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- (54) Benævnelse: **Elektrisk generator til vindkraftturbine og vindkraftturbine udstyret med en sådan elektrisk generator**
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EP-A1- 2 063 116
FR-A1- 2 613 148
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DESCRIPTION

[0001] The present invention relates to a wind power turbine electric generator.

[0002] Preferably, the present invention relates to an electric generator for a direct-drive wind power turbine.

[0003] An electric generator normally comprises a tubular first supporting structure extending about an axis of rotation; a second supporting structure extending about the axis of rotation, substantially coaxial with the first supporting structure, and fitted to the first supporting structure to rotate about the axis of rotation; first active parts fitted to the first supporting structure; and second active parts fitted to the second supporting structure, facing the first active parts, and separated from the first active parts by an annular gap.

[0004] Electric generators of the above type are known and used widely on wind power turbines. More recently, permanent-magnet synchronous electric generators have also been used, particularly on direct-drive wind power turbines, i.e. comprising a blade assembly connected directly to the electric generator, with no gearboxes in between. Examples of direct-drive wind power turbines equipped with permanent-magnet synchronous electric generators are described in documents EP 1,425,840; EP 1,792,381; EP 2,102,496; EP 2,063,115; EP 2,063,116; EP 2,063,117; EP 2,143,938; EP 2,143,942; and EP 2,143,944.

[0005] Though direct-drive wind power turbines are more efficient mechanically and cheaper to maintain than gearbox types, and synchronous electric generators are more efficient electrically than asynchronous types, direct-drive wind power turbines are characterized by fairly low rotation speed, which, combined with the need for more and more electric power, makes it necessary to employ permanent-magnet synchronous electric generators with numerous poles and a high maximum torque, and therefore large-size electric generators which can pose structural problems.

[0006] The first supporting structure and first active parts define the stator or rotor of the electric generator, and the second supporting structure and second active parts define the rotor or stator, so the larger the electric generator is, the larger the first and second supporting structures are. Moreover, because it weighs on the wind power turbine structure as a whole, the weight of the electric generator must be maintained within given limits, over and above which a larger, more expensive wind power turbine is needed. Also, it is preferable that the first and second supporting structure not be too massive or heavy.

[0007] The first supporting structure is often defined by a tubular structure which, besides supporting the first active parts, also defines a load-bearing structural element of the wind power turbine as a whole, as shown, for example, in EP 1,425,840 and EP 2,102,496. As a result, the first supporting structure is subject to a normally small amount of strain, particularly during assembly but also possibly during operation of the electric generator. Even a small amount of strain of the first supporting structure, however, may have serious effects, by modifying the annular gap between the first and second active parts and so impairing operation of the electric generator. The normal practice, in fact, is to minimize the radial size of the annular gap to increase the efficiency of the electric generator and reduce flux dispersion, but it is often necessary to oversize the annular gap to prevent strain of the first supporting structure from affecting the electric generator. An example of control of the first supporting structure is given in JP 56-081053. However the device disclosed in there is not adequate for being installed on wind turbine and do not provide the necessary accuracy.

[0008] It is an object of the present invention to provide an electric generator designed to reduce the drawbacks of the known art.

[0009] Another object of the present invention is to provide an electric generator designed to give maximum efficiency when installed on a wind power turbine.

[0010] According to the present invention, there is provided an electric generator for a wind power turbine; the electric generator comprising :

- a tubular first supporting structure extending about an axis of rotation;
- a second supporting structure extending about the axis of rotation, substantially coaxial with the first supporting structure, and fitted to the first supporting structure to rotate about the axis of rotation;
- first active parts fitted to the first supporting structure;
- second active parts fitted to the second supporting structure, facing the first active parts, and separated from the first active parts by an annular gap; and
- a radial tensioning device designed to adjust the shape of the first supporting structure about the axis of rotation;

wherein the radial tensioning device comprises an annular plate; and a number of radial arms extending from the annular plate to the first supporting structure; characterized in that each radial arm is fixed releasably to the first supporting structure.

[0011] The circular shape of the first supporting structure can thus be adjusted to control and if necessary correct the radial size of the annular gap.

