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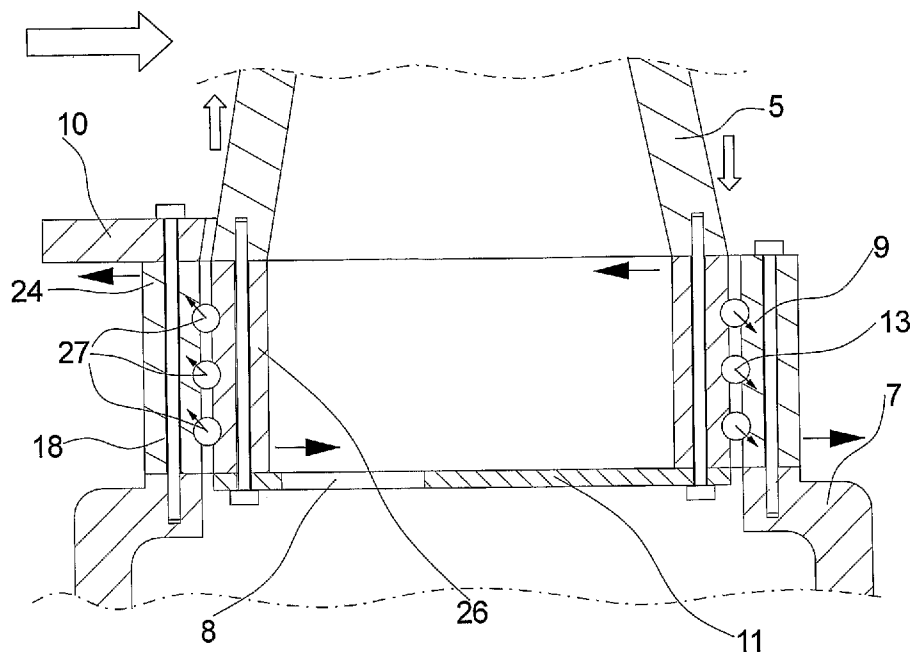
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(54) Title: A WIND TURBINE PITCH BEARING, AND USE HEREOF



(57) Abstract: The invention relates to a wind turbine (1) comprising at least two pitch controlled wind turbine blades (5). Each blade (5) comprise pitch bearings (9) including two or more bearing rings (24, 25, 26), and pitch controlling means for pitching the blades (5) by means of the bearings (9). The blades (5) are mounted on a hub (7) via the pitch bearings (9) and the pitch bearings (9) comprise separate flexibility enhancing means (10, 11, 12, 14, 19, 20, 28) for controlling loads in the bearings (9). The invention further relates to a use hereof.

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A WIND TURBINE PITCH BEARING, AND USE HEREOF.

Background of the invention

- 5 The invention relates to a wind turbine according to the preamble of claim 1, and use hereof.

Description of the Related Art

- 10 A wind turbine known in the art comprises a wind turbine tower and a wind turbine nacelle positioned on top of the tower. A wind turbine rotor with three wind turbine blades is connected to the nacelle through a low speed shaft, which extends out of the nacelle front as illustrated on figure 1.

- 15 Modern wind turbines control the load on the rotor by pitching the blades in and out of the incoming wind. The blades are pitched to optimize the output or to protect the wind turbine from damaging overloads.

- To perform the pitch each blade is provided with a pitch bearing between the hub and
20 the blade, and some sort of mechanism, most often a hydraulic cylinder, to provide the force for pitching the blade and maintaining it in a given position. This pitching arrangement enables each blade to be turned approximately 90° around their longitudinal axis.

- 25 The wind load on the blades get bigger as modern wind turbines get bigger, and as both blades and hub get bigger the more relatively soft and flexible they get. These facts make the pitch bearings very crucial components of the rotor, in that they have to be able to transfer the moment produced by the wind load to the hub and at the same time enable that the blades can rotate freely and accurately.

