

(19) **DANMARK**

(10) **DK/EP 2577058 T3**



(12) **Oversættelse af
europæisk patentskrift**

Patent- og
Varemærkestyrelsen

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- (51) Int.Cl.: **F 03 D 80/00 (2016.01)** **F 03 D 13/00 (2016.01)** **H 02 G 3/30 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2016-09-26**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2016-08-10**
- (86) Europæisk ansøgning nr.: **11723075.5**
- (86) Europæisk indleveringsdag: **2011-06-03**
- (87) Den europæiske ansøgnings publiceringsdag: **2013-04-10**
- (86) International ansøgning nr.: **EP2011059230**
- (87) Internationalt publikationsnr.: **WO2011151465**
- (30) Prioritet: **2010-06-03 DE 102010022581**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
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- (54) Benævnelse: **TÅRN TIL EN VINDMØLLE**
- (56) Fremdragne publikationer:
JP-A- 2008 298 051
US-A1- 2004 094 965
US-A1- 2009 206 610
WO-A1-2007/094736
JP-A- 2004 084 518
JP-A- 2006 246 549

Description

[0001] The invention relates to a tower for a wind turbine and a cable guide for a tower of a wind turbine, wherein a machine housing of the wind turbine is mounted on the tower and rotates about an axis extending vertically to the longitudinal direction of the tower by means of the yaw bearing. A generator for generating electrical energy is provided in the machine housing, and is driven by a rotor of the wind turbine. The yaw bearing allows horizontal alignment of the machine housing according to the wind direction, the so-called yaw system of the wind turbine. For automatic alignment of the machine housing, one or more yaw drives are provided on the yaw bearing and are rotatably connected to the machine frame of the nacelle. The yaw bearings must thus transfer the bearing forces arising, such as shear, centrifugal and yaw forces, from the machine carrier of the machine housing in the tower.

[0002] In the yaw system, also referred to as "yaw", the machine housing is rotated about a vertical axis of rotation perpendicular to the horizontal plane in order to rotate the rotor into the wind and thus to maximize the energy yield. Since the wind direction varies or even rotates, it may happen that the machine housing rotates several times about its own axis.

[0003] The details disclosed below with respect to axial direction, radial direction, circumferential direction, and above and below, relate to the tower axis of the erected tower of the wind turbine.

[0004] In the tower of the wind turbine, current-carrying cables, such as power cables, may be led from electrical components out of the machine housing to the ground. This involves a variety of cables, for example, several cables for electrical conduction of the individual phases of alternating current, in particular three-phase alternating current, i.e. cable for the grounding conductor and/or signal and control cables. The precise number of cables, in particular power cables, is dependent on the cross-section of the individual electrical conductors and the rated current to be transmitted. Normally, the current-carrying capacity of a single conductor of the power cables is too low to transfer the rated current, and therefore the rated current is divided among a plurality of power cables.

[0005] The cables are fixed in a lower part of the tower, preferably by means of clamping clips on the tower wall. In a middle part of the tower, the cables are routed from the tower wall via a cable support in a radially-central area of the interior of the tower. From there, the cables are then run centrally into the machine housing and are freely suspended from an upper end of the tower. To prevent swinging of the cables in known wind turbines, the cables are led through a pipe, preferably a PE pipe, and out through a round opening in the upper platform of the tower. By guiding the cable through the pipe, the cables are gathered into a large bundle. The bundling may result in a reduced current capacity of the cable due to mutual induction of the closely spaced current-carrying cables. If, due to the yaw system, the machine housing repeatedly turns about its own axis, then the cable is twisted. This may lead to damage or deterioration of insulation creating a safety risk as a result of friction between the individual cables. Moreover, the individual cable become closer to each other, which in turn reduces the current-carrying capacity of the cables. This has the result that the required number of cables to transmit the rated current increases, whereby the associated costs also increase.

[0006] Examples from the prior art are known from JP 2008 298 051, US 2004 094 965, JP 2006 246 549 and WO 2007 094 736.

[0007] It is an object of the invention to provide improved routing of the cable, which avoids, inter alia, the drawbacks of the prior art. In particular, it ensures the current-carrying capacity of the cable and/or reduces wear between the cables.

[0008] The object is solved according to the invention with the features of the main claim 1.

[0009] According to a preferred embodiment, the bundling device is so formed that all the adjacent power cables are spaced at the minimum distance. In the case of a wind turbine with a doubly-fed asynchronous generator, wherein the inverter unit is arranged in the base of the tower, there may be more power cables extending from the stator, preferably also the power cables and/or grounding cable extending from the generator rotor.

[0010] In the case where multi-phase current, in particular three-phase current, is conducted through the cable, in particular through the power cable, each power cable

comprises three individual conductors. These conductors may be bundled together as the magnetic fields of the respective phases of the current mutually cancel out. In the context of this invention, this multiphase cable featuring bundled conductors may be regarded as one cable or as a current-carrying cable, in particular, power cable. The individual conductors need not necessarily be surrounded by a common sheath. This applies, for example, to the combining of the three phases of a three-phase current in a cloverleaf structure.

[0011] According to a further embodiment, the bundling device is so configured that all adjacent cables, such as power cables, grounding cable, and control and signal cables, are spaced at the minimum distance.

[0012] In another embodiment, the bundling device comprises fixing devices for arranging the cables. These may be so arranged at the bundling device, that the cables are disposed in a polygonal and equilateral structure. The structure may have, for example, the shape of an equilateral triangle, a square, a regular pentagon or polygon, or equilateral shape with any number of corners. However, the number of corners and sides must be at least the same as the number of cables to be separated by the minimum distance of the power cables or current-carrying cables. The fixing devices are to be so arranged that the distance between the nearest cables fixed in the receptors, is the minimum distance in order to prevent a reduction in the current capacity of the various cables as a result of mutual inductance according to IEC 60364-5-52. By maintaining the minimum distance of the cables with respect to each other, the current capacity of the cables is optimized so that the number of cables required to transmit the rated current may be reduced. This is especially important in the case of cable management of wind turbines, since very high currents are conducted through the tower.

[0013] The multi-angled and equilaterally-sided form of the bundling device has the advantage that the distance of the individual cables to each other is at a maximum at a minimum overall size of the bundling device, and thus the mutual electromagnetic interference of the cables is minimized. As small a diameter as possible of the bundling device is most favorable in terms of shortening the cable bundle by twisting. The distance between the receptors of the fixing devices should be kept as short as possible,

so that the amount of excess cable needed to compensate for the shortening of the bundle may be kept as low as possible.

[0014] In a preferred embodiment, the fixing devices are so arranged that the structure of the receptors comprises an additional area and side. The resulting additional receptor
5 is used to receive the cable of the neutral conductor, so that there is also a minimum distance according to IEC 60364-5-52 between the cable of the neutral conductor and the nearest current-carrying cables.