[0012] The annular plate thus provides a high degree of structural rigidity, while the radial arms allow forces to be exchanged between different parts of the first supporting structure, and permit local deformation of the first supporting structure to correct any flaws in its circular shape.

[0013] More specifically, each radial arm is connected to the annular plate to slide radially with respect to the axis of rotation, and is fixable to the annular plate.

[0014] In another preferred embodiment of the present invention, the electric generator comprises a bearing between the radial tensioning device and the second supporting structure.

[0015] The radial tensioning device thus provides for correcting the circular shape of the first supporting structure, and coaxial alignment of the first and second supporting structure.

[0016] A number of non-limiting embodiments of the present invention will be described by way of example with reference to the accompanying drawings, in which :

Figure 1 shows a side view, with parts removed for clarity, of a wind power turbine;

Figure 2 shows a larger-scale, partly sectioned side view, with parts removed for clarity, of the Figure 1 wind power turbine;

Figure 3 shows a larger-scale, partly sectioned view in perspective, with parts removed for clarity, of a detail in Figure 2;

Figure 4 shows a front view, with parts removed for clarity, of a detail in Figure 2;

Figure 5 shows a partly sectioned view in perspective, with parts removed for clarity, of an alternative embodiment of the present invention.

[0017] Number 1 in Figure 1 indicates as a whole a direct-drive wind power turbine for generating electric power, and which comprises a vertical support 2; a nacelle 3; an electric generator 4; and a rotary assembly 5 fitted to nacelle 3 to rotate about an axis of rotation A1. Nacelle 3 is in turn fitted to vertical support 2 to rotate about an axis of rotation A2; and, in the example shown, electric generator 4 is a permanent-magnet synchronous electric generator.

[0018] Nacelle 3 is substantially a tubular member supporting rotary assembly 5, which extends partly inside and partly outside nacelle 3. In the example shown, nacelle 3 comprises a curved tubular member 6; part of electric generator 4; and a ring 7 comprising two complementary sectors 8 and 9 connected about axis of rotation A1.

[0019] With reference to Figure 2, electric generator 4 is tubular, and comprises a stator 10 and a rotor 11. Stator 10 comprises a tubular supporting structure 12; and active parts 13 - in the example shown, stator segments - arranged about axis of rotation A1 and fixed to the inner face of supporting structure 12. Rotor 11 comprises a tubular supporting structure 14; and active parts 15 - in the example shown, rotor segments - arranged about axis of rotation A1 and fixed to the outer face of supporting structure 14. And nacelle 3, more specifically, comprises curved tubular member 6; stator 10, or rather supporting structure 12 of stator 10; and ring 7.

[0020] Active parts 13 comprise stator segments parallel to axis of rotation A1. Each stator segment comprises a magnetic gap and at least one electric winding, and is of the type described in EP 1,792,381.

[0021] Active parts 15 comprise rotor segments parallel to axis of rotation A1. Each rotor segment comprises a magnetic gap and permanent magnets, and is of the type described in EP 1,792,381.

[0022] Supporting structure 12 has two opposite flanged ends fixed to curved tubular member 6 and ring 7 by respective bolted joints 16 and 17. More specifically, ring 7 is fitted slidably to supporting structure 12, and is locked in position by bolted joint 17. More specifically, sectors 8 and 9 are each semicircular in shape, and are connected by two bolted joints 18 to form ring 7. In the

example shown, sector 8 is located below sector 9. Wind power turbine 1 comprises a bearing 19 between nacelle 3 and rotary assembly 5. In the example shown, wind power turbine 1 comprises a single bearing 19 capable of withstanding axial and radial stress between nacelle 3 and rotary assembly 5; it being understood, however, that the specific configuration shown in the drawings and described herein in no way limits the protective scope of the present invention. Bearing 19 is fitted to the inside of ring 7, is fixed directly to sectors 8 and 9 in the example shown, and is fixed to the outside of rotary assembly 5.

