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(71) Applicant: **Rolls-Royce plc**
London N1 9FX (GB)

(72) Inventor: **Palmer, Chloe**
Derby, DE24 8BJ (GB)

(74) Representative: **Rolls-Royce plc**
Intellectual Property Dept SinA-48
PO Box 31
Derby DE24 8BJ (GB)

(54) CENTRIFUGAL COMPRESSOR

(57) A centrifugal compressor (300) is shown, comprising: an impeller (201a); a rotatably mounted diffuser (202a) surrounding the impeller (201a); and a driving arrangement (301, 303) configured to drive the impeller (201a) and diffuser (202a) to rotate in opposing directions.

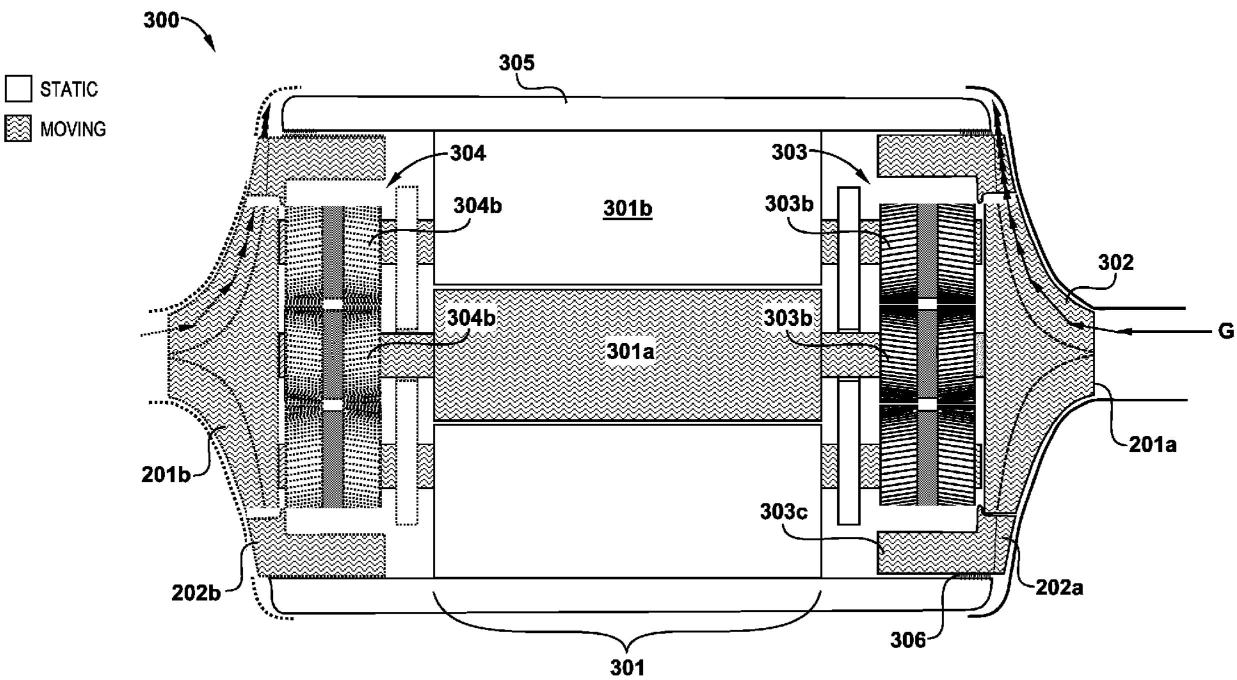

FIG 3

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Description

TECHNICAL FIELD

[0001] This disclosure relates to a centrifugal compressor.

BACKGROUND

[0002] Compressors suitable for compressing low density gases such as helium and hydrogen are typically centrifugal, single-stage, and usually offer low compression ratios. To achieve higher pressure ratios, compressors may be linked together with multiple individual compressors in series. This increases weight and cost, as well as increasing the likelihood of losses. Existing material limits for compressors are generally known and fixed. A titanium impeller for example is limited to its outer edge periphery operating at a maximum speed of around 550 metres per second. Since the speed of sound of helium at atmospheric conditions is over 1000 metres per second, compression is difficult to achieve in a single stage design. Helium in particular suffers from a high ratio of specific heats, meaning that more heat is generated through compression than normal fluids as a result of the molecular degrees of freedom available (three) compared to diatomic molecules (five or six).

