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(54) Keksinnön nimitys - Uppfinningens benämning - Title of the invention

KOMPRESSORIN STABILISAATTORIKANAVA

COMPRESSOR STABILIZER CHANNEL

COMPRESSOR STABILIZER CHANNEL

TECHNICAL FIELD

[0001] The invention relates to the field of compressors, in particular radial compressors and diagonal compressors. In particular, the invention relates to a stabilizer channel at the compressor inlet for improving the characteristic map width and the characteristic curve gradient of a compressor stage.

TECHNICAL BACKGROUND

[0002] Exhaust gas turbochargers are used to increase the performance of internal combustion engines, in particular reciprocating piston engines. An exhaust gas turbocharger usually has a radial or diagonal compressor and a radial or axial turbine.

[0003] The viable operating range of radial and diagonal compressors is limited to smaller mass flows due to the pump limit/flow instability: When the compressor is throttled, the incidence angles deteriorate progressively until the flow separates and pumping occurs. The permissible incidence angular range at which the flow is still present decreases with an increasing flow Mach number. This means that the characteristic map width tends to decrease for stages with a high pressure ratio and/or high flow capacity.

[0004] A bypass in the form of an annular cavity within the compressor housing can be provided above the wheel contour of the compressor wheel, parallel to the intake duct, as a measure to stabilize the characteristic curve. This type of bypass is also known as a stabilizer chamber or recirculator. The mass flow at the compressor wheel inlet can be artificially increased near the pump limit by using a recirculator. Part of the mass flow is diverted from the compressor wheel into the side chamber (bypass). This mass flow has a strong swirl component (in the direction of rotation of the impeller—co-rotating swirl). This co-rotating swirl causes the working volume in the compressor to be reduced, resulting in flat characteristic curves near the pump limit.

[0001] Flat characteristic curves near the pump limit can lead to unexpected pumping in applications with pressure pulsations (e.g., caused by the valve movement of the supercharged internal combustion engine). For this reason, it is necessary to provide a minimum pressure increase between the operating point and the pump limit point on the operating speed curve. This requirement can hardly be met in stages with high pressure ratios and conventional bypass/stabilizer channels due to the high working volume and the flat working ratio curve over the mass flow at a constant speed.

Reference is made to the prior art in documents SU 478 957 A2, EP 2 434 165 A1, and DE 101 05 456 A1. Document SU 478 957 A2 describes an inlet area of a compressor stage with an annular cavity in the compressor housing. Document EP 2 434 165 A1 describes a compressor for an exhaust gas turbocharger in which the structure of the inlet slot, the outlet slot, and the recirculation channel can be formed simultaneously during assembly of a two-piece compressor housing. Document DE 101 05 456 A1 describes a compressor for an internal combustion engine, which has a compressor housing with a flow channel structure and a recirculation arrangement with a bypass structure for recirculating part of the air entering the supercharger wheel.

BRIEF PRESENTATION OF THE INVENTION

[0002] The object of the present invention is to provide a stabilizer channel of a compressor, in particular a radial compressor or diagonal compressor, which is improved at least with respect to one of the disadvantages known from the prior art. Furthermore, the object of the present invention is to provide an improved compressor and an improved turbocharger.

[0003] To achieve the aforementioned objects, a stabilizer channel of a compressor, in particular a radial compressor or diagonal compressor, is provided in accordance with independent claim 1. Furthermore, a compressor with a stabilizer channel in accordance with the embodiments described herein and a turbocharger with such a compressor are provided.

[0008] Further aspects, advantages, and features of the present invention are apparent from the dependent patent claims, the description, and the accompanying figures.

[0009] According to the invention, a stabilizer channel of a compressor, in particular a radial compressor or diagonal compressor, is provided in accordance with claim 1. The stabilizer channel comprises an annular stabilizer chamber which surrounds a main flow channel in the intake region of a compressor wheel and is delimited from the main flow channel by an annular web. The annular stabilizer chamber is free of vanes and is connected via a downstream inlet channel and an upstream outlet opening. A plurality of flow-guiding elements are arranged in the downstream inlet channel. The downstream inlet channel is arranged between an upstream part of the annular web and a downstream part of the annular web.

[0010] Thus, a stabilizer channel is advantageously provided which enables an improvement in the characteristic map width and the characteristic curve gradient of a compressor stage. Furthermore, the stabilizer channel according to the invention with flow-guiding elements in the downstream inlet channel provides a stabilizer channel which has advantages over conventional stabilizers known from the prior art in terms of component integration, containment properties, and manufacturing costs.

[0011] Furthermore, a compressor, in particular a radial compressor or a diagonal compressor, is provided in accordance with claim 14.

Thus, a compressor with improved characteristic map width and characteristic curve gradient can be provided.

[0012] Finally, a turbocharger is provided in accordance with claim 15, which is an improvement over the prior art.