[0023] Rotary assembly 5 comprises rotor 11, a hub 20, and blades 21 fitted to hub 20. In the example shown, rotary assembly 5 also comprises a connecting member 22 located between rotor 11 and hub 20, and at and substantially inside bearing 19. More specifically, bearing 19 is fixed directly to connecting member 22; and hub 20 is connected directly to rotor 11, which rotates at the same speed as hub 20.

[0024] Electric generator 4 generally comprises supporting structure 12, which extends about axis of rotation A1; supporting structure 14, which extends about axis of rotation A1, is substantially coaxial with supporting structure 12, and is fitted to supporting structure 12 to rotate about axis of rotation A1; active parts 13 fitted to supporting structure 12; and active parts 15 fitted to supporting structure 14, facing active parts 13, and separated from active parts 13 by an annular gap. Electric generator 4 also comprises a radial tensioning device 23 designed to adjust the shape of supporting structure 12 about axis of rotation A1, i.e. to correct any deformation, ovalization, or any other flaw in the circular shape of the inner face of supporting structure 12, so as to maintain as circular a shape as possible of supporting structure 12.

[0025] In the example shown, radial tensioning device 23 is located inside supporting structure 12 and is annular in shape.

[0026] More specifically, and as shown in Figure 3, radial tensioning device 23 comprises an annular plate 24; and a number of radial arms 25 extending from annular plate 24 to supporting structure 12, and equally spaced about axis of rotation A1.

[0027] Each radial arm 25 is connected to annular plate 24 to slide radially with respect to axis of rotation A1 (Figure 2), and is fixable to annular plate 24.

[0028] Radial tensioning device 23 comprises a number of adjusting mechanisms 26, each associated with a respective radial arm 25 to slide radial arm 25 radially with respect to annular plate 24. That is, annular plate 24 comprises a number of seats 27, each for housing a respective radial arm 25; each adjusting mechanism 26 comprises a screw 28 housed inside annular plate 24 and for pushing respective radial arm 25 outwards against supporting structure 12; and each radial arm 25 is fixed releasably to supporting structure 12.

[0029] Each radial arm 25 comprises a projection 29 located between supporting structures 12 and 14, close to supporting structure 14, and designed to prevent relative radial movements between supporting structures 12 and 14. In other words, projection 29 is made of low-friction material to permit relative rotation between supporting structures 12 and 14, even when projection 29 is positioned contacting supporting structure 14.

[0030] With reference to Figure 2, active parts 13 and active parts 15 are in the form of segments extending parallel to axis of rotation A1, and are equal in number. The number of radial arms 25 is less than or equal to the number of active parts 13 and active parts 15, so that removal of one radial arm 25 extracts at least one segment of active parts 13 or one segment of active parts 15. The number of radial arms 25 may even be a multiple of, e.g. twice, the number of active parts, so that removing two radial arms 25 extracts a segment of active parts 13 or a segment of active parts 15, though this solution is not as advantageous as the previous one.

[0031] Accordingly, annular plate 24 has an outer edge 30 smaller in diameter than the maximum diameter of supporting structure 12, so as not to obstruct extraction of the segments of active parts 15; and an inner edge 31 defining a manhole opening.

[0032] With reference to Figure 3, electric generator 4 comprises a brake 32; and locking devices 33 (only one shown in Figure 3) arranged about axis of rotation A1. Brake 32 comprises a brake disk 34; and a number of brake calipers 35 (only one shown in Figure 3) arranged about axis of rotation A1. Brake disk 34 is integral with supporting structure 14, and is defined by an annular plate parallel to annular plate 24 and extending inside supporting structure 14. Each brake caliper 35 comprises a frame 36 fixed to annular plate 24; two jaws 37 mounted on opposite sides of brake disk 34; and an actuating mechanism 38 for activating jaws 37 (only one shown in Figure 3) to selectively grip brake disk 34. Each locking device 33 comprises a pin 39; and an actuator 40 fixed to annular plate 24 to move pin 39 between a rest position (Figure 3) and a work position (not shown). And brake disk 34 comprises a number of holes 41 arranged about axis of rotation A1 and engaged by pin 39 when pin 39 is in the work position.