To ensure this the obvious solution would be simply to make the pitch bearings bigger, but the bearing balls has already almost reached the limit of what is industrially available, and bigger balls would therefore be economically
5 disadvantageous. Furthermore, the ring size would increase with increased ball size and thereby increase the bearing cost and weight significantly.

Another solution would be to provide the blade with more than one bearing spaced apart as shown in e.g. DE 3415428 A1 and US 4,668,109. This is advantageous in
10 that it enables relatively small bearings to transfer the moment. But this design is space consuming and requires a high degree of rigidity and thereby increased cost and weight of both the hub and the blades.

An object of the invention is therefore to provide a large modern wind turbine pitch
15 bearing without the mentioned disadvantages.

Especially it is an object of the invention to provide for a cost and weight efficient wind turbine pitch bearing which can transfer the loads on and from the blades to the hub without reducing the bearings durability or functionality.
20

The invention

The invention provides for a wind turbine comprising at least two pitch controlled wind turbine blades. Each blade comprising one or more pitch bearings including
25 two or more bearing rings, and pitch controlling means for pitching the blades by means of the bearings. The blades being mounted on a hub via the pitch bearings characterized in that, the one or more pitch bearings comprise separate flexibility enhancing means for controlling loads in the bearings.

It is advantageous to provide the pitch bearings with separate flexibility enhancing means, in that the flexibility enhancing means ensures the durability or functionality of the bearing even though the bearing rings are distorted by the load on and from the blades. Hereby the bearings can transfer a bigger moment or load without the weight
5 or the cost of the bearing being raised much.

It should be emphasised that the term “hub” is to be understood as the part of the wind turbine to which the blades are attached. The term “hub” therefore also covers the teetering device to which the blades are attached on teeter wind turbines.

10

In an aspect of the invention, said bearings comprise two rows of rolling elements.

The more rows of rolling elements the more sensitive the bearings life and functionality are to a distortion of the bearing rings. It is therefore advantageous to
15 provide a bearing comprising two rows of rolling elements with separate flexibility enhancing means.

It should be emphasised that the term “rolling elements” is to be understood as any form of rolling parts of a bearing such as balls, rollers, needles or other.

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In an aspect of the invention, said bearings comprise three or more rows of rolling elements.

Herby is achieved an advantageous embodiment of the invention.

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In an aspect of the invention, said bearings comprise one or more first and one or more second separate flexibility enhancing means.

By providing the bearings with both a first and a second separate flexibility
30 enhancing means the bearing becomes more flexible. This is advantageous in that it

that it ensures the durability or functionality of the bearing even though the bearing rings are distorted.

In an aspect of the invention, said separate flexibility enhancing means are displaced
5 from the load transferring surfaces of said bearing rings.

It is advantageous to position the separate flexibility enhancing means away from the surfaces of the bearing rings on which the rolling elements roll in that it enables a more simple design of the separate flexibility enhancing means and it enables the
10 flexibility enhancing means to provide the bearing with more flexibility.

In an aspect of the invention, at least one of said one or more bearing rings comprise through holes for blade attachment means such as screws, bolts, studs or rivets.

15 It is advantageous that one or more of the bearing rings comprise through holes in that it enables a simple way of attaching the bearing.

In an aspect of the invention, said bearings comprise three bearing rings.

20 Bearings comprising three bearing rings always comprise at least two rows of rolling elements. The more rows of rolling elements the more sensitive the bearings durability and functionality are to a distortion of the bearing rings. It is therefore advantageous to provide a bearing comprising three bearing rings with separate flexibility enhancing means.

25

In an aspect of the invention, said separate flexibility enhancing means comprise at least one angle compensating mean.

30 Angle compensating means enables the rolling elements of the bearing to transfer the loads from one bearing ring to another even though one or more of the bearing rings

are distorted and therefore not perfectly aligned. Angle compensating means are therefore advantageous in that they increase the bearings flexibility.

In an aspect of the invention, said at least one angle compensating mean is a separate
5 360° ring or more than one ring parts together forming a full 360° ring.