BRIEF DESCRIPTION OF THE FIGURES

[0013] The invention will be explained in the following with reference to embodiments shown in the figures, from which further advantages and modifications will become apparent. In the drawings:

Figure 1 shows a schematic view of a stabilizer channel in accordance with the prior art;

Figure 2 shows a schematic view of a stabilizer channel in accordance with embodiments described herein;

Figures 3a and 3b show schematic views of a stabilizer channel in accordance with further embodiments described herein;

Figure 4a shows a schematic view of a stabilizer channel in accordance with a further embodiment of the invention described herein:

Figure 4b shows an enlarged view of a section of Figure 4a;

Figures 5 and 6 show schematic views of an inlet channel of a stabilizer channel in accordance with further embodiments of the invention described herein;

Figure 7 shows a schematic view of a configuration of flow-guiding elements for generating a flow counter-swirl when the flow passes through the guiding elements; and

Figure 8 shows a schematic view of a configuration of flow-guiding elements for reducing flow swirl as the flow passes through the guiding elements

DETAILED DESCRIPTION OF THE FIGURES

[0014] Figure 1 shows a schematic view of a stabilizer channel 10 in accordance with the prior art. In particular, Figure 1 shows a section through a housing of a radial compressor, such as is used for compressing air in exhaust gas turbochargers, along the axis of rotation 11 of the compressor wheel 21. A stabilizer chamber 12 is arranged in the compressor housing 5. The stabilizer chamber 12 is connected to the main flow channel 13 via an inlet channel 15 and an outlet opening 16. The stabilizer chamber 12 is delimited from the main flow channel 13 by means of an annular web 14. Support ribs 121 are arranged in the stabilizer chamber 12, which connect the annular web 14 to the compressor housing.

[0015] A compressor stabilizer channel in accordance with the present disclosure is described with reference to Figures 2 to 8. The compressor can be a radial compressor or a diagonal compressor.

[0016] In accordance with an embodiment that can be combined with other embodiments described herein, the stabilizer channel 10 comprises an annular stabilizer chamber 12 which surrounds a main flow channel 13 in the intake region of a compressor wheel 21. In other words, the stabilizer channel 10 is typically arranged at the compressor inlet. In this context, it should be noted that in the present disclosure, a “stabilizer channel” is understood to mean, in particular, a channel in the compressor inlet that is configured to improve the characteristic map width of a compressor stage. For example, the stabilizer channel 10 can be a recirculation channel.

[0017] Furthermore, the annular stabilizer chamber 12 is delimited from the main flow channel 13 by an annular web 14, as is shown, for example, in Figure 2. The annular stabilizer chamber 12 is free of vanes. In other words, no vanes, in particular no flow-guiding vanes, are arranged in the annular stabilizer chamber 12. In particular, the annular stabilizer chamber 12 may also be without struts. In other words, the annular stabilizer chamber 12 can be free of vanes and struts, so that neither flow-guiding vanes nor struts are present in the annular stabilizer chamber 12.

Furthermore, the annular stabilizer chamber 12 is connected to the main flow channel 13 via a downstream inlet channel 15 and an upstream outlet opening 16. The annular stabilizer chamber 12 can be designed to be rotationally symmetrical.

[0018] As shown schematically in Figure 2, a plurality of flow-guiding elements 17 are arranged in the downstream inlet channel 15. The plurality of flow-guiding elements 17 are typically arranged circumferentially around a central axis 11 of the main flow channel 13. In particular, the plurality of flow-guiding elements 17 may be arranged concentrically around the central axis 11 of the main flow channel 13. It should further be noted that the flow-guiding elements 17 may be designed to be flush with the inlet opening 15A of the inlet channel 15 on the main flow channel side and/or flush with the outlet opening 15B of the inlet channel 15 on the stabilizer chamber side.

Alternatively, the flow-guiding elements 17 can be spaced apart from the inlet opening 15A of the inlet channel 15 on the main flow channel side and/or from the outlet opening 15B of the inlet channel on the stabilizer chamber side, as is shown, for example, in Figure 2.

The downstream inlet channel 15 is arranged between an upstream part 141 of the annular web 14 and a downstream part 142 of the annular web 14.

[0019] In the present disclosure, the term “inlet channel” refers to a channel that serves as a flow inlet channel into the stabilizer chamber. The inlet channel 15 typically comprises an inlet opening 15A on the main flow channel side and an outlet opening 15B on the stabilizer chamber side, as is shown, for example, in Figure 2.

[0020] In the present disclosure, the terms “downstream” and “upstream” refer to the main flow in the main flow channel in the intake region of a compressor wheel. The main direction of flow 1 is shown in the figures for a better understanding. In accordance with one example, the inlet channel 15 of the stabilizer chamber may be arranged downstream of an inlet edge 24 of the compressor wheel 21, as shown in Figure 2. The outlet opening 16 of the stabilizer chamber is typically arranged upstream of the inlet edge 24 of the compressor wheel 21.

[0021] In accordance with an embodiment that can be combined with other embodiments described herein, the plurality of flow-guiding elements 17 are designed and arranged to provide a deflection grid which can be flowed through. For example, the deflection grid can be designed and arranged to provide a deflection grid which can be flowed through substantially radially. In the present disclosure, the term “substantially radially” refers to an angular range of $\alpha=\pm 45°$ or less, in particular $\alpha=\pm 25°$ or less, relative to the radial direction r. As shown by way of example in Fig. 2, the radial direction r extends perpendicular to the central axis 11. In accordance with one example, “substantially radially” is to be understood as meaning an angular range of ± 10° or less relative to the radial direction r. For a better understanding, Figure 5 shows an example of an inlet channel 15 inclined at an angle α, which falls under the above definition of “substantially radially”. The angle α is located in the x-r plane.

[0022] In accordance with an embodiment that can be combined with other embodiments described herein, the downstream inlet channel 15 extends substantially in the radial direction, as exemplified in the embodiments shown in Figures 2 to 5.