SUMMARY

[0003] In an aspect there is provided a centrifugal compressor comprising:

an impeller;
a rotatably mounted diffuser surrounding the impeller; and
a driving arrangement configured to drive the impeller and diffuser to rotate in opposing directions.

[0004] In an embodiment, the driving arrangement may comprise a motor and a gearbox. The gearbox may be an epicyclic gearbox comprising a sun gear, a planetary gear and a ring gear, the impeller being connected to the sun gear and the diffuser connected to the ring gear.

[0005] In an embodiment, a first end of a rotor of the motor may be connected to the sun gear and a stator of the motor fixed relative to the planetary gear.

[0006] In an embodiment, where the impeller is a first impeller, the diffuser is a first diffuser and the epicyclic gearbox a first epicyclic gearbox, the compressor may further comprise:

a second epicyclic gearbox comprising a sun gear, a planetary gear and a ring gear;
a second impeller connected to the sun gear of the second epicyclic gearbox and to a second opposing end of the rotor; and
a second diffuser connected to the ring gear of the second epicyclic gearbox.

[0007] In an embodiment, the driving arrangement may comprise first and second motors, the impeller and diffuser being connected to respective rotors of the first and second motors.

[0008] In an embodiment, the impeller may comprise vanes angled towards a direction of rotation of the impeller. The diffuser may also comprise vanes angled towards a direction of rotation of the diffuser.

[0009] In an embodiment, the centrifugal compressor may further comprise an inlet inducer in an inlet gas path of the compressor.

[0010] In an embodiment, the centrifugal compressor may further comprise a housing surrounding the diffuser and a seal between the housing and the diffuser. The seal may be a labyrinth seal.

[0011] In an embodiment, the centrifugal compressor may be used for the compression of gas. The centrifugal compressor may be used for the compression of neon, or hydrogen, or helium.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Embodiments will now be described by way of example only with reference to the accompanying drawings, which are purely schematic and not to scale, and in which:

Figure 1 is a schematic diagram illustrating example impeller designs with rearward-facing, perpendicular and forward-facing impeller vanes;
Figure 2 is a schematic sectional diagram of an impeller and diffuser arrangement of an example centrifugal compressor; and
Figure 3 is a schematic sectional diagram of an example centrifugal compressor.

DETAILED DESCRIPTION

[0013] Figure 1 illustrates three different example impeller designs for a centrifugal compressor. In each case the impeller 101a-c has a central hub 102a-c and a plurality of radially extending vanes 103a-c. In a first example, the impeller 101a has backward-swept vanes 103a, in which the vanes 103a extend radially from the hub 102a angling against the direction of rotation R, with an angle β between the vanes 103a and a tangent of an outer circumference 104 being less than 90 degrees. In a second example, the impeller 101b has radial vanes 103b that remain in line with a radial direction from the hub 102b, with each vane 103b being perpendicular to the outer circumference 104 such that the angle β is 90 degrees. In a third example, the impeller 101c has forward-swept vanes 103c, in which the vanes 103c extend radially from the hub 102c angling towards the direction of rotation R, with the angle β being greater than 90 degrees. The corresponding velocity triangles below each example indicate the impeller gas exit velocity v_2, which increases as the blade angle β increases. Forward-swept vanes 103c therefore allow for a more rapid acceleration of gas flow and consequently a more rapid pressure increase. This results in an increased compression ratio, allowing for more efficient compression in a single stage. In example embodiments having forward-swept vanes, the angle β may be between around 100 and 170 degrees.