[0015] In a particularly preferred embodiment, the fixing devices are so arranged that the structure of the receptors comprises as many corners and sides as the number of
10 cables provided. The thus resulting additional receptors are used to receive the signal cables, so that there is a minimum distance according to IEC 60364-5-52 between the signal cables and the nearest current-carrying cables or the cable of the neutral conductor.

[0016] According to the invention, the bundling device comprises a support on which the
15 fixing devices are arranged in order to attach the cable to the bundling device. In this case, the fixing device comprises a receptor to receive the cable. The support may be constructed in one piece or several pieces and may, for example, have an annular, cruciform or star-shaped form. It is also conceivable that the support is at least partially formed by the fixing devices or the fixing devices are at least partially formed by the
20 support. In this case, a plurality of fixing devices may be mounted adjacent to the receptor, so that this combined structure takes over the function of the support. The bundling device may be easily extended by adding more clamping clips for the number of cables provided, which saves costs during installation as well as for the storage of spare parts for the bundling device.

[0017] The fixing devices are preferably in the form of clamping clips attachable to the
25 support by means of fixing elements. The fixing elements may, for example, be screws. In a first embodiment, the clamping clips are rotatably connected to the support and constructed in one piece, so that the clamping clips, together with the support, form the fixing device. The clamping clips are advantageously arched in shape in order to form a
30 receptor for a cable or a cable with a plurality of conductors. The cable located in the

receptor is clamped in place between the clamping clip and the support upon attaching the clamping clip to the support, to securely connect the bundling device to the cable.

[0018] In a preferred embodiment, the clamping clip is formed as a V-shaped arc so that the receptor has a triangular cross-section. This has the advantage that, in the case of a three-phase cable comprising three conductors, the current-carrying cable is fixed by the clamping clip in the clover-leaf structure. In the case where cables with smaller diameters, e.g. signal cables, are provided, the receptor may use an insert to reduce the size of the receptor.

[0019] According to the invention the fixing devices are arranged rotatably about an axis on the support extending substantially in the radial direction. Due to the rotatable arrangement of the fixing devices, the fixing devices can twist with the twisting of the cable, so that a normal axis to the triangular cross-section of the receptors of the fixing devices is always parallel to a longitudinal axis of the cable. Thus, both the loading on the cable as well as the loading on the fixing devices and the connecting members may be reduced. The fixing device is constructed in several parts in this embodiment.

[0020] In the case of annular supports, the bundling device comprises a radial inner circle-like unused cross-section. According to another embodiment, this cross-section may be used to guide other cables, such as data, control, or signal cables. Conveniently, a further loose guide is attached to the support, for example in the form of round steel bent into a spiral, which is mounted in radial bores of the support.

[0021] An advantageous embodiment of the invention discloses that the lower part of the cable bundle is connected with the cable guide of the tower fixed to the tower via a cable loop. By twisting the cable, the cable bundle is shortened in the axial direction. In this way, the free rotation of the machine housing is not prevented by clamping the cable or in the event that the cable is damaged as the cables are guided in the loop. The shortening of the cable bundle is compensated by the excess of cable in the loop.

[0022] Advantageously, the tower comprises a plurality of bundling devices which are fixed to the cables at regular intervals between the upper and the lower areas of the cable bundle. The distance between the bundling devices is so selected that twisting of the cable is in fact allowed, but even in the case of a maximum rotation of the machine housing, the cables would still be at the prescribed minimum distance from each other.

[0023] The cable bundle advantageously comprises an axial distance of 500 to 1000 mm from each other, while the distances between 500 to 600 mm are particularly advantageous. The cable bundle is suspended substantially freely in the tower of the wind turbine and only the upper part is rotatably connected to the machine housing while the lower part is rotatably connected to a guide device. The cable bundle is self-supporting and stabilized by the bundling devices.

[0024] Movements of the tower and resonances may cause oscillation of the cable bundle in the radial direction. In order to limit the radial movement of the cable bundle, in a further embodiment, the tower comprises at least one axially-acting ring conduct which is fixedly connected to the tower. The cable bundle is passed through the ring conduct and is suspended substantially freely in the tower of the wind turbine. Conveniently, multiple ring conducts may be used, preferably two, more preferably three, and most preferably four ring conducts.

[0025] The twisting of the cable bundle has the effect of shortening it, wherein the bundling devices move towards the machine housing, more at the bottom than at the top. By axial displacement of the bundling devices, it may happen that the bundling device is caught axially in a ring conduct. If the bundling devices become caught, further rotation of the machine housing prevents the cable bundle from being heavily loaded, inter alia, to destruction. To avoid this, at least one of the bundling devices comprises a radial support, which is arranged in axial proximity to form a ring conduct as a protection against being hooked. This provides suitable self support during the entire axial movement of the cable bundle with respect to the rings in the radial direction. The radial support must therefore comprise an axial length which is greater than the axial shortening of the cable bundle in the actual position.

[0026] In another embodiment, the radial support connects at least two successive bundling devices. In this embodiment, the axial length of the radial support must be greater than the axial shortening of the cable bundle generated in the actual area. Only in this way, may it be ensured that the support remains in contact with the ring conduct throughout the axial movement of the cable bundle.

[0027] In particular, the distances between the bundling device connected by the axial ring conduct is greater than the axial shortening of the cable bundle generated in the

actual area. Thus, in this embodiment, the bundling devices may be mounted at irregular intervals on the cables.

[0028] Since the radial support is connected to two bundling devices that are arranged to be mutually rotatable with respect to the longitudinal axis of the cable bundle, the radial support might be bent upon twisting of the cable bundle. To prevent this, the two bundling devices may also be connected to the connecting radial support by a stiffener. This stiffener is connected to the radial support, The two bundling devices may be rotatably connected with each other, which prevents twisting of the cable bundle in the field and bending of the radial support.

[0029] Further details of the invention will become apparent from the drawings with reference to the description.

[0030] In the drawings:

Fig. 1 shows a wind turbine,

Fig. 2 shows an upper part of the tower of the wind turbine,

Fig. 3a shows a first embodiment of a bundling device which is not part of the claimed invention

Fig. 3b shows a support of the bundling device,

Fig. 3c shows a cross-section of the bundling device,

Fig. 4 shows a clamping clip of the bundling device,

Fig. 5 shows a use of the clamping clip,

Fig. 6a shows an axial plan view of a second embodiment of the bundling device,

Fig. 6b shows a radial top view of a second embodiment of the bundling device,

Fig. 7 shows a bundling device with loose guides,

Fig. 8a shows a bundling device with radial supports,

Fig. 8b shows a ring conduct for the radial guidance of the cable bundle

[0031] Fig. 1 shows a wind turbine 1 with a tower 2, and with a machine housing 8 mounted on the tower 2 that is rotatable about a tower axis 4 of the tower 2, and connected with a generator rotor 9 arranged in the machine housing 8, via a rotor shaft. In the yaw system - also referred to as "yaw" - the machine housing 8 is rotated about the tower axis 4 of the tower 2 in the horizontal plane in order to rotate the rotor 9 into the wind and thus maximize the energy yield. Since the wind direction varies during the

operation of the wind turbine 1 or even rotates, it may happen that the machine housing 8 rotates about its own axis several times.