[0023] In accordance with an alternative embodiment that can be combined with other embodiments described herein, the plurality of flow-guiding elements 17 are designed and arranged to provide a deflection grid which can be flowed through substantially axially, as is shown, for example, in Figure 6. In the present disclosure, the term “substantially axially” refers to an angular range of =± 45° or less, in particular =± 25° or less, relative to the axial direction x. As shown by way of example in Fig. 2, the axial direction x extends along the central axis 11. In accordance with one example, “substantially axially” is to be understood as meaning an angular range of ± 10° or less relative to the axial direction x. A deflection grid which can be flowed through substantially axially can be provided, for example, by a configuration of the inlet channel 15 of the stabilizer chamber and an arrangement of the flow-guiding elements 17 in accordance with Figure 6.

[0024] In accordance with an embodiment that can be combined with other embodiments described herein, the downstream inlet channel 15 comprises a part 15C which extends substantially radially and a part 15D which extends substantially axially, as is shown, for example, in Figure 6.

Between the part 15C which extends substantially radially and the part 15D which extends substantially axially, there is typically a curved transition region 15F.

[0025] According to the invention, the upstream part 141 of the annular web 14 comprises a first projection 18 which extends substantially in the radial direction. The downstream part 142 of the annular web 14 comprises a second projection 19A which extends substantially in the radial direction, as shown, for example, in Figures 4a, 4b, and 5. Alternatively, the downstream part 142 of the annular web 14 comprises a second projection 19B which extends substantially in the axial direction, as shown in Fig. 6.

[0026] In accordance with an embodiment that can be combined with other embodiments described herein, the stabilizer channel 10 is an integral part of a compressor housing, as is shown, for example, in Figure 2. Alternatively, the stabilizer channel 10 can be integrated into an insert part 22 which can be mounted in the intake region of a compressor, as shown, for example, in Figure 3a. In accordance with a further example, the stabilizer channel may be part of an inner compressor housing 20A, as shown, for example, in Figure 3b, in which a compressor 20 is shown with an inner compressor housing 20A and an outer compressor housing 20B.

[0027] In accordance with an embodiment that can be combined with other embodiments described herein, the upstream part 141 of the annular web 14 and the downstream part 142 of the annular web 14 are connected via the plurality of flow-guiding elements 17, for example by means of a screw connection. The screw connection can extend through the flow-guiding elements 17. It should be noted that the screw connections can also be designed in other ways, i.e. so that they do not extend through the flow-guiding elements

17. Alternatively, or in addition, other connection types such as shrinkage or clamping can also be used.

[0028] In accordance with an embodiment that can be combined with other embodiments described herein, the plurality of flow-guiding elements 17 are designed as separate components. In accordance with an alternative embodiment, which can be combined with other embodiments described herein, the plurality of flow-guiding elements 17 are formed integrally (in one piece) with the upstream part 141 of the annular web 14 and/or integrally (in one piece) with the downstream part 142 of the annular web 14.

[0029] In accordance with an embodiment that may be combined with other embodiments described herein, the downstream part 142 of the annular web 14 has a centering shoulder 143. Alternatively, or in addition, the upstream part 141 of the annular web 14 may have a centering shoulder (not explicitly shown). The centering shoulder can be designed to be cylindrical or conical.

[0030] In accordance with an embodiment that may be combined with other embodiments described herein, the plurality of flow-guiding elements 17 each have a centering seat which is configured so as to arrange the flow-guiding elements 17 in the inlet channel 15 circumferentially, in particular concentrically, around the central axis 11 of the main flow channel 13.

[0031] In accordance with an embodiment that can be combined with other embodiments described herein, at least one, in particular at least half or all, of the plurality of flow-guiding elements 17 formed from Curtis-type vane profiles. In particular at least one, in particular at least half or all, of the plurality of flow-guiding elements 17 are formed from prismatic Curtis-type vane profiles. The flow-guiding elements 17 are typically designed as radial deflection vanes. One embodiment of the flow-guiding elements made of Curtis-type vane profiles, in particular flow-guiding elements in the form of prismatic Curtis-type vanes, has the advantage that these can be designed relatively thick, so that a better connection of the upstream part 141 of the annular web 14 with the downstream part 142 of the annular web 14 is made possible via such guiding elements, for example by means of screw connections or other suitable connection types.

[0032] In accordance with an embodiment that can be combined with other embodiments described herein, the plurality of flow-guiding elements 17 are arranged in an outflow region of the inlet channel 15 of the stabilizer chamber, as shown, for example, in Figures 4a and 4b. The outflow region of the inlet channel 15 is understood to be the region of the inlet channel 15 which is located on the side of the outlet opening 15B on the stabilizer chamber side.

The outflow region can extend over half or less of the inlet channel length L, for example. The outflow region 15E of the inlet channel 15 is shown by way of example in Figure 4b for a better understanding. An arrangement of the flow-guiding elements 17 in an outflow region of the inlet channel 15 can have a favorable effect on flow velocities and vane vibration excitation.

[0033] In accordance with an embodiment that can be combined with other embodiments described herein, the flow-guiding elements 17 each have an inflow-side end 17A and an outflow-side end 17B, wherein the respective outflow-side ends 17B of the flow-guiding elements 17 are inclined in the circumferential direction relative to the respective inflow-side ends 17A of the flow-guiding elements 17 so that a swirl is reduced as they are flowed through, as shown, for example, by the arrows between the inflow-side ends 17A and the outflow-side ends 17B in Figure 8.

[0034] Alternatively, the respective outflow-side ends 17B of the flow-guiding elements 17 may be inclined in the circumferential direction relative to the respective inflow-side ends 17A of the flow-guiding elements 17 in such a way that a counter-swirl is generated, as shown, for example, by the arrows between the inflow-side ends 17A and the outflow-side ends 17B in Figure 7. The direction of rotation 2 of the compressor wheel is shown in Figures 7 and 8 for a better understanding. The rotation of the compressor wheel causes a swirling flow.