[0014] An end view of an example centrifugal compressor 200 is illustrated in Figure 2. The compressor 200 comprises an impeller 201 and a diffuser 202. The impeller 201 comprises radially outwardly extending vanes 203 that are angled towards a direction of rotation R_I of the impeller 201, i.e. forward-swept. The diffuser 202 comprises radially inwardly extending vanes 205 that are angled towards a direction of rotation R_D of the diffuser 202, i.e. also forward-swept. In conventional applications, the diffuser 202 will be fixed and the impeller rotatable, the compressor 200 comprising a motor configured to drive the impeller 201. In the present embodiment, however, both the impeller 201 and diffuser 202 are rotatable and the compressor 200 is configured to rotate the impeller 201 and diffuser 202 in opposing directions. An advantage of this arrangement is that there is a higher relative tip speed between the impeller and diffuser. With the above-mentioned material limits providing an upper limit on the tip speed of the impeller vanes, the higher relative speed allows for a relative tip speed to be up to Mach 1 even for low density gases such as helium, compared to traditional impellers where the tip speed may be limited to Mach 0.5 or lower. Using such a contra-rotating impeller-diffuser arrangement, the relative speed between the impeller 201 and diffuser 202 can effectively be doubled, allowing not only more efficient compression in a single stage, but also allowing existing materials to be used.

[0015] Figure 3 illustrates an example centrifugal compressor 300 comprising a contra-rotating impeller and diffuser arrangement. As indicated in the Figure, static parts are non-patterned whilst moving components are patterned. The compressor 300 comprises a first impeller 201a and a first diffuser 202a. Gas G to be compressed enters the compressor 300 through a gas path 302, which passes through the impeller 201a and diffuser 202a and exits the compressor 300 from an outer circumference of the diffuser 202a.

[0016] A driving arrangement is configured to drive the impeller 201a and diffuser 202a in opposing directions. The driving arrangement comprises a motor 301 and a gearbox 303. The motor 301 drives the impeller 201a and diffuser 202a in opposing directions via the gearbox 303. In this example the gearbox 303 is an epicyclic gearbox comprising a sun gear 303a, a plurality of planetary gears 303b and a ring gear 303c. The sun gear 303a is driven by the rotor 301a of the motor 301. In alternative arrangements the motor 301 may drive the ring gear 303c instead. The planetary gears 303b are fixed relative to each other and to the stator 301b of the motor 301, which causes the outer ring gear 303c to rotate in an opposing direction to the sun gear 303a. A ratio between the rotational speeds of the ring gear 303c and sun gear 303a is selectable by selecting the relative sizes of the gears 303a-c. The rotor 301a and sun gear 303a are connected to the impeller 201a, while the ring gear 303c is connected to the diffuser 202a. The ring gear 303c may be integral with the diffuser 202a or may be separate components that are joined to each other.

[0017] A second impeller 201b and a second diffuser 202b is also be driven by the same motor 301 via a second gearbox 304. In this way, axial loads may be balanced. The second gearbox 304 is similar to the first gearbox 303 in having a sun gear 304a connected to the impeller 201b and to an opposing end of the rotor 301a, planetary gears 304b fixed relative to the stator 301b and an outer ring gear 304c connected to the diffuser 202b.

[0018] Alternative examples which are outside the scope of the present application may include separate motors driving the impeller 201a and diffuser 202a. An advantage of using a single motor is that the compressor may be made more compact.

[0019] The compressor 300 comprises a housing 305 surrounding the motor 301 and diffuser 202a. The housing may also define the gas path 302. A seal is required between the housing 305 and the diffuser 202a that prevents gas from leaking away from the gas path 302. The seal may be in the form of a labyrinth seal 306 used between the ring gear 303c and the housing 305. Other ways of sealing against the housing 305 may alternatively be used, such as an air bearing seal.

[0020] In some examples, an inlet inducer may be provided in the gas path 302 leading to the impeller 201a to increase a static pressure of gas entering the compressor 300.

[0021] Using a single motor 301 to drive impellers 201a, 201b and diffusers 202a, 202b at opposing ends of the rotor 301a has a further advantage of allowing high aerodynamic load stresses to be better managed as well as providing improved gas sealing, which is particularly difficult for low density gases such as helium. In alternative examples a single-sided compressor may be sufficient.