[0032] The details disclosed below referring to axial direction 5, 6 radial direction, circumferential direction 7 and above and below, relate to the longitudinal axis of the erected tower 2 of the wind turbine 1.

[0033] Fig. 2 shows an upper part of the tower 2 of a wind turbine 1. In the tower 2 of the wind turbine 1, several current-carrying cables 10, 11, 12, 13 of the electrical components are led out of the machine housing 8 to the ground. These current-carrying cables 10, 11, 12, 13 are, for example, cable 10 for electrical conduction of the three-phase alternating current (power cable 10), cable grounding conductor 11 and/or signal and control cable 12. The current-carrying cables 10, 11, 12, 13 are grouped together in the upper part of the tower 2 by a plurality of bundling devices 17, 27 to form a cable bundle 14. This cable bundle 14 is rotatably connected at the upper end 15 to the rotatably mounted machine housing 8 on the tower 2, and rotatably connected at the lower part 16 of the cable bundle 14 to the tower 2, but is suspended substantially freely in the tower 2. In order to support a radial movement of the cable bundle 14, the tower 2, also comprises a plurality of ring conducts 19 which are firmly connected to the tower 2 and through which the cable bundle 14 is led out.

[0034] Fig. 3a and Fig. 3c show a bundling device 17 that is not part of the claimed invention and comprises a two-part support 18 and a plurality of clamping clips 20. The annular support 18 consists of two parts to be screwed to one another. The support 18 has a plurality of bores 21 which serve to attach the clamping clips 20 in the radial direction 6. Furthermore, the support 18 comprises holes 21 to fix, for example, radial supports 22. The individual parts of the support 18 are also shown in Fig. 3b. The clamping clips 20 are substantially V-shaped and comprise two flanges with holes for securing the clamping clips 20 to the support 18. The clamping clips 20 are rotatably fixed with the support 18 by means of screws 23 and, together with the support 18, form a fixing device 24 for the cables 10, 11, 12. The fixing devices 24 are so arranged that they form an equilateral and polygonal structure. The cables 10, 11, 12 fixed in the fixing devices 24 always maintain a distance D to each other by means of this structure. The V-shape of the clamping clip 20 forms a receptor 26 for the cables 10, 11, 12 between

the support 18 and clamping clip 20. The substantially triangular cross-section of the receptor 26 advantageously retain, in particular, three-phase cable 10, 12 - including three one-phase conductors 10a, 10b, 10c - in a cloverleaf structure. The clamping clip 20 and the cloverleaf structure of the cables 10, 12 are also shown in Fig. 4. The fixing device 24 may also include an insert 25. The insert 25 reduces the size of the receptor 26 of the fixing device 24 in order to fix a cable 12 with a smaller cross-section. Such cables 12 may be the three-phase cable of a rotor of a doubly-fed asynchronous generator. Fig. 5 shows the insert 25 in a dismantled state.

[0035] Fig. 6a and 6b show another embodiment of the bundling device 27. Figure 6a shows the bundling device 27 in an axial plan view, and in a radial plan view in Fig. 6b. In this embodiment, the fixing devices 29 are respectively rotatably mounted about an axis 30 extending in the radial direction 6 of the support 28. The fixing devices 29 alone form the receptors 26 for the cables 10, 11, 12. The rotatable mounting of the fixing devices 29 allow the cables 10, 11, 12 to rotate with an oblique orientation, so that the longitudinal axes of the receptors 26 of the fixing device 29 and the cables 10, 11, 12 fixed therein remain parallel even in the case of oblique orientation of the cable 10, 11, 12. In this way, the loading acting on the cables 10, 11, 12 and on the fixing devices 29 is reduced.

[0036] The bundling device 17 shown in Fig. 7 has a radially inner circular-like cross-section 31. This cross-section 31 may be used in accordance with a further embodiment for guiding further cables 14, such as data, control, or signal cables. For this purpose, a further loose guide 33 mounted on the support 18 of the bundling device 17, for example in the form of round steel bent into a spiral, which is mounted in radial bores 21 of the support 18. Fig. 7 also shows the cloverleaf structure of the cables 10, 11, 12 fixed in the fixing devices 24, as well as the distance D of the cables 10, 11, 12 maintained with respect to each other.

[0037] Fig. 8a shows a cable bundle 14 with bundling devices 17 and radial support 22. In this embodiment, the radial supports 22 are formed as U-shaped rods, which are respectively connected with two successive bundling devices 17 in the axial direction. Fig. 8b shows the slidably-arranged radial supports 22 and the ring conduct 19

connected with the tower 2. The radial support 22 prevents the bundling devices 17 being caught in a ring conduct 19 during an axial movement.

[0038] The combinations of features disclosed in the described embodiments do not have a limiting effect on the invention, but rather the features of the various
5 embodiments may be combined with each other.

	1	Wind turbine
	2	Tower
	3	Tower wall
	4	Tower axis
5	5	Axial direction
	6	Radial direction
	7	Circumferential direction
	8	Nacelle
	9	Rotor
10	10	Power cables
	11	Grounding conductor
	12	Cable
	13	Signal and control cables
	14	Cable bundle
15	15	End
	16	Lower area
	17	Bundling device
	18	Support
	19	Ring conduct
20	20	Clamping clip
	21	Bore
	22	Support
	23	Screws
	24	Fixing device
25	25	Insert
	26	Receptor
	27	Bundling device
	28	Support
	29	Fixing device
30	30	Axis
	31	Cross-section
	32	Guide (spiral)
	D	Distance

Patentkrav**1. Tårn (2) til en vindmølle (1), der omfatter**

- en øvre ende, hvorpå en nacelle (8) kan arrangeres drejeligt,
- hvor mindst tre kabler (10, 11, 12) er arrangeret i længderetningen i
5 tårnet (2) og danner et kabelbundt (14) med en længdeakse,
- og en øvre ende (15) af kabelbundtet (14) kan forbindes drejningsfast med nacellen (8),
- og et nedre område (16) af kabelbundtet (14) er forbundet drejningsfast med tårnet (2),
- 10 - der er tilvejebragt mindst to bundtningsindretninger (17, 27), der omfatter fastgørelsesindretninger (24, 29) til fastgørelse af bundtningsindretningen (17, 27) på kablerne (10, 11, 12, 13),
- hvor bundtningsindretningerne (17, 27) er arrangeret således mellem den øvre ende (15) og det nedre område (16) på kablerne (10, 11, 12, 13),
- 15 - og bundtningsindretningerne (17, 27) er fremstillet således,
- at mindst tre kabler (10, 11, 12) i kabelbundtet (14) har en indbyrdes mindsteafstand (D),

kendetegnet ved, at

- bundtningsindretningen (17, 27) omfatter en bærer (18, 28) og
20 fastgørelsesindretninger (24, 29), og fastgørelsesindretningerne (24, 29) er arrangeret drejeligt på bæreren (18), således at der kan foretages en skråstilling af kablerne (10, 11, 12) i forhold til kabelbundtets (14) længdeakse ved hjælp af fastgørelsesindretningen (29).