[0035] In accordance with a second aspect of the present disclosure, a compressor, in particular a radial compressor or a diagonal compressor, is provided which comprises a compressor wheel 21 and a stabilizer channel 10 in accordance with one of the embodiments described herein. In accordance with an embodiment that can be combined with other embodiments described herein, the compressor wheel 21 comprises a number N_1 of compressor wheel vanes 23 in the region of the inlet opening 15A. A number N_2 of guiding elements in the downstream inlet channel 15 is $N_2 \geq 1.5 \times N_1$. This is advantageous for reducing noise and vibration during compressor operation.

[0036] A third aspect of the invention relates to a turbocharger with a compressor in accordance with one of the embodiments described herein, so that a turbocharger is advantageously provided which is improved over the prior art.

LIST OF REFERENCE SIGNS

1 Main direction of flow

2 Direction of rotation of the compressor wheel

5 Compressor housing

10	Stabilizer channel
11	Central axis / axis of rotation of the compressor wheel
12	Annular stabilizer chamber
121	Strut
13	Main flow channel
14	Annular web
141	Upstream part of the annular web
142	Downstream part of the annular web
143	Centering shoulder
15	Inlet channel of the stabilizer chamber
15A	Inlet opening of the inlet channel on the main flow channel side
15B	Outlet opening of the inlet channel on the stabilizer chamber side
15C	Part of the inlet channel which extends substantially radially
15D	Part of the inlet channel which extends substantially axially
15E	Outflow region of the inlet channel
15F	Transition region
16	Outlet opening of the stabilizer chamber
17	Flow-guiding elements
17A	Inflow-side end of the flow-guiding elements
17B	Outflow-side end of the flow-guiding elements
18	First projection which extends substantially in the radial direction
19A	Second projection which extends substantially in the radial direction
19B	Second projection which extends substantially in the axial direction
20	Compressor
20A	Inner compressor housing
20B	Outer compressor housing
21	Compressor wheel
22	Insert part
23	Compressor wheel vanes
24	Inlet edge of the compressor wheel
r	Radial direction
x	Axial direction
L	Length of the inlet channel
α	Angle in the x-r plane to explain “substantially radially"

KOMPRESSORIN STABILISAATTORIKANAVA

PANTENTTIVAATIMUKSET

1. Kompressorin stabilisaattorikanava (10), erityisesti keskipakokompressorin tai puoliaksiaalikompressorin, jossa on rengasmuotoinen stabilointitila (12), joka ympäröi päävirtauskanavaa (13) kompressoripyörän (21) imualueella ja joka on rajoitettu päävirtauskanavan (13) vastapuolella olevalla rengasosalla (14), jossa rengasmainen stabilointitila (12) on kuoreton ja yhdistetty virtaussuunnan jälkipäässä olevaan sisääntulokanavaan (15) sekä virtaussuunnan alkupäässä olevaan poistoaukkoon (16), jossa useat virtauksenjohtoelementit (17) on järjestelty virtaussuunnan jälkipäässä olevaan sisääntulokanavaan (15), ja jossa virtaussuunnan jälkipäässä oleva sisääntulokanava (15) on asetettu rengasosan (14) virtaussuunnan alkupään osan (141) ja rengasosan (14) virtaussuunnan jälkipään osan (142) välille, jolle on ominaista, että rengasosan (14) virtaussuunnan alkupään osa (141) käsittää pääasiallisesti radiaaliseen suuntaan ulottuvan ensimmäisen jatkeen (18) ja rengasosan (14) virtaussuunnan jälkipään osa (142) käsittää pääasiallisesti radiaaliseen suuntaan ulottuvan toisen jatkeen (19A), tai että rengasosan (14) virtaussuunnan jälkipään osa (142) käsittää pääasiallisesti aksiaaliseen suuntaan ulottuvan toisen jatkeen (19B).

2. Patenttivaatimuksen 1 mukainen stabilisaattorikanava, jossa useat virtauksenohjainelementit (17) on muodostettu ja järjestetty siten, että ne muodostavat läpivirtaavan suuntausritilän, erityisesti pääasiallisesti radiaalisesti tai pääasiallisesti aksiaalisesti läpivirtaavan suuntausritilän.

3. Patenttivaatimuksen 1 tai 2 mukainen stabilisaattorikanava, jossa virtaussuunnan jälkipäässä oleva sisääntulokanava (15) ulottuu pääasiallisesti radiaaliseen suuntaan, virtaussuunnan jälkipäässä oleva sisääntulokanava (15) käsittää pääasiallisesti radiaalisesti ulottuvan osan (15C) ja pääasiallisesti aksiaalisesti ulottuvan osan (15D).

4. Jonkin patenttivaatimuksista 1–3 mukainen stabilisaattorikanava, jossa useat virtauksenohjainelementit (17) on järjestetty kehän muotoon, erityisesti samankeskisesti, päävirtauskanavan (13) keskiakselin (11) ympärille.

5. Jonkin patenttivaatimuksista 1–4 mukainen stabilisaattorikanava, joka on kiinteä osa kompressorin runkoa, tai stabilisaattorikanava, joka on integroitu soviteosaan (22), joka on asennettavissa kompressorin imualueelle, tai stabilisaattorikanava, joka on osa kompressorin sisärunkoa (20A).