[0022] A centrifugal compressor 200 of the type disclosed herein may be particularly useful for compressing gases that are normally more difficult to compress such as neon, hydrogen, and helium. A compressor of the type disclosed herein may also enable smaller and lighter compressors for other gases, particularly where fixed pressure ratios are desired.

[0023] Various examples have been described, each of which comprise various combinations of features. It will be appreciated by those skilled in the art that, except where clearly mutually exclusive, any of the features may be employed separately or in combination with any other features and thus the disclosed subject-matter extends to and includes all such combinations and sub-combinations of the or more features described herein.

Claims

1. A centrifugal compressor (300) comprising:

   a first impeller (201a);
   a first rotatably mounted diffuser (202a) surrounding the first impeller (201a); and
   a driving arrangement (301, 303) configured to drive the first impeller (201a) and first diffuser (202a) to rotate in opposing directions, the driving arrangement comprising a motor (301) and a first epicyclic gearbox (303) comprising a sun gear (303a), a planetary gear (303b) and a ring gear (303c), the first impeller (201) being connected to the sun gear (303a) and the first diffuser (202) connected to the ring gear (303c), the compressor (300) further comprising:

      a second epicyclic gearbox (304) comprising a sun gear (304a), a planetary gear (304b) and a ring gear (304c);
      a second impeller (201b) connected to the sun gear (304a) of the second epicyclic gearbox (304) and to a second opposing end of the rotor (301a); and
      a second diffuser (202b) connected to the ring gear (304c) of the second epicyclic gearbox (304); wherein
      a first end of a rotor (301a) of the motor (301) is connected to the sun gear (303a) of the first epicyclic gearbox (303) and a second end of the rotor (301a) of the motor (301) is connected to the sun gear (304a) of the second epicyclic gearbox (304) and a stator (301b) of the motor (301) is fixed relative to the planetary gear (303b).

2. The centrifugal compressor (300) of claim 1, wherein the first and second impeller (201a, 201b) each comprises vanes angled towards a direction of rotation of the respective impeller.

3. The centrifugal compressor (300) of any preceding claim, wherein the first and second diffuser (202a, 202b) each comprises vanes angled towards a direction of rotation of the respective diffuser.

4. The centrifugal compressor (300) of any preceding claim, further comprising an inlet inducer in an inlet gas path of the compressor (300).

5. The centrifugal compressor (300) of any preceding claim further comprising a housing (305) surrounding the diffuser (202a) and a seal between the housing and the diffuser (202a).