2. Tårn (2) ifølge krav 1, **kendetegnet ved, at** antallet af fastgørelsesindretninger (24, 29) i det mindste svarer til antallet af kabler (10, 11, 12).
- 5
3. Tårn (2) ifølge krav 1 eller 2, **kendetegnet ved, at** bæreren (18) i det mindste delvist er dannet ved hjælp af fastgørelsesindretningerne (24, 29), eller at fastgørelsesindretningerne (24, 29) i det mindste delvist er dannet ved hjælp af bæreren (18).
- 10
4. Tårn (2) ifølge krav 3, **kendetegnet ved, at** fastgørelsesindretningerne (29) alene danner en modtager (26) for kablerne, og modtageren (26) har et i det væsentlige trekantet tværsnit.
- 15
5. Tårn (2) ifølge et eller flere af de foregående krav, **kendetegnet ved, at** bundtningsindretningen (17, 27) omfatter mindst tre fastgørelsesindretninger (24, 29), fortrinsvis seks fastgørelsesindretninger (24, 29) og især otte fastgørelsesindretninger (24, 29).
- 20
6. Tårn (2) ifølge et eller flere af de foregående krav, **kendetegnet ved, at** mindst én fastgørelsesindretning (24, 29) omfatter en indsats (25), hvor modtagerens (26) tværsnit formindskes af indsatsen (25).
- 25
7. Tårn (2) ifølge et eller flere af de foregående krav, **kendetegnet ved, at** der i tårnet (2) er arrangeret ringføringer (19), hvorved kabelbundtets (14) radiale bevægelsesmulighed begrænses.
- 30
8. Tårn (2) ifølge et eller flere af de foregående krav, **kendetegnet ved, at** bundtningsindretningerne (17, 27) har en indbyrdes afstand, hvor afstanden vælges således, at der tillades en fri vridning af kablerne (10, 11, 12, 13), idet kablerne (10,

11, 12, 13) dog aldrig kan vrides så kraftigt, at de kommer i kontakt med hinanden.

9. Tårn (2) ifølge krav 8, **kendetegnet ved, at** bundtningsindretningerne (17, 27) er arrangeret i en indbyrdes afstand på 500-600 mm.

5

10. Tårn (2) ifølge krav 7, **kendetegnet ved, at** en eller flere af bundtningsindretningerne (17, 27) omfatter en radial afstivning (22), hvor afstivningen (22) er arrangeret glidende i ringføringen (19).

10 **11.** Tårn (2) ifølge krav 9, **kendetegnet ved, at** den radiale afstivning (22) er U-formet udformet og forbundet med to bundtningsindretninger (17, 27).

12. Tårn (2) ifølge krav 10, **kendetegnet ved, at** en forstærkning forbinder bundtningsindretningerne (17, 27), der er forbundet med afstivningen (22), hvor
15 forstærkningen forhindrer en udbøjning af afstivningen (22) ved vridning af kabelbundtet (14).