6. Jonkin patenttivaatimuksista 1–5 mukainen stabilisaattorikanava, jossa rengasosan (14) virtaussuunnan alkupään osan (141) ja rengasosan (14) virtaussuunnan jälkipään osan (142) ovat toisiinsa liitetyt useiden virtauksenohjainelementtien (17) kautta, erityisesti ruuvikiinnityksellä.

7. Jonkin patenttivaatimuksista 1–6 mukainen stabilisaattorikanava, jossa useat virtauksenohjainelementit (17) ovat erillisiä rakenneosia.

8. Jonkin patenttivaatimuksista 1–6 mukainen stabilisaattorikanava, jossa useat virtauksenohjainelementit (17) on muodostettu integroidusti rengasosan (14) virtaussuunnan alkupään osan (141) ja/tai rengasosan (14) virtaussuunnan jälkipään osan (142) kanssa.

9. Jonkin patenttivaatimuksista 1–8 mukainen stabilisaattorikanava, jossa rengasosan (14) virtaussuunnan jälkipään osan (142) ja/tai rengasosan (14) virtaussuunnan alkupään osan (141) käsittää keskitysolkapään (143), erityisesti lieriömäisen tai kartiomaisen keskitysolkapään.

10. Jonkin patenttivaatimuksista 1–9 mukainen stabilisaattorikanava, jossa kukin virtauksenohjainelementti (17) käsittää keskityspesän, joka on muodostettu siten, että virtauksenohjainelementit (17) voidaan järjestää sisääntulokanavassa (15) kehämäisesti, erityisesti samankeskisesti, päävirtauskanavan (13) keskiakselin (11) ympärille.

11. Jonkin patenttivaatimuksista 1–10 mukainen stabilisaattorikanava, jossa vähintään yksi virtauksenohjainelementti, erityisesti vähintään puolet tai kaikki virtauksenohjainelementeistä (17), on muodostettu Curtis-tyyppisistä lapaprofiileista, ja jossa vähintään yksi virtauksenohjainelementti, erityisesti vähintään puolet tai kaikki virtauksenohjainelementeistä (17), on prismaattinen Curtis-tyyppinen lapa.

12. Jonkin patenttivaatimuksista 1–11 mukainen stabilisaattorikanava, jossa useat virtauksenohjainelementit (17) on sijoitettu stabilisaattoritilan sisääntulokanavan (15) poistoalueelle (15E).

13. Jonkin patenttivaatimuksista 1–12 mukainen stabilisaattorikanava, jossa kukin virtauksenohjainelementti (17) käsittää tulopuolen pään (17A) ja poistopuolen pään (17B), jossa virtauksenohjainelementtien (17) poistopuolen päät ovat kallistettuina ympäryssuunnassa suhteessa virtauksenohjainelementtien (17) tulopuolen päihin (17A) siten, että virtauksen läpimenon yhteydessä pyörre vähennetään tai synnytetään vastapyörre.

14. Kompressori (20), erityisesti keskipakokompressori tai puoliaksiaalikompressori, jossa on kompressoripyörä (21) ja jonkin patenttivaatimuksista 1–13 mukainen stabilisaattorikanava (10), ja jossa erityisesti kompressoripyörä (21) sijaitsee sisääntulokanavan (15) sisääntuloaukon (15A) alueella käsittää määrän N_1 kompressoripyörän lapoja (23) ja määrän N_2 virtauksenohjainelementtejä siten, että $N_2 \geq 1{,}5 \times N_1$.