It is advantageous that the angle compensating means is a 360° ring or more than one ring parts together forming a full 360° ring in that the bearings form a 360° ring.

10 In an aspect of the invention, said at least one angle compensating mean is positioned so that at least on of said rows of rolling elements rolls on one first surface of said angle compensating mean and one second opposing surface of said angle compensating mean is in contact with the middle section of said bearing.

15 By placing the angle compensating mean between the rolling elements and it opposing contact surface on the middle section of a bearing ring, it enables the angle compensating mean to absorb or distribute any misalignment or angle differences between the rolling elements and their opposing contact surface on the middle section, whether that being a temporary, a permanent, a local or an overall
20 misalignment or angle difference.

In an aspect of the invention, said first surface is a plane roller surface and said second opposing surface is a semicircular or substantially semicircular contact surface.

25

It is advantageous to provide the angle compensating mean with a plane roller surface for the rolling elements to roll on and an opposing semicircular contact surface facing the contact surface of the bearing, in that it enables the angle compensating mean to twist or distort locally or overall to absorb or distribute any

misalignment or angle differences between the rolling elements and their opposing contact surface.

In an aspect of the invention, said separate flexibility enhancing means include one
5 or more plates attached to one or more of said bearing rings by means of e.g. screws, bolts, studs, rivets, adhesive means or welding.

By providing the bearing rings with one or more plates it is possible to control the bearing rings rigidity and thereby ensure that even though the rings are distorted the
10 bearing still have its full functionality and no part of the bearing are damaged or get excessively strained.

In an aspect of the invention, at least one of said one or more plates is a strengthening plate providing additional non-uniform or substantially non-uniform
15 rigidity to said the bearing ring on which it is attached.

By making the plates so that they provide non-uniform rigidity to the bearing ring on which they are attached, the plates can provide the bearings with rigidity and/or flexibility where it is needed, without increasing the bearings weight much.
20

In an aspect of the invention, said additional non-uniform or substantially non-uniform rigidity is provided by means of one or more holes in said strengthening plates.

25 It is advantageous to provide the plates with one or more holes, in that it is a simple and efficient way of controlling the plates rigidity and/or flexibility

In an aspect of the invention, said separate flexibility enhancing means comprises two or more radial separated rolling element cages.
30

It is advantageous to provide the bearings with several radial separate rolling element cages, in that it enables the possibility of varying distances between the cages and thereby increases the bearings flexibility.

5 In an aspect of the invention, said rolling element cages are separated by compression zones.

By separating the rolling element cages by means of compression zones the bearing becomes more flexible.

10

In an aspect of the invention, said compression zones are formed integrally in one or both longitudinal ends of said rolling element cages.

15 Forming the compression zones integrally in the ends of the rolling element cages is advantageous, in that it provides for a simple and cost efficient way of providing a bearing with compression zones.

In an aspect of the invention, said integrally formed compression zones are formed as transverse slits in the rolling element cages.

20

Transverse slits in the rolling element cages are a simple and cost efficient way of providing a bearing with compression zones.

25 In an aspect of the invention, facing transverse slits of juxtaposed rolling element cages are slit transversely from opposite sides.

By slitting the rolling element cages from opposite sides the facing slits together forms a simple and efficient compression zone.

In an aspect of the invention, said compression zones are compression parts separate from said rolling element cages.

5 By using compression parts separate from said rolling element cages it is possible to use rubber blocks, springs or other as the compression zones. This is advantageous, in that it provides for a simple and cost efficient way of providing a bearing with compression zones.

10 In an aspect of the invention, said separate flexibility enhancing means includes hollow rolling elements such as hollow rollers.

By making the rolling elements hollow they become more flexible and therefore their ability to handle distortion and misalignment of the bearing rings are improved.

15 In an aspect of the invention, the hole in said hollow rollers has a larger diameter at the ends than in the middle.

20 Distortion and misalignment of the bearing rings results in, that one end of e.g. a roller has to transfer a bigger load than the rest of the roller. It is therefore advantageous to make the hole of a larger diameter at the ends and make the hole of a smaller diameter at the middle, to make the rolling element more rigid towards evenly distributed loads.