Drawings

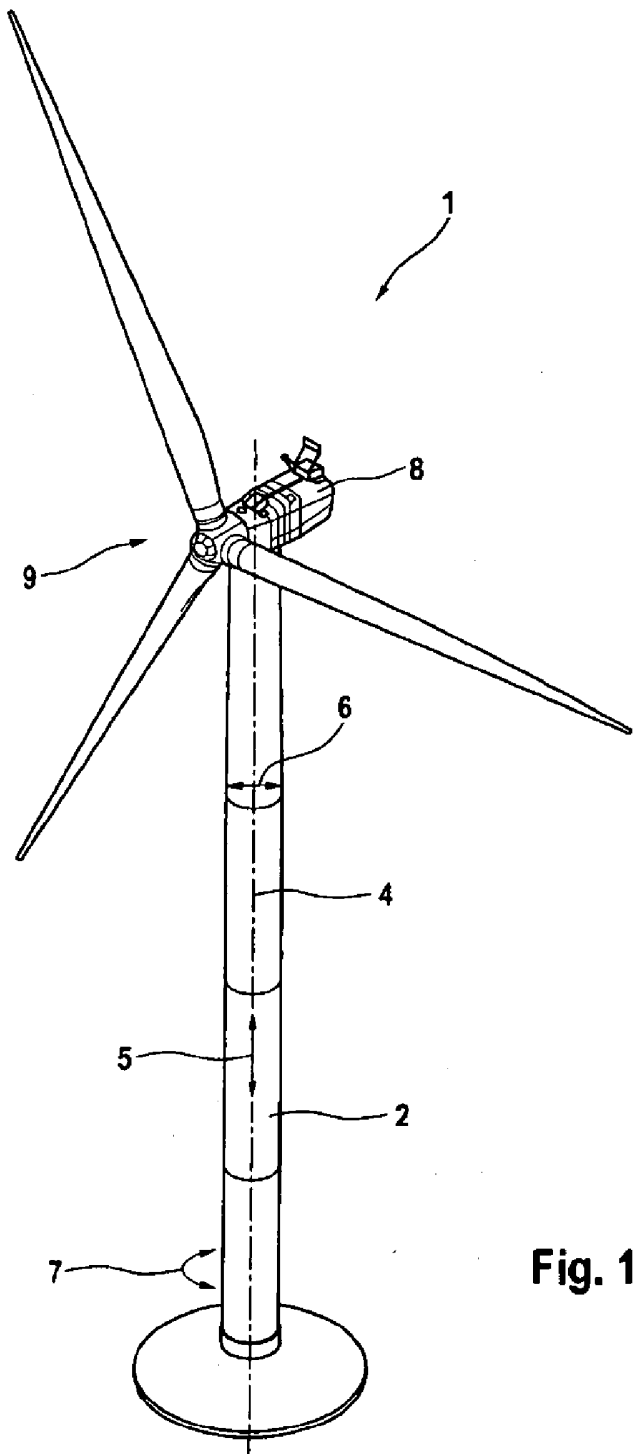


Fig. 1

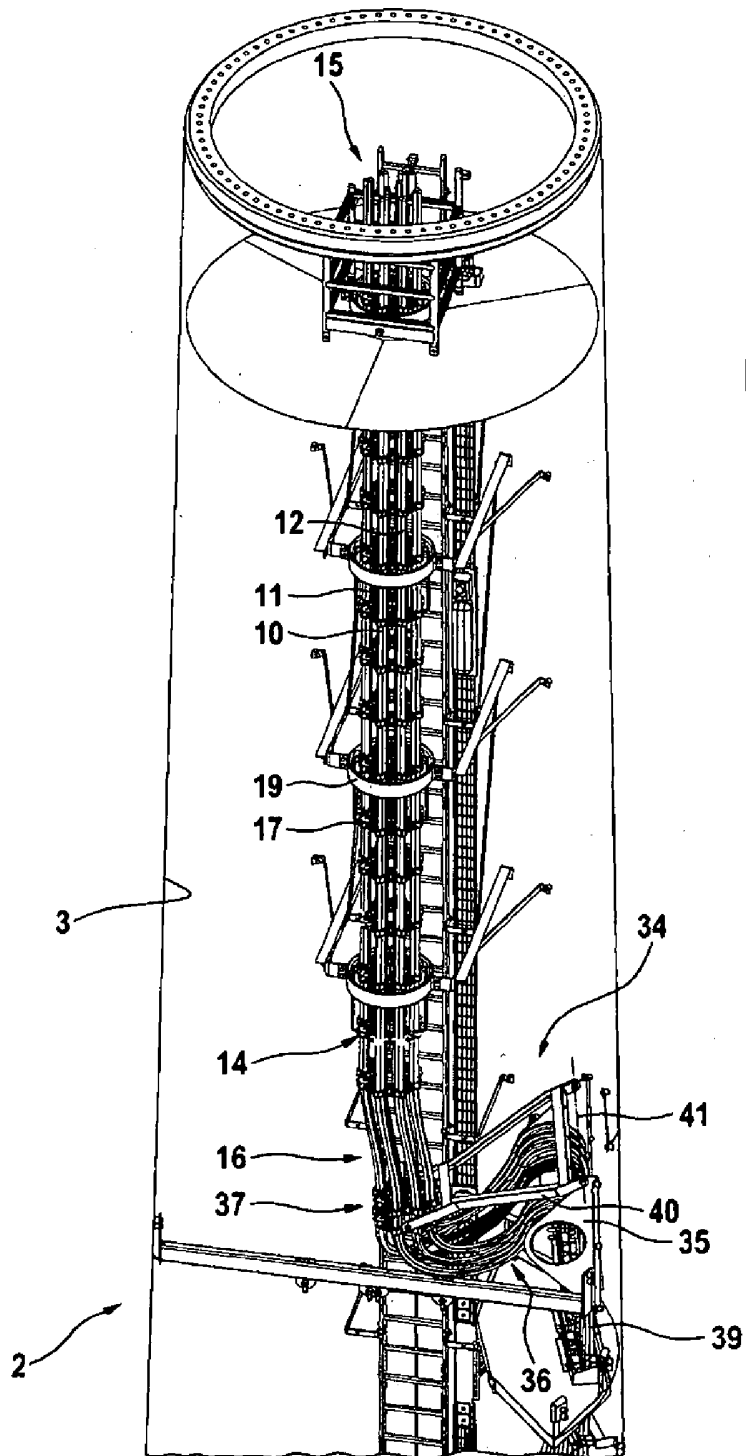


Fig. 2

3