15. Turboahdin, jossa on 14. vaatimuksen mukainen kompressori (20).

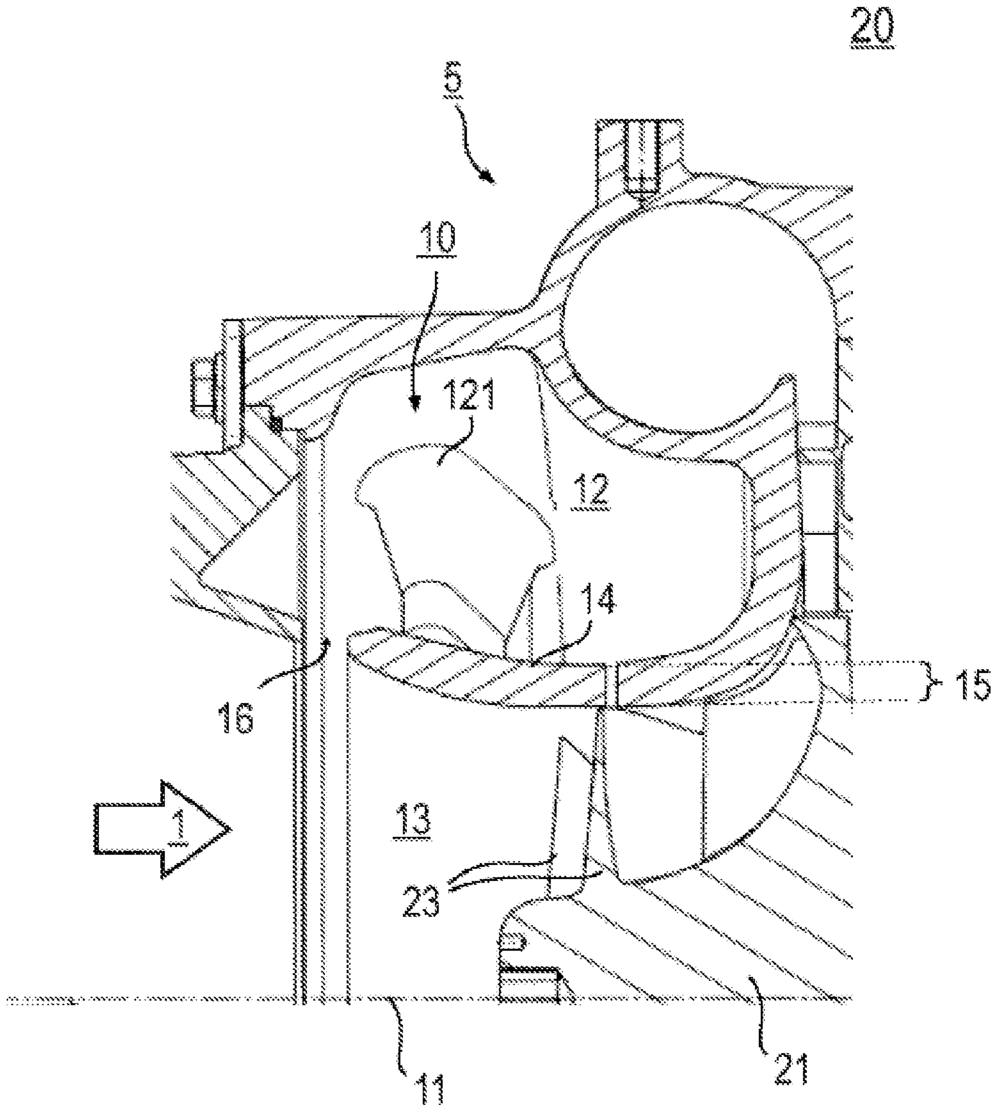


Fig. 1

(Prior Art)

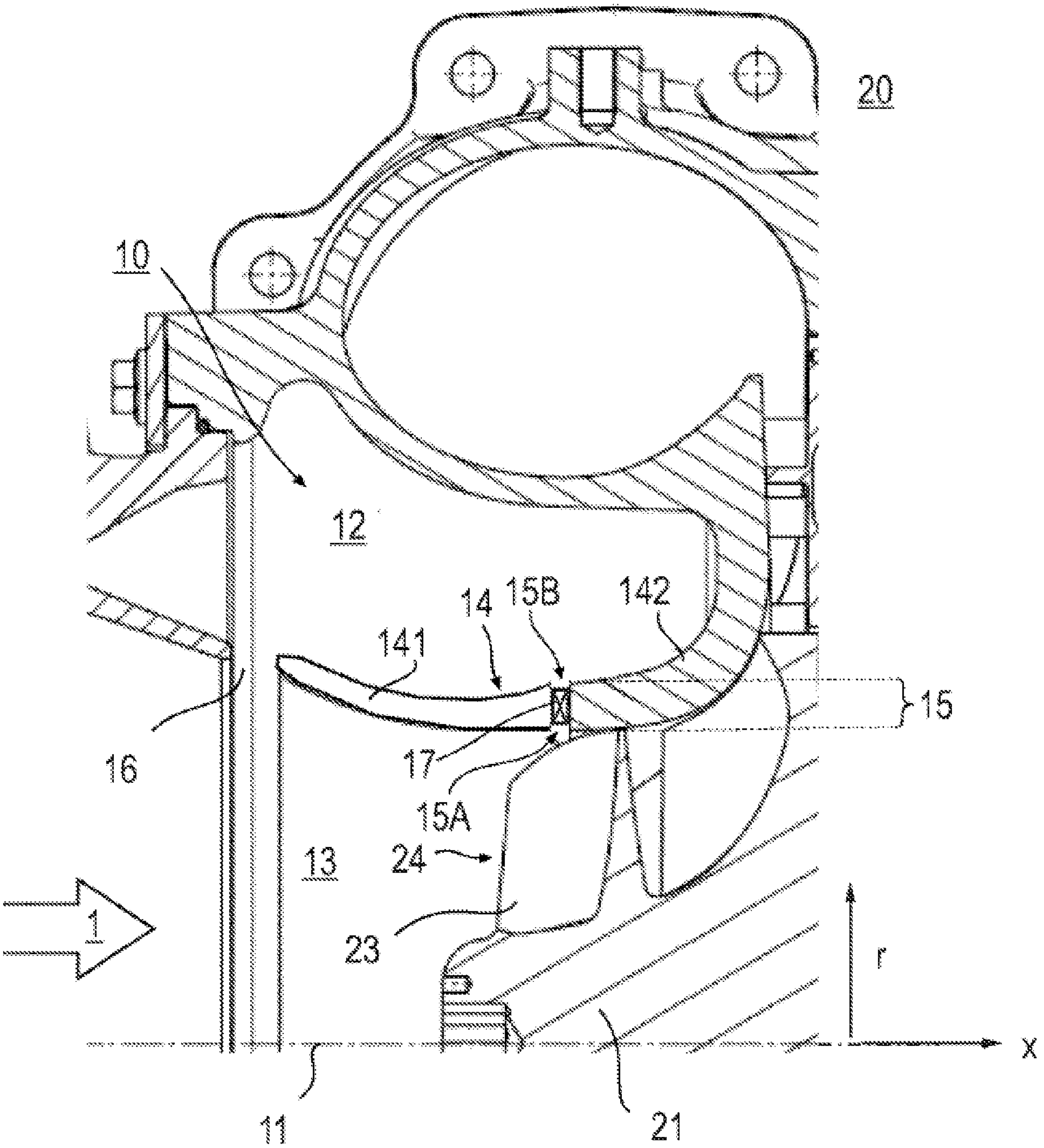
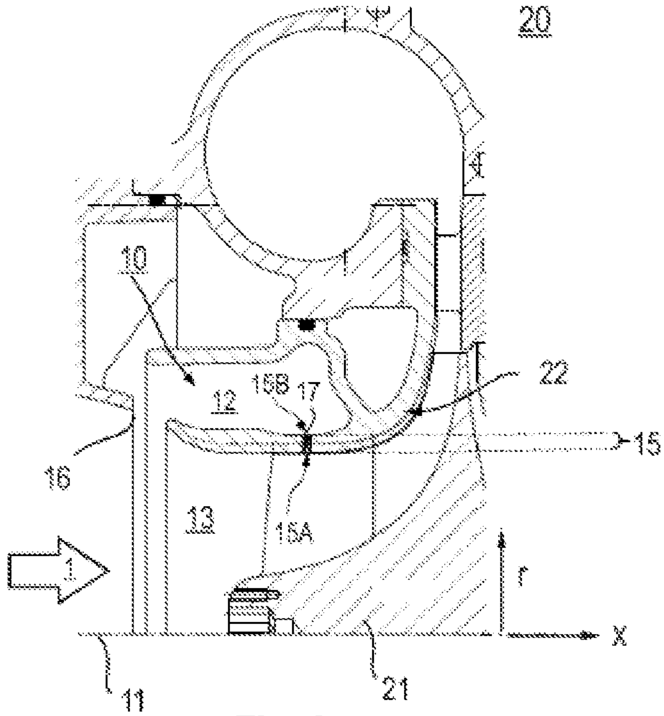
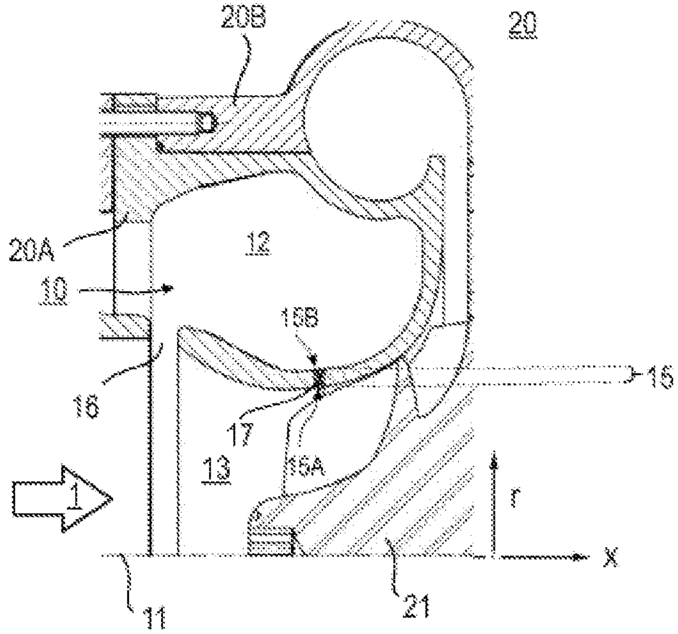