[0033] Figure 4 shows electric generator 4 in a locked configuration, i.e. in which locking devices 33 lock supporting structures 12 and 14 with respect to each other. Also, electric generator 4 is less one radial arm 25 and fitted with an extracting device 42, which is fitted to the two radial arms 25 adjacent to the missing radial arm 25, and serves to extract a segment of active parts 13 and/or 15 at the missing radial arm.

[0034] The outer face of supporting structure 12 is fitted with cooling fins F.

[0035] In Figure 5, radial tensioning device 23 is replaced by a radial tensioning device 43, which, in addition to correcting the circular shape of supporting structure 12, also serves to connect supporting structures 12 and 14 in rotary manner about axis of rotation A1.

[0036] Like radial tensioning device 23, radial tensioning device 43 comprises an annular plate 44; and a number of radial arms 45 extending from annular plate 44 to supporting structure 12, and equally spaced about axis of rotation A1. Each radial arm 45 is connected to annular plate 44 to slide radially with respect to axis of rotation A1 (Figure 2), and is fixable to annular plate 44. Radial tensioning device 43 comprises a number of adjusting mechanisms 46, each associated with a respective radial arm 45 to slide radial arm 45 radially with respect to annular plate 44. In the Figure 5 example, annular plate 44 comprises openings 47 designed and located to enable use of adjusting mechanisms 46 similar to adjusting mechanisms 26. And annular plate 44 comprises an outer edge 48 and an inner edge 49 of the same size as outer edge 30 and inner edge 31 (Figure 3).

[0037] Electric generator 4 comprises a bearing 50 between radial tensioning device 43 and supporting structure 14. That is, inner edge 49 of radial tensioning device 43 contacts bearing 50; and rotor 11 comprises a ring 51 located inside bearing 50, and a flange 52 connecting ring 51 to supporting structure 14. Electric generator 4 also comprises a disk 53 fixed to ring 51, and which may also be used as a brake disk. Generally speaking, radial tensioning device 43 can be fitted with a brake and locking devices 33 as shown in Figures 3 and 4 of the previous embodiment of the invention.

[0038] The radial tensioning device in the Figure 5 embodiment provides for simultaneously adjusting the circular shape of supporting structure 12, and coaxial alignment of supporting structures 12 and 14.

[0039] Clearly, changes may be made to the electric generator and wind power turbine as described herein without, however, departing from the scope of the accompanying Claims.

[0040] More specifically, in a variation not shown, ring 7 is eliminated, and stator 10 and bearing 19 are connected in accordance with alternative embodiments, as described, for example, in Patent EP 1,425,840.

[0041] In the above description, specific reference is made repeatedly, for the sake of simplicity, to bolted joints, which are intended to mean joints made using bolts and nuts, or screws screwed directly into one of the parts for connection, and may be replaced by any other type of releasable joint.

REFERENCES CITED IN THE DESCRIPTION

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- [EP2102496A](#) [0004] [0007]
- [EP2063115A](#) [0004]
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- EP2143942A [0004]
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- JP56081053A [0007]

PATENTKRAV

1. Elektrisk generator til en vindkraftturbine; hvilken elektriske generator (4) omfatter:
- en rørformet første støttestruktur (12), som strækker sig omkring en rotations-
akse (A1);
 - en anden støttestruktur (14), som strækker sig omkring rotationsaksen (A1) i
det væsentlige koaksialt med den første støttestruktur (12) og er monteret til
den første støttestruktur (12) til at rotere omkring rotationsaksen (A1);
 - første aktive dele (13), som er monteret til den første støttestruktur (12);
 - andre aktive dele (15), som er monteret til den anden støttestruktur (14) og
vender mod de første aktive dele (13) og er adskilt fra de første aktive dele (13)
med et ringformet mellemrum; og
 - en radial spændeanordning (23; 43), som er udformet til at indstille formen af
den første støttestruktur (12) omkring rotationsaksen (A1);
- hvor den radiale spændeanordning (23; 43) omfatter en ringformet plade (24; 44);
og et antal radiale arme (25; 45), som strækker sig fra den ringformede plade (24;
44) til den første støttestruktur (12); kendetegnet ved, at hver radial arm (25; 45) er
fastgjort aftageligt til den første støttestruktur (12).
2. Elektrisk generator ifølge krav 1, hvor den radiale spændeanordning (23; 43) be-
finder sig inde i den første støttestruktur (12).
3. Elektrisk generator ifølge krav 1 eller 2, hvor den radiale spændeanordning (23;
43) er ringformet.
4. Elektrisk generator ifølge et hvilket som helst af de foregående krav, hvor hver
radial arm (25; 45) er forbundet til den ringformede plade (24; 44) til at glide radiale i
forhold til rotationsaksen (A1) og kan fastgøres til den ringformede plade (24; 44).
5. Elektrisk generator ifølge krav 4, hvor den radiale spændeanordning (23; 43) om-
fatter et antal justeringsmekanismer (26; 46), som hver er forbundet med en radial
arm (25; 45) til at få den radiale arm (25; 45) til at glide i forhold til den ringformede
plade (24; 44).