25 In an aspect of the invention, the hole in said hollow rollers is a straight through hole.

Providing the rollers with straight through holes is a simple and cost efficient way of providing the roller with enhanced flexible qualities.

30 In an aspect of the invention, the hole in said hollow rollers is a blind hole in one or both ends of said hollow rollers.

Providing the rollers with blind hole in the ends, is a simple and cost efficient way of providing the roller with enhanced flexible qualities and maintain the rollers rigidity towards evenly distributed loads.

5

In an aspect of the invention, said separate flexibility enhancing means include rollers with varying diameter.

If the rollers are of varying diameter their ability to handle distortion and misalignment of the bearing rings are improved. This is advantageous in that it provides for a more flexible bearing.

10

In an aspect of the invention, said rollers are rounded in a longitudinal direction.

Rounding the rollers in a longitudinal direction is a simple and cost efficient way of providing the rollers with the ability to handle distortion and misalignment of the bearing rings.

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In an aspect of the invention, said rollers bulges at the middle.

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By making the rollers bulges at the middle, they are able to handle distortion and misalignment of the bearing rings more efficiently.

25

The invention further provides for a wind turbine comprising at least two pitch controlled wind turbine blades, each blade comprising one or more pitch bearings including two or more bearing rings, and pitch controlling means for pitching said blades by means of said bearings, said blades being mounted on a hub via said pitch bearings, characterized in that said pitch bearings comprise at least three rows of rolling elements, said rows having a common diameter.

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Herby is achieved an advantageous embodiment of the invention.

In an aspect of the invention, said pitch bearings comprise at least three further rows of rolling elements, said further rows having another common diameter.

5

Herby is achieved an advantageous embodiment of the invention.

The invention further provides for use of wind turbine according to any of claims 1 to 28, wherein said wind turbine is a variable speed pitch wind turbine.

10

Figures

The invention will be described in the following with reference to the figures in which

15

fig. 1. illustrates a large modern wind turbine as seen from the front,

fig. 2 illustrates a cross section of a wind turbine hub connected to a hub through a pitch bearing comprising plates,

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fig. 3 illustrates the same embodiment of a pitch bearing as illustrated in fig. 2 as seen from the top,

fig. 4 illustrates a part of a cross section of a pitch bearing comprising three rows of rolling elements,

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fig. 5 illustrates a part of a cross section of a pitch bearing comprising six rows of rolling elements,

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- fig. 6 illustrates a part of a cross section of a pitch bearing comprising angle compensating means,
- 5 fig. 7 illustrates the same embodiment of a pitch bearing as illustrated in fig. 6 as seen from the top,
- fig. 8 illustrates an embodiment of a hollow roller as seen from the front and the side,
- 10 fig. 9 illustrates an embodiment of a rounded roller as seen from the front and the side,
- fig. 10 illustrates a part of a cross section of a pitch bearing comprising rollers,
- 15 fig. 11 illustrates a part of a cross section of another pitch bearing comprising rollers,
- fig. 12 illustrates an embodiment of rolling element cages and separate compression parts,
- 20 fig. 13 illustrates an embodiment of rolling element cages comprising compression zones,
- 25 fig. 14 illustrates the same embodiment of rolling element cages as illustrated in fig. 13 in a compressed state, and
- fig. 15 illustrates a part of a cross section of a pitch bearing comprising rolling element cages.

Detailed description

Fig. 1 illustrates a wind turbine 1, comprising a tower 2 and a wind turbine nacelle 3 positioned on top of the tower 2. The wind turbine rotor 4, comprising two wind turbine blades 5, is connected to the nacelle 3 through the low speed shaft which extends out of the nacelle 3 front.

Fig. 2 illustrates a cross section of a wind turbine blade 5 connected to a hub 7 through an embodiment of a pitch bearing 9. In this embodiment the pitch bearing 9 is a triple row 27 ball bearing, but it could also be a double or four rowed 27 bearing.