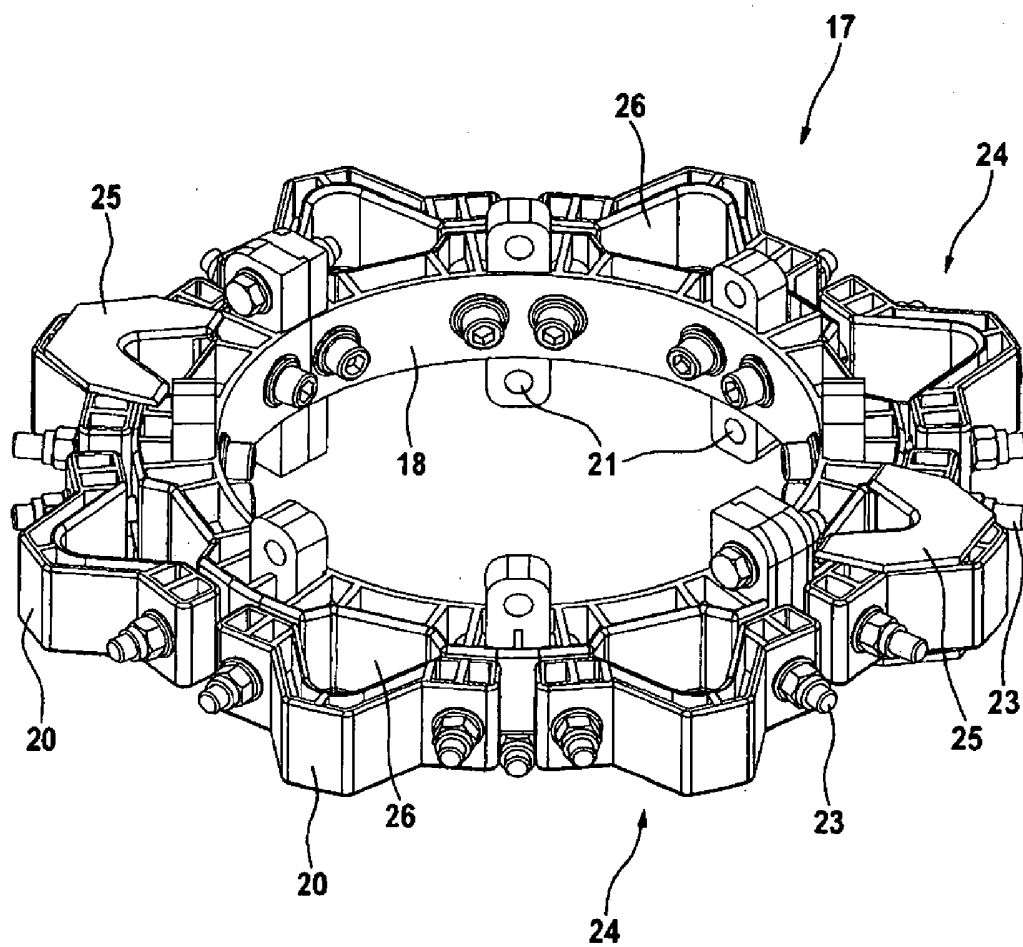


Fig. 3a

4

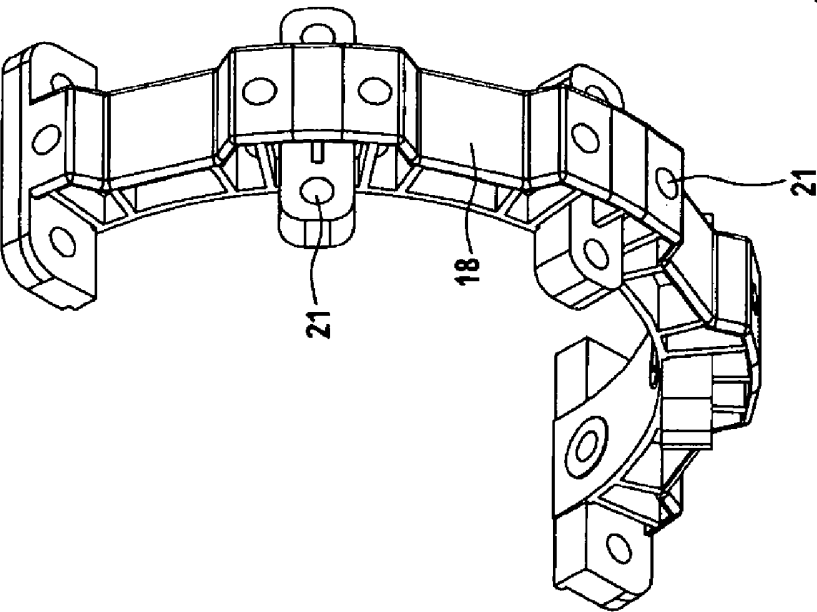
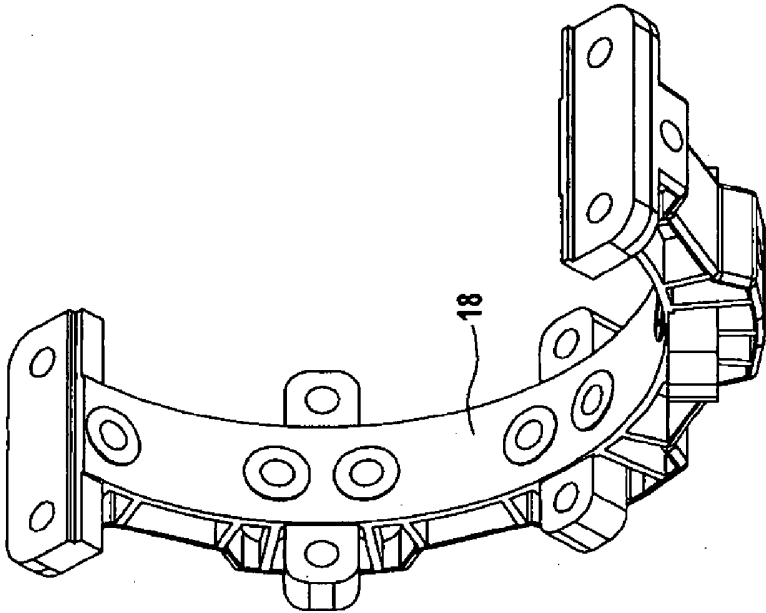