- 5 6. Elektrisk generator ifølge et hvilket som helst af de foregående krav, hvor hver radial arm (25) omfatter et fremspring (29), som befinder sig mellem den første og den anden støttestruktur (12, 14) nær ved den anden støttestruktur (14) for at forhindre relative radiale bevægelser mellem den første og den anden støttestruktur (12, 14).
- 10 7. Elektrisk generator ifølge et hvilket som helst af de foregående krav, hvor antallet af de første aktive dele (13) og de andre aktive dele (15) er lige stort, mens antallet af radiale arme (25; 45) er mindre end eller lig med antallet af første aktive dele (13) eller er et multiplum af de første aktive dele (13).
- 15 8. Elektrisk generator ifølge et hvilket som helst af de foregående krav og omfattende mindst én låseanordning (33), som parallelt med rotationsaksen omfatter en stift (39), som er understøttet af den ringformede plade (24) og kan bevæges selektivt parallelt med rotationsaksen (A1); og en skive (35), som er parallel med den ringformede plade (24) og har mindst ét hul (41), som går i indgreb med stiften (39), når stiften (39) er i arbejdspositionen.
- 20 9. Elektrisk generator ifølge et hvilket som helst af de foregående krav og omfattende en bremse (32), som parallelt med den ringformede plade (24) omfatter en bremseskive (34), der er fastgjort til den anden støttestruktur (14); og mindst én bremsekaliber (35), som er monteret til den ringformede plade (24) og omfatter to kæber (37) til selektivt at gribe fat i bremseskiven (34).
- 25 10. Elektrisk generator ifølge et hvilket som helst af kravene 1 til 8 og omfattende et leje (50), som befinder sig mellem den radiale spændeanordning (43) og den anden støttestruktur (14).
- 30 11. Elektrisk generator ifølge et hvilket som helst af de foregående krav, hvor den anden støttestruktur (14) fortrinsvis er rørformet.
- 35 12. Vindkraftturbine, som omfatter en vertikal struktur (2); en nacelle (3) oven på den vertikale struktur (2); en bladsamling (5), som på roterende måde er monteret til nacellen (3); og en elektrisk generator (4) ifølge et hvilket som helst af de foregående krav.

13. Vindkraftturbine ifølge krav 12, hvor bladsamlingen (5) er forbundet direkte til den anden støttestruktur (14).

5 14. Vindkraftturbine ifølge krav 12 eller 13, hvor den første støttestruktur (12) delvist definerer nacellen (3).

15. Vindkraftturbine ifølge et hvilket som helst af kravene 12 til 14 og omfattende kølefiner (F) langs med den ydre flade af den første støttestruktur (12).

