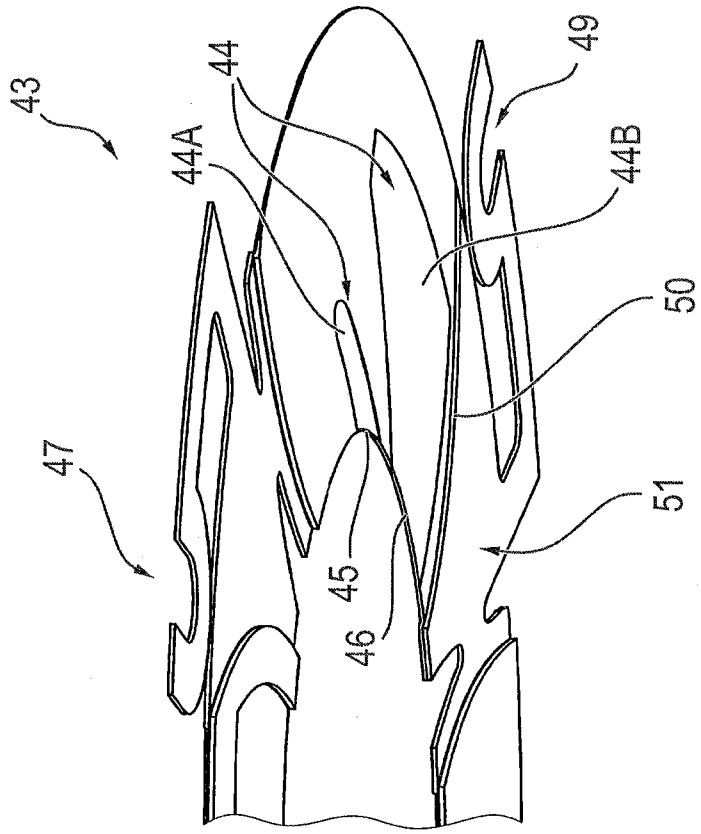
FIG.10


43
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44A
44B
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FIG. 11