The pitch bearing has to transfer forces mainly from three different sources. The blade 5 (and the bearings 9 themselves off cause) is under constant influence of the force of gravitation. The direction of the gravitational force varies depending on the blades 5 position, inducing different loads on the pitch bearings 9. When the blade is in motion the bearing 9 is also under influence of a centrifugal force, which mainly produces an axial pull in the bearing 9. Finally the bearings 9 are under influence of the wind load on the blades 5. This force is by far the greatest load on the bearings 9 and it produces a massive moment, which the bearings 9 have to stand.

20

Since the pitch mechanism on traditional pitch wind turbine 1 usually can pitch the blade 5 a little over 90°, the load on the pitch bearings 9 is far from uniform under normal operation. The wind load on the blade 5 will make the blade 5 pull in the part of the inner ring 26 of the bearing 9 facing the wind and push on the part of the inner ring 26 facing away from the wind. When the inner ring 26 is pulled forcefully by the blade 5 the balls are pushed outwards and upwards in an angle of approximately 45° as indicated by the arrows. This force will result in an axial pull in the outer ring 24 and a radial push on the outer ring 24. Since the bottom of the outer ring 24 is fixed against the hub 7, the top of the ring 24 will have a tendency to deflect. Likewise will the inner ring 26 have a tendency to deflect at the bottom, since it is fixed against the

30

blade at the top. If this deflection becomes too big, one or more of the rows 27 will be unable to transfer the loads, which could lead to a damaging load on the remaining balls. Because of the direction of the forces this problem is most pronounced at the part of the bearing facing the wind. This deflection could be
5 reduced by making the rings thicker and therefore more rigid, but this would increase the cost and the weight of the bearing significantly.

Multi-rowed ball bearings are relatively cheap due to the well proven and relatively simple design, but they have the disadvantage of being relatively high in relation to
10 the width, making them relatively poor regarding the transfer of large moment forces.

Fig. 2 therefore illustrates that the free end of the outer ring 24 is provided with an outer plate 10. The outer plate 10 is fixed to the outer ring 24 and thereby enables the
15 possibility of providing the outer ring 24 with rigidity where it is needed. Likewise, the inner ring 26 is provided with an inner plate 11. To ensure flexibility of the inner plate 11 in the right places, the plate 11 is provided with a hole 8, allowing for the inner ring 26 to deflect a little at the bottom to compensate for a little deflection at the top of the outer ring 24, and thereby ensuring a constant distance between the two
20 rings 24, 26 and a substantially identically load on all the rows 27 of balls 13.

Fig. 3 illustrates the same embodiment of a pitch bearing as illustrated in fig. 2 as seen from the top. In this embodiment of the invention the outer plate 10 is shaped as an annular semicircular ring with increased width towards the middle of the
25 semicircle. This design ensures most rigidity where the deflection of the outer ring 24 is biggest. In this embodiment of the invention the outer plate 10 covers approximately 180° of the outer ring 24 but in another embodiment the outer plate could cover more or less of the outer ring 24 or it could be formed as a full 360° annular ring. In another embodiment of the invention the outer plate 10 could also be
30 of constant width.

Fig. 3 also illustrates that the inner plate 11 is provided with a plate hole 8 shaped as an ellipse. The hole 8 is also placed near the part of the bearing 9 where the load on the outer ring 24 is biggest. In another embodiment of the invention the hole 8 could
5 have another shape such as circular, polygonal or the flexibility could be provided by means of a number of strategically placed holes 8.

Fig. 4 illustrates a part of a cross section of a pitch bearing 9 comprising three rows
10 27 of rolling elements 13. In this embodiment of the invention the pitch bearing 9 comprise an outer bearing ring 24 and an inner bearing ring 26. The figure further illustrates that the bearing 9 comprise three rows 27 of balls 13. The three rows of rolling elements 13 have the same diameter as illustrated by d_1 .