DRAWINGS

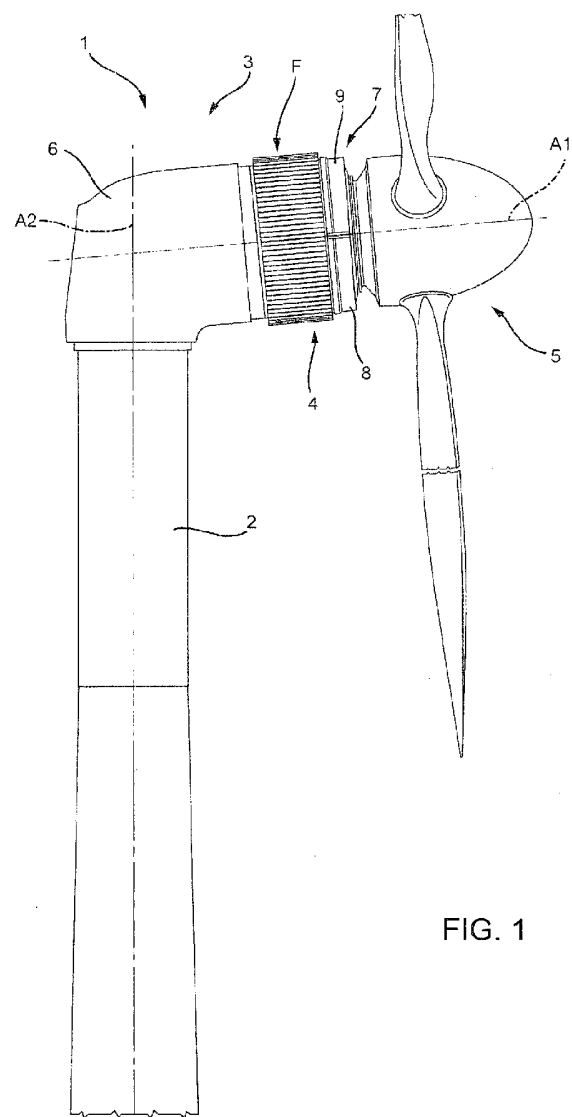


FIG. 1