Fig. 3b

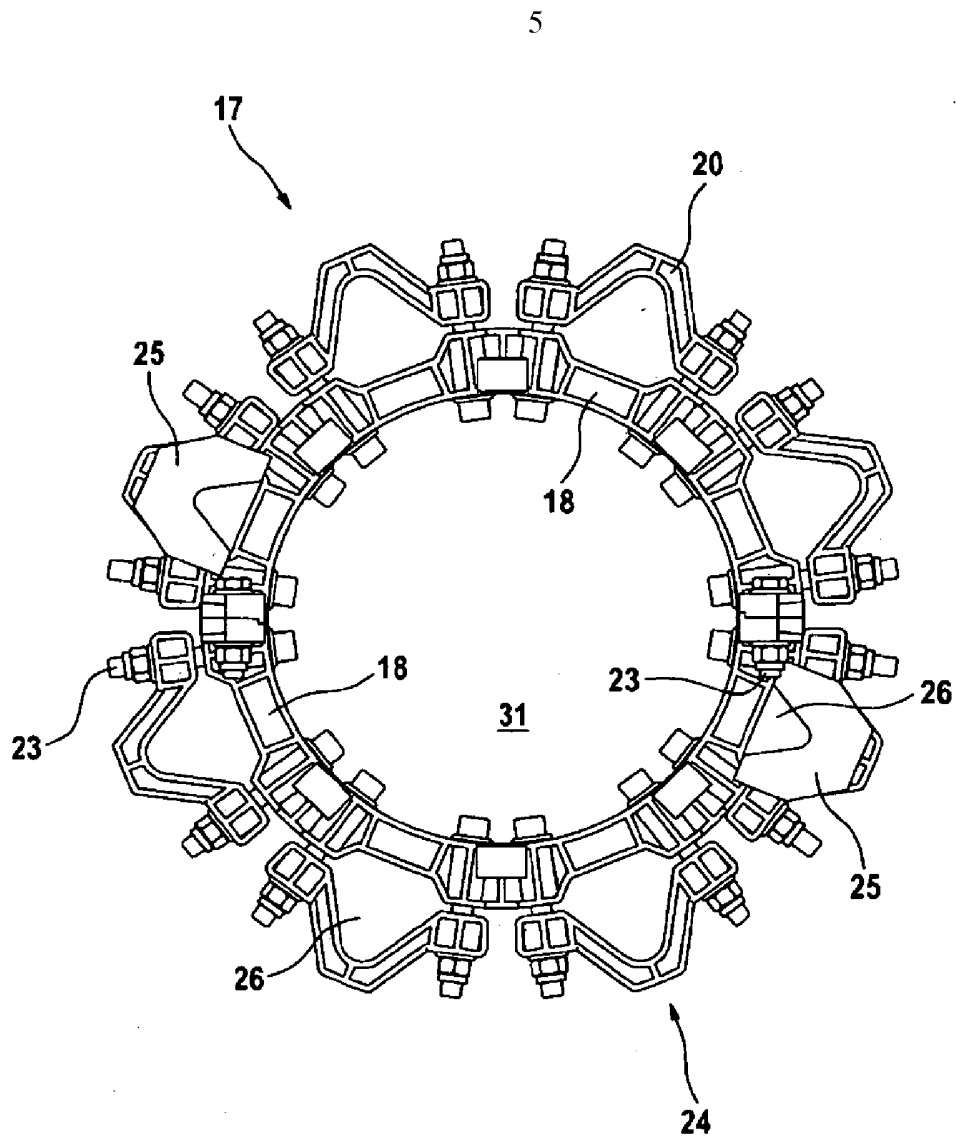


Fig. 3c

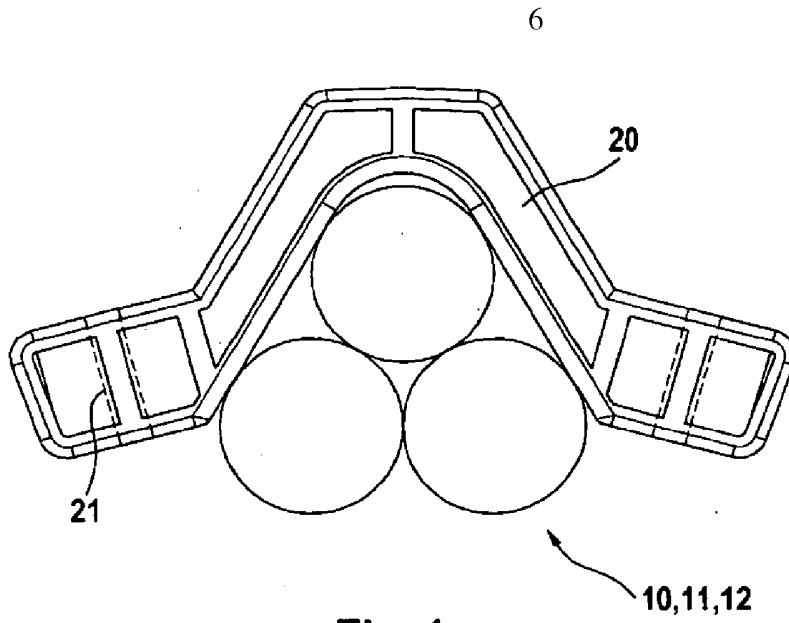


Fig. 4

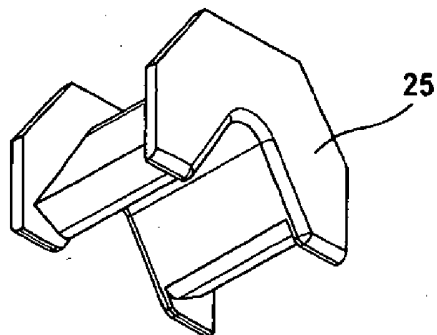


Fig. 5

7

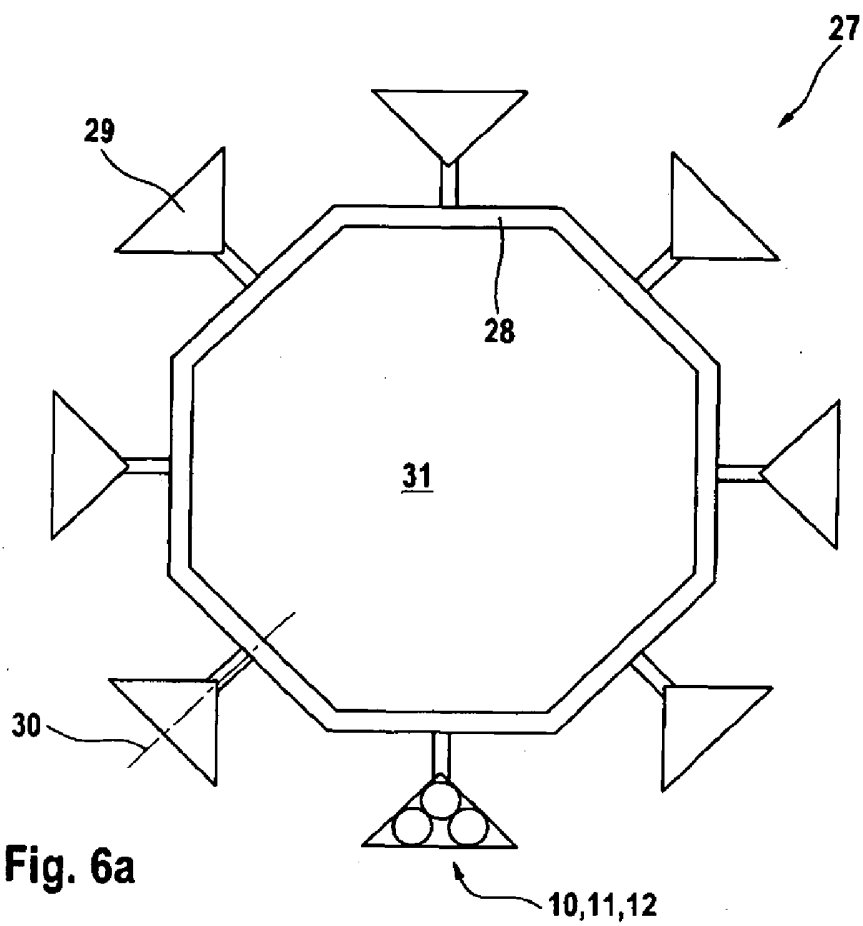