Fig. 5 illustrates a part of a cross section of a pitch bearing 9 comprising two
15 columns of each three rows 27 of rolling elements 13. Between the outer bearing ring 24 and the centre bearing ring 25 is positioned three rows 27 of balls 13 on the same diameter d_2 . Between the centre bearing ring 25 and the inner bearing ring 26 is positioned three other rows 27 of rolling elements 13 on a common diameter d_1 , which is different from d_2 .

20 Fig. 6 illustrates a part of a cross section of a pitch bearing 9 comprising angle compensating means 14. On an ordinary bearing 9 of this type the top and/or the bottom row 27 of rollers 13 would press against the middle section during normal operation. To ensure long life of the rollers 13 and the bearing 9, the transferred load
25 has to be distributed evenly over the entire roller surface. This could be ensured if the rings were made very strong and rigid, but this would also mean a significant increase in cost and weight.

Fig. 6 therefore illustrates that the bearing 9 is provided with angle compensating
30 means 10 in form of two separate rings provided with a plan surface 16 facing the

rollers 13 and a semicircular surface 15 facing the middle section 29. In another embodiment of the invention the plane surface 16 could be provided with a groove, in which the rollers 13 would roll and/or the semicircular surface 15 could be formed as a plane surface with more or less rounded corners.

5

The angle compensating means 10 could be made of hardened steel, but it would still be so flexible, that it can twist a little to compensate for any angle differences between the roller surface and the opposing surface on the middle section 29.

10 Fig. 7 illustrates the same embodiment of a pitch bearing as illustrated in fig. 6 as seen from the top. The angle compensating mean 10 is illustrated in dotted lines as one full 360° ring. In another embodiment of the invention the angle compensating mean 10 could be made of several individual or joined ring parts e.g. to lower the production costs.

15

Fig. 8 illustrates an embodiment of a hollow roller 12 as seen from the front and the side. The rollers 13 in roller bearings 9 as the ones illustrated in fig. 4, 8 and 9 are all very sensitive to angle differences between the different rings 24, 25, 26. If one of the rings 24, 25, 26 is under the influence of a heavy load, the design of the bearings 20 9 could result in such an angle difference, if the rings 24, 25, 26 are not strong and rigid enough. To ensure that the rollers 13 are not damaged by such an angle difference the rollers 13 could be provided with a hole 22 in the middle, providing it with that much flexibility that the roller 12 is not damaged even though the load on it is not evenly distributed.

25

In this embodiment of the invention the hole 22 is bigger near the ends of the roller 12, to ensure most flexibility where it is most needed, but in another embodiment of the invention the hole could be straight or the flexibility could be provided by a blind hole in one or each end of the roller 12.

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Fig. 9 illustrates an embodiment of a rounded roller 28 as seen from the front and the side. As explained above angle differences between the bearing rings 24, 25, 26 can damage the rollers 13 or reduce their life. To provide the bearings 9 with the flexibility enabling it to handle distortion of the bearing rings 24, 25, 26 the rollers 13 could also be provided with a curved roller surface either by making it bulge or by rounding 17 the two edges.

Fig. 10 and fig. 11 illustrates parts of cross sections of two different embodiments of pitch bearings 9. In these bearings 9 no angle compensating means are provided, so if the bearing rings 24, 25, 26 are distorted by the loads on and/or from the blades 5, the rollers or their respective opposing contact surfaces could be damaged. In these types of bearings flexibility enhancing means such as angle compensating means 14, inner and/or outer plates 10, 11, hollow rollers 12, rounded rollers 28 or any combination thereof would enable the bearings 9 to transfer a much greater load than otherwise possible without significantly increasing the cost or the weight of the bearings.