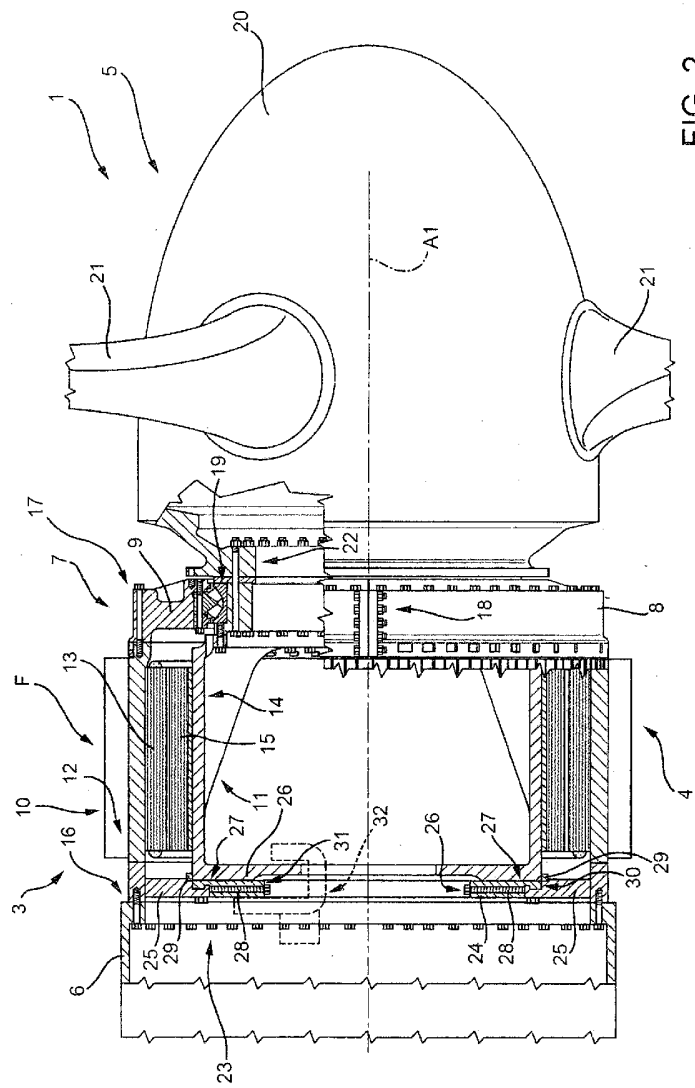
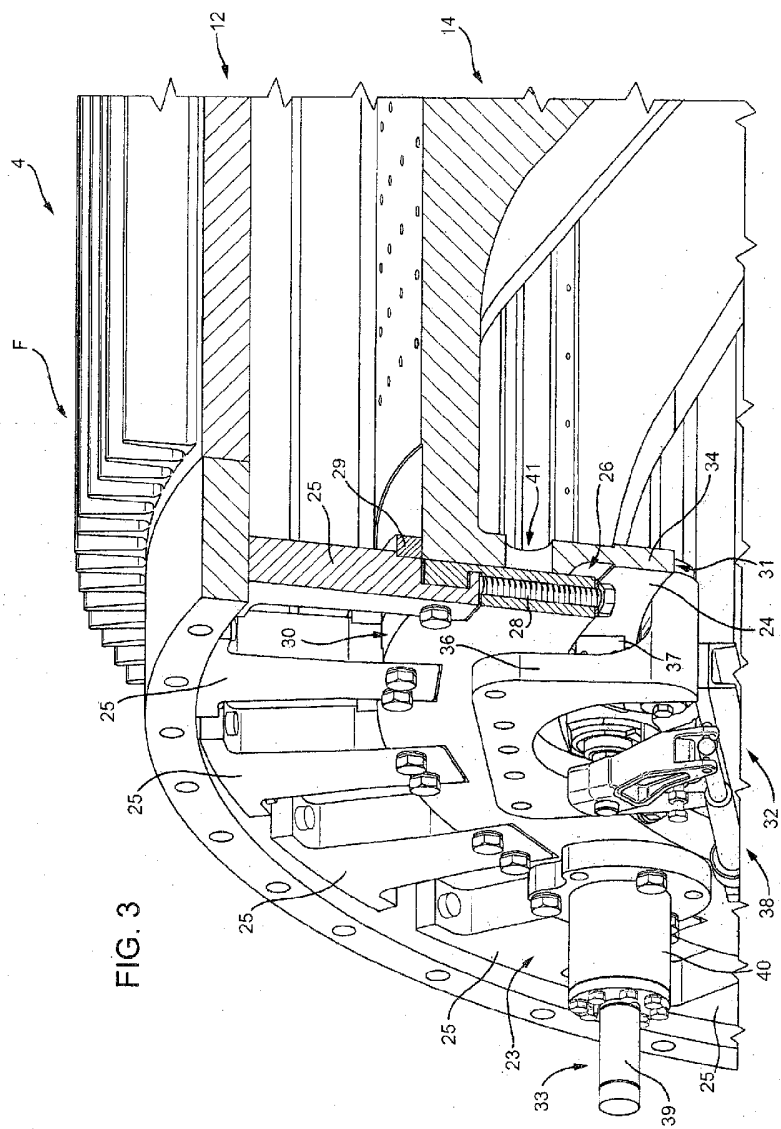