Fig. 2



20
10
12
15B
17
22
15
16
13
15A
1
r
x
11
21

Fig. 3a



20B
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21

Fig. 3b

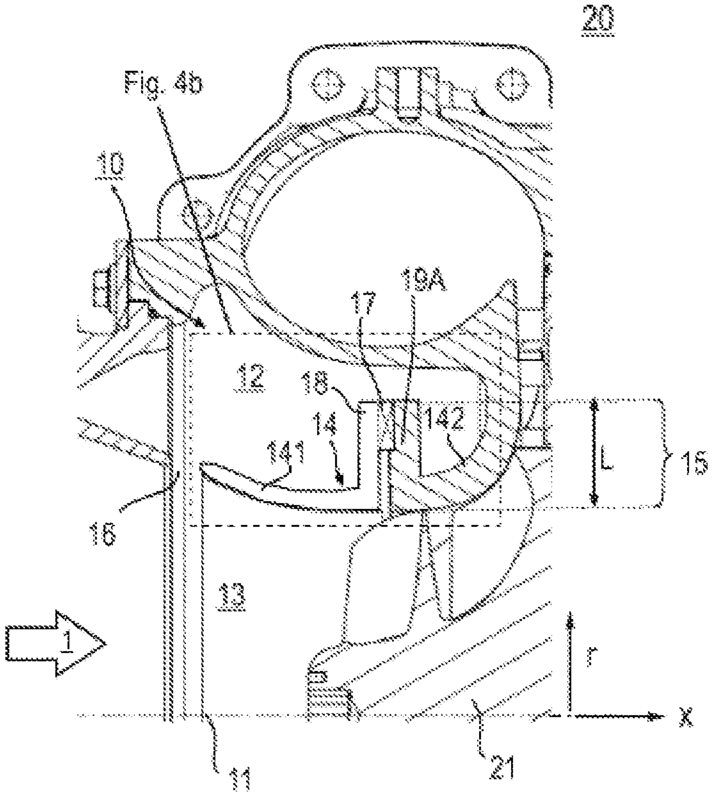
20
Fig. 4b
10
19A
17
12
18
14
142
141
L
15
16
13
1
r
x
11
21

Fig. 4a

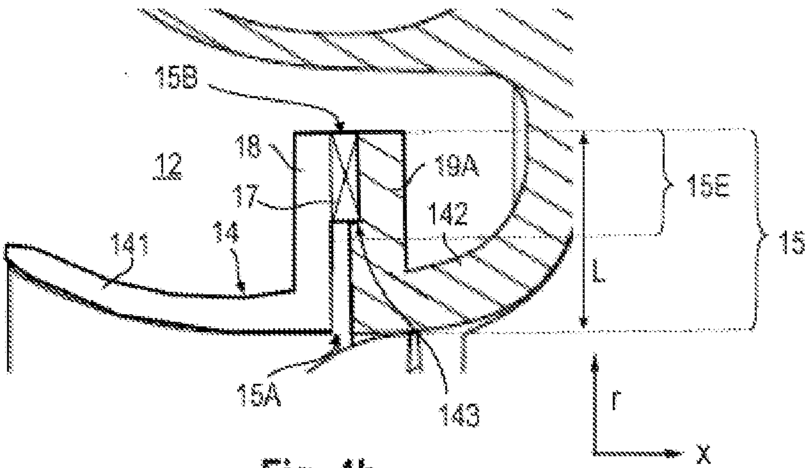
15B
18
12
19A
17
15E
142
141
14
15
L
15A
143
r
x

Fig. 4b

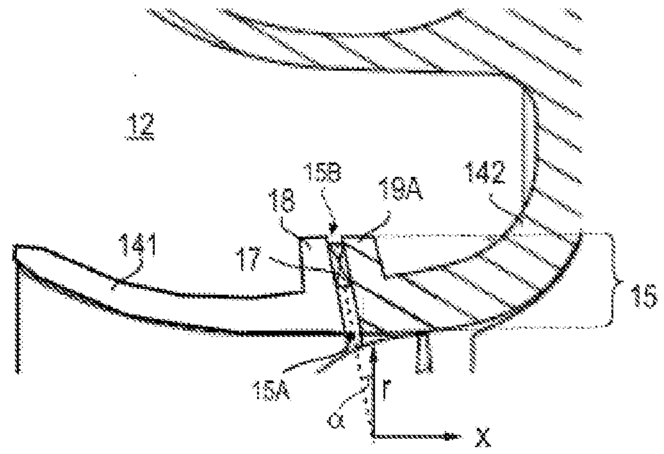
12
15B
19A
142
18
141
17
15
15A
r
α
x

Fig. 5

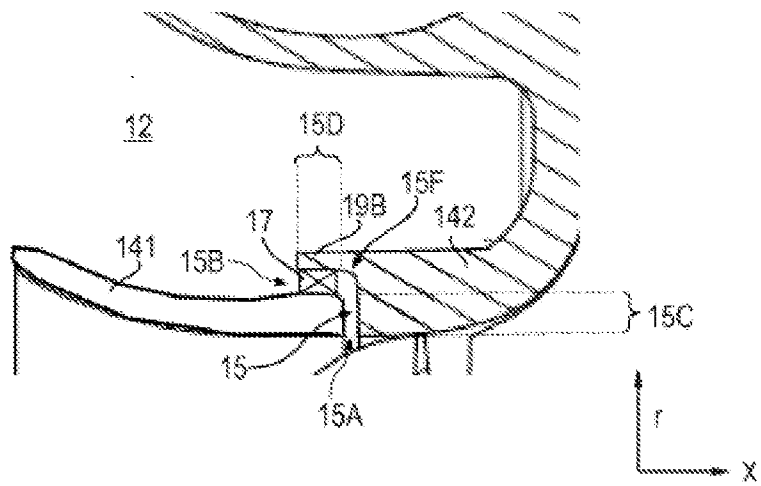
12
15D
17
19B
15F
142
141
15B
15C
15
15A
r
x

Fig. 6

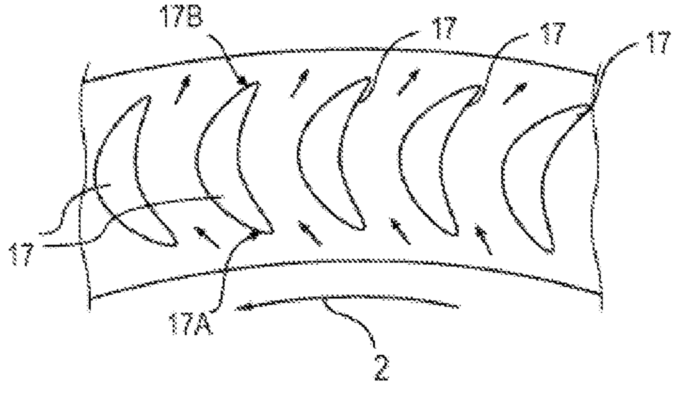

Fig. 7

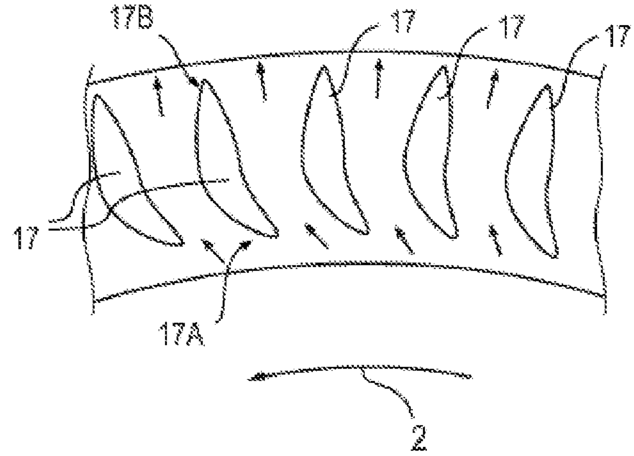

Fig. 8