Fig. 12 illustrates an embodiment of rolling element cages 19. To ensure that the rolling elements 13 of the pitch bearing 9 are separated and stay in place, the rolling elements 13 are provided with rolling element cages 19. This could be a single 360° cage ensuring a constant distance between all the rolling elements 13, but if one or more bearing rings 24, 25, 26 are distorted, a force could arise forcing one or more rolling elements 13 apart. If the rolling elements 13 mutual distance is fixed, this force could potentially damage the rolling elements 13 or their corresponding contact surfaces on the bearing rings 24, 25, 26. As illustrated in fig. 12 the rolling element cages 19 could be divided into a number of separate cages 19 kept apart by compression parts 6. The compression parts 6 can be compressed and thereby absorbing some or the separating forces. The compression parts 6 could e.g. be rubber blocks, metal springs or other elastical devices or materials.

In this embodiment of the invention each cage 19 contains 4 balls but in another embodiment of the invention the cage 19 could contain two, three, five, six or more balls or rollers 13.

5 Fig. 13 illustrates another embodiment of rolling element cages 19. In this embodiment of the invention each cage 19 comprise a compression zone 20, in form of a transverse slit 21 formed integrally in the cage 19. The cages 19 could be made from some sort of steel plate which then could be flame or laser cut into the desired shape.

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Fig. 14 illustrates the same embodiment of rolling element cages 19 as illustrated in fig. 13 in a compressed state.

15

Fig. 15 illustrates a part of a cross section of an embodiment of a pitch bearing 9 comprising rolling element cages 19.

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The invention has been exemplified above with reference to specific examples of separate flexibility enhancing means in pitch bearings 9 for a wind turbine 1. However, it should be understood that the invention is not limited to the particular examples described above but may be designed and altered in a multitude of varieties within the scope of the invention as specified in the claims.

List

1. Wind turbine
2. Tower
3. Nacelle
- 5 4. Rotor
5. Blade
6. Compression part
7. Hub
8. Plate hole
- 10 9. Pitch bearing
10. Outer plate
11. Inner plate
12. Hollow roller
13. Rolling elements
- 15 14. Angle compensating mean
15. Semicircular contact surface
16. Plane roller surface
17. Rounding
18. Through hole
- 20 19. Rolling element cage
20. Compression zone
21. Transverse slit
22. Roller hole
23. Rolling element bed
- 25 24. Outer ring
25. Centre ring
26. Inner ring
27. Rolling element row
28. Rounded roller

- 29. Middle section
 - d1. Common diameter of rows of rolling elements
 - d2. Common diameter of other rows of rolling elements

Claims

1. A wind turbine (1) comprising
- 5 at least two pitch controlled wind turbine blades (5), each blade (5) comprising one or more pitch bearings (9) including two or more bearing rings (24, 25, 26), and
- pitch controlling means for pitching said blades (5) by means of said bearings (9),
- 10 said blades (5) being mounted on a hub (7) via said pitch bearings (9)

characterized in that

- said one or more pitch bearings (9) comprise separate flexibility enhancing means
- 15 (10, 11, 12, 14, 19, 20, 28) for controlling loads in said bearings (9).
2. A wind turbine (1) according to claim 1, wherein said bearings (9) comprise two rows (27) of rolling elements (13).
- 20 3. A wind turbine (1) according to claim 1 or 2, wherein said bearings (9) comprise three or more rows (27) of rolling elements (13).
4. A wind turbine (1) according to any of the preceding claims, wherein said bearings (9) comprise one or more first and one or more second separate flexibility enhancing
- 25 means (10, 11, 12, 14, 19, 20, 28).
5. A wind turbine (1) according to any of the preceding claims, wherein said separate flexibility enhancing means (10, 11, 12, 14, 19, 20, 28) are displaced from the load transferring surfaces of said bearing rings (24, 25, 26).