Fig. 6a

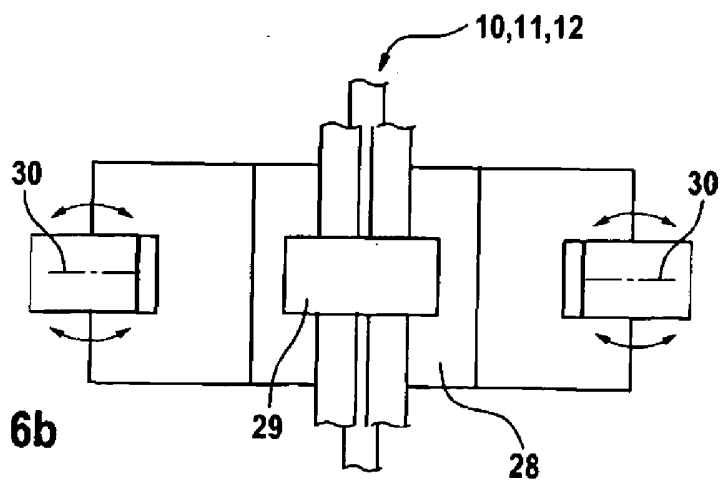


Fig. 6b

8

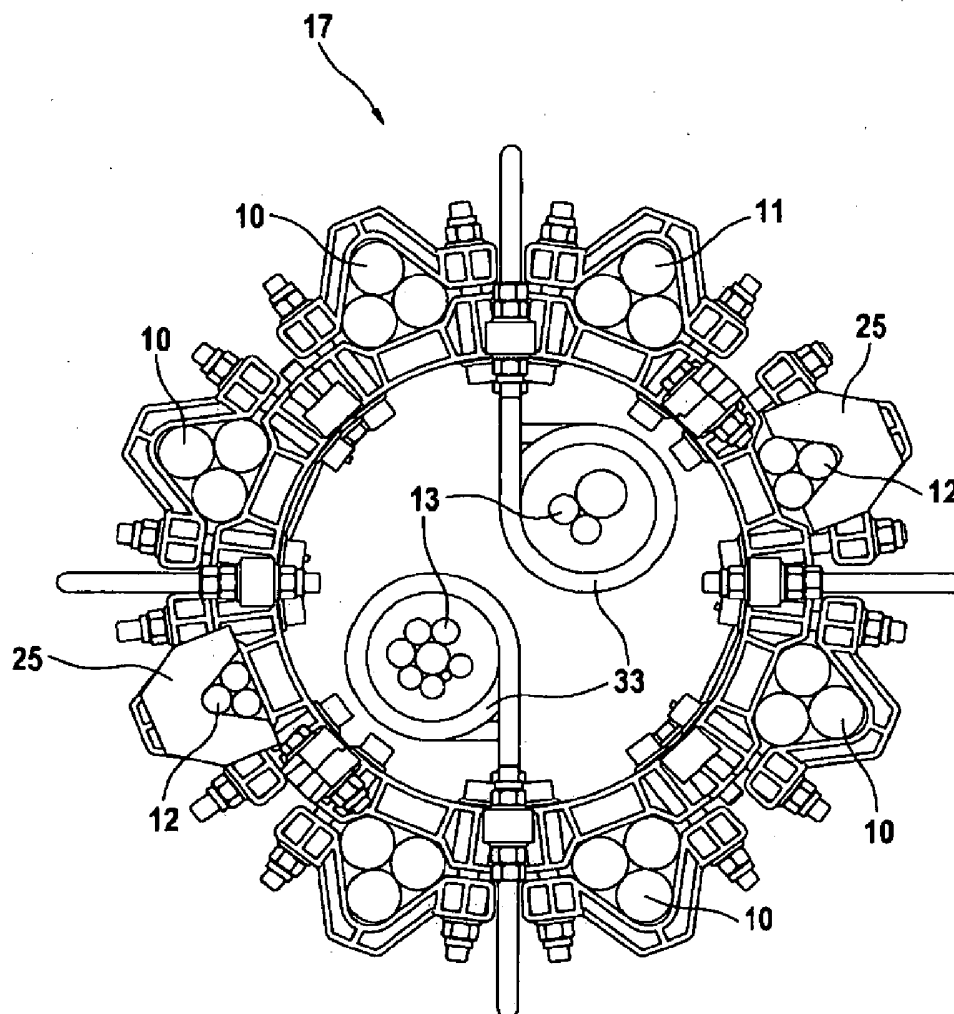


Fig. 7

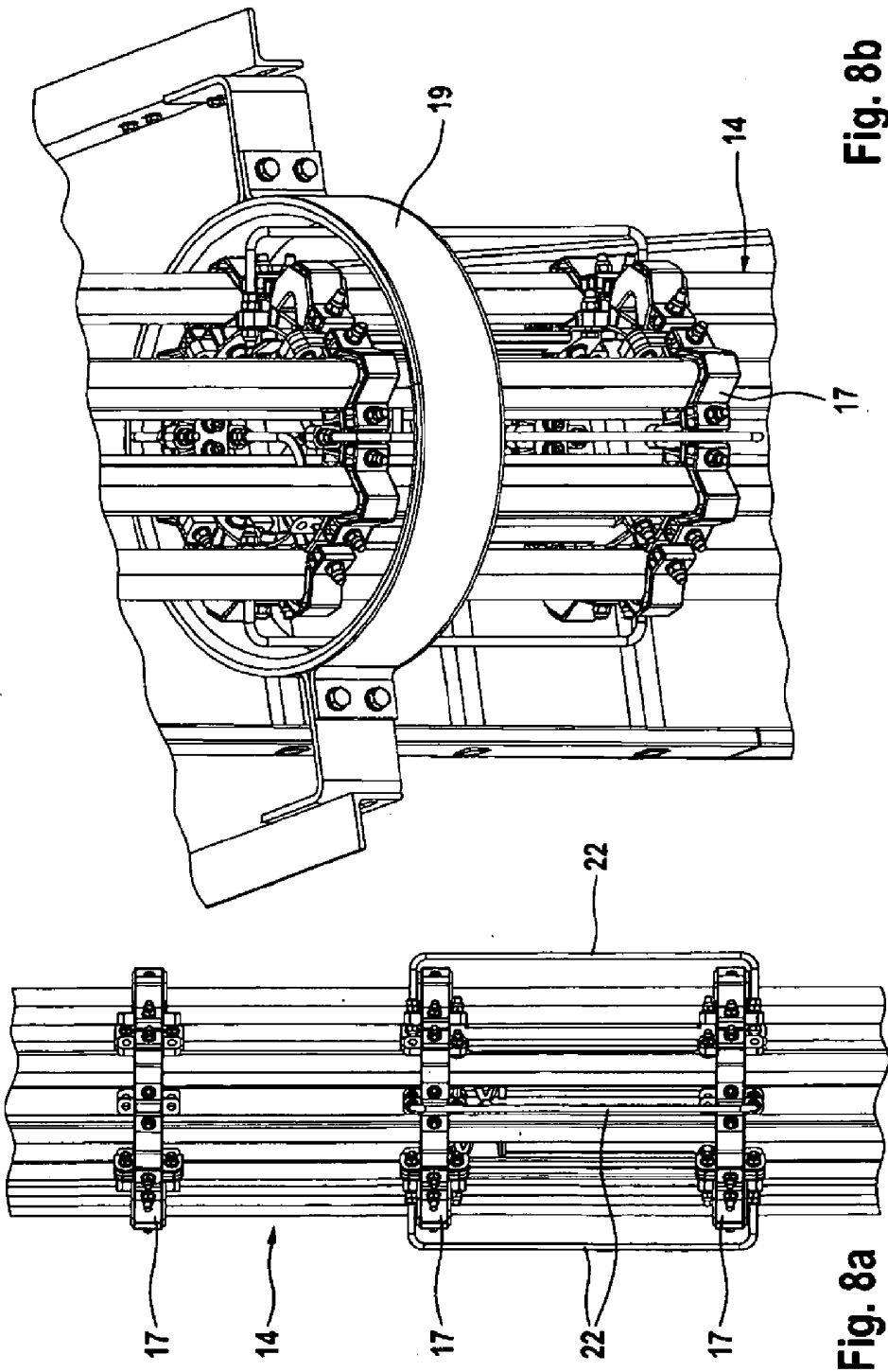


Fig. 8b

Fig. 8a