FIG. 2



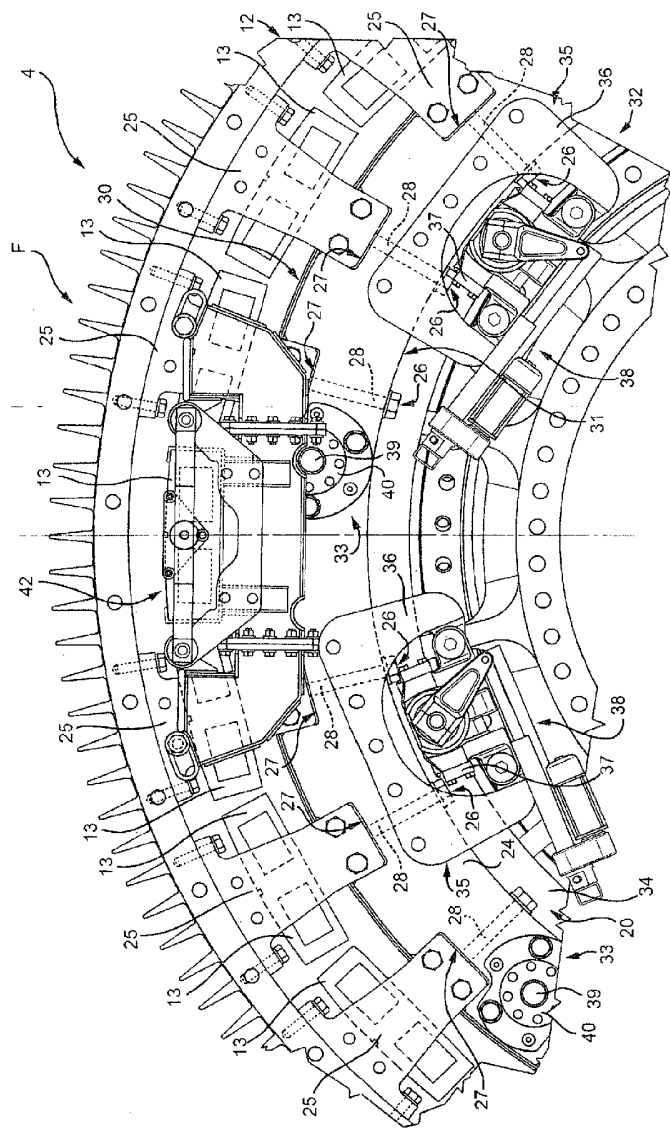


FIG. 4

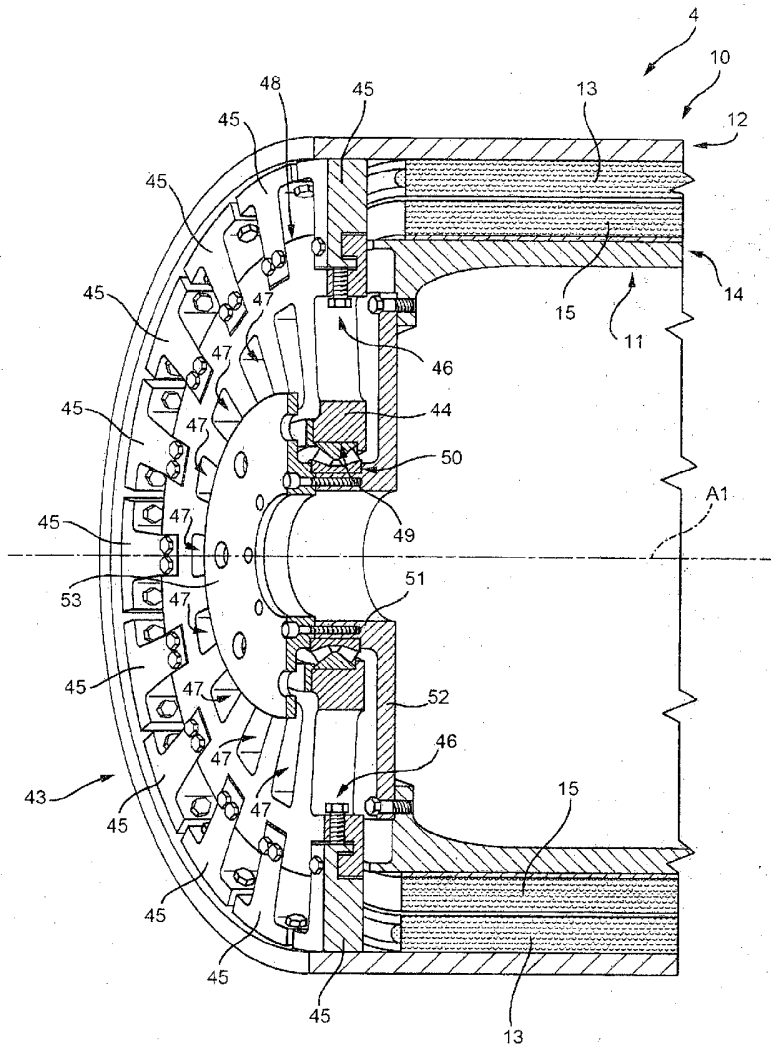


FIG. 5