6. A wind turbine (1) according any of the preceding claims, wherein at least one of said one or more bearing rings (24, 25, 26) comprise through holes (18) for blade (5) attachment means such as screws, bolts, studs or rivets.
- 5 7. A wind turbine (1) according to any of the preceding claims, wherein said bearings (9) comprise three bearing rings (24, 25, 26).
8. A wind turbine (1) according to any of the preceding claims, wherein said separate flexibility enhancing means (10, 11, 12, 14, 19, 20, 28) comprise at least one angle
10 compensating mean (14).
9. A wind turbine (1) according to claim 8, wherein said at least one angle compensating mean (14) is a separate 360° ring or more than one ring parts together forming a full 360° ring.
- 15 10. A wind turbine (1) according to claim 8 or 9, wherein said at least one angle compensating mean (14) is positioned so that at least one of said rows (27) of rolling elements (13) rolls on one first surface of said angle compensating mean (14) and one second opposing surface of said angle compensating mean (14) is in contact with
20 the middle section (29) of said bearing (9).
11. A wind turbine (1) according to claim 10, wherein said first surface is a plane roller surface (16) and said second opposing surface is a semicircular or substantially semicircular contact surface (15).
- 25 12. A wind turbine (1) according to any of claims 1 to 7, wherein said separate flexibility enhancing means (10, 11, 12, 14, 19, 20, 28) include one or more plates (10, 11) attached to one or more of said bearing rings (24, 25, 26) by means of e.g. screws, bolts, studs, rivets, adhesive means or welding.

13. A wind turbine (1) according to claim 12, wherein at least one of said one or more plates (10, 11) is a strengthening plate (10, 11) providing additional non-uniform or substantially non-uniform rigidity to said bearing ring (24, 25, 26) on which it is attached.

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14. A wind turbine (1) according to claim 13, wherein said additional non-uniform or substantially non-uniform rigidity is provided by means of one or more holes (8) in said strengthening plates (10, 11).

10 15. A wind turbine (1) according to any of claims 1 to 7, wherein said separate flexibility enhancing means (10, 11, 12, 14, 19, 20, 28) comprises two or more radial separated rolling element cages (19).

15 16. A wind turbine (1) according to claim 15, wherein said rolling element cages (19) are separated by compression zones (20).

17. A wind turbine (1) according to claim 16, wherein said compression zones (20) are formed integrally in one or both longitudinal ends of said rolling element cages (19).

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18. A wind turbine (1) according to claim 17, wherein said integrally formed compression zones (20) are formed as transverse slits (21) in the rolling element cages (19).

25 19. A wind turbine (1) according to claim 18, wherein facing transverse slits (21) of juxtaposed rolling element cages (19) are slit transversely from opposite sides.

20. A wind turbine (1) according to claim 16, wherein said compression zones (20) are compression parts (6) separate from said rolling element cages (19).

30

21. A wind turbine (1) according to any of claims 1 to 7, wherein said separate flexibility enhancing means (10, 11, 12, 14, 19, 20, 28) includes hollow rolling elements such as hollow rollers (12).
- 5 22. A wind turbine (1) according to claims 21, wherein the hole (22) in said hollow rollers (12) has a larger diameter at the ends than in the middle.
23. A wind turbine (1) according to claims 21, wherein the hole (22) in said hollow rollers (12) is a straight through hole.
- 10 24. A wind turbine (1) according to claims 21, wherein the hole (22) in said hollow rollers (12) is a blind hole in one or both ends of said hollow rollers (12).
25. A wind turbine (1) according to any of claims 1 to 7, wherein said separate flexibility enhancing means (10, 11, 12, 14, 19, 20, 28) include rollers (13) with varying diameter.
- 15 26. A wind turbine (1) according to claim 25, wherein said rollers are rounded (17) in a longitudinal direction.
- 20 27. A wind turbine (1) according to claim 25, wherein said rollers bulges at the middle.
28. A wind turbine (1) comprising
- 25 at least two pitch controlled wind turbine blades (5), each blade (5) comprising one or more pitch bearings (9) including two or more bearing rings (24, 25, 26), and
- pitch controlling means for pitching said blades (5) by means of said bearings (9),

said blades (5) being mounted on a hub (7) via said pitch bearings (9)

characterized in that

5 said pitch bearings (9) comprise at least three rows of rolling elements (13), said rows having a common diameter (d1).

29. A wind turbine (1) according to claim 28, wherein said pitch bearings (9)
10 comprise at least three further rows of rolling elements (13), said further rows having another common diameter (d2).