6. The centrifugal compressor (300) of claim 10, wherein the seal is a labyrinth seal (306).

7. Use of the centrifugal compressor (300) of any preceding claim.

8. Use of the centrifugal compressor (300) of any preceding claim for the compression of neon.

9. Use of the centrifugal compressor (300) of any preceding claim for the compression of hydrogen.

10. Use of the centrifugal compressor (300) of any preceding claim for the compression of helium.

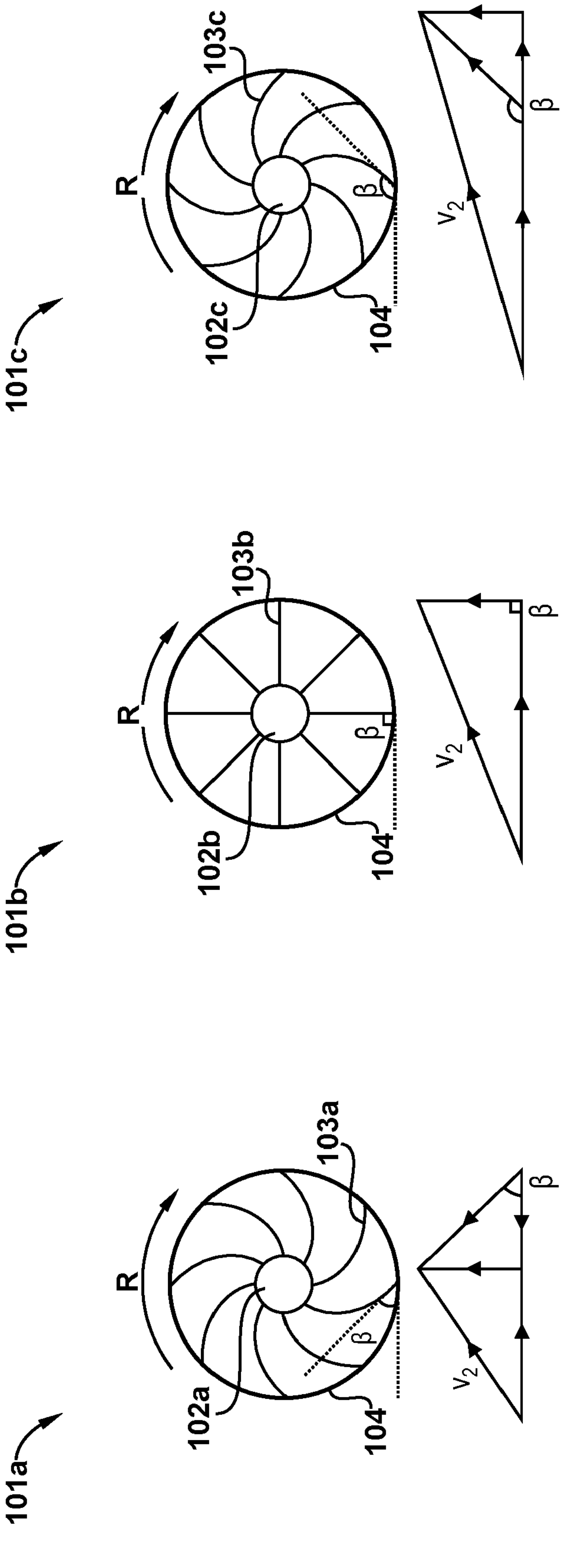

FIG 1

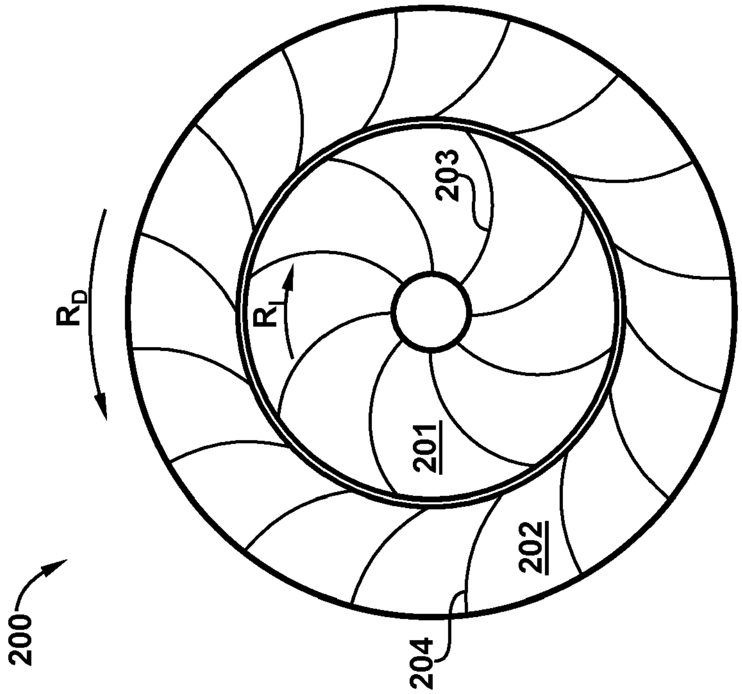

FIG 2

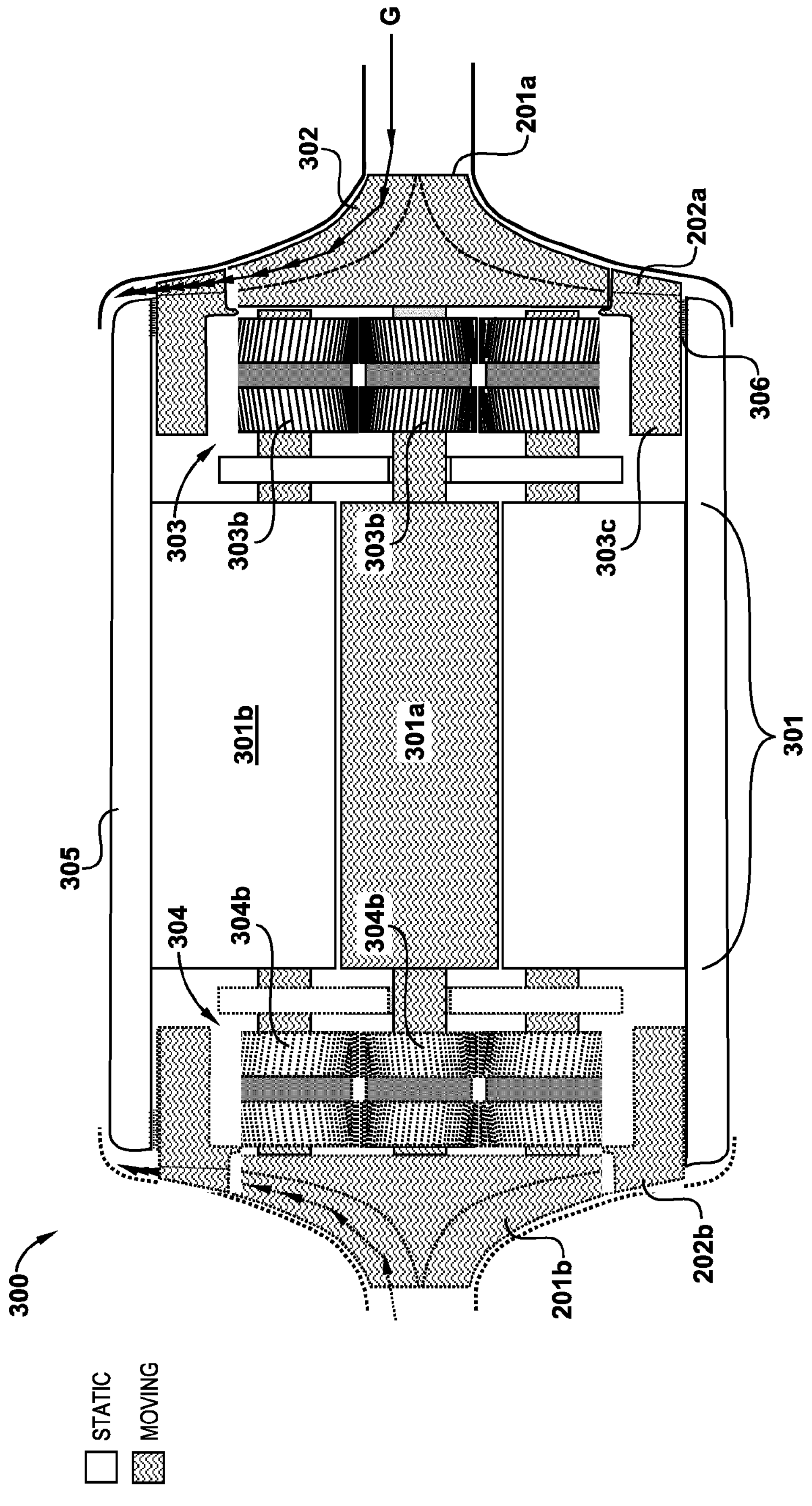
G
201a
302
202a
306
303
303b
303b
303c
301b
301a
301
305
304
304b
304b
300
201b
202b
STATIC
MOVING

FIG 3

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EUROPEAN SEARCH REPORT

Application Number
EP 22 19 0384

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A	US 9 371 835 B2 (STANKO MICHAEL J [US]; SCHWARZ CARL L [US] ET AL.) 21 June 2016 (2016-06-21) * column 1, line 15 - column 2, line 8 * * figure 1 *	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

F04D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	20 January 2023	Lovergine, A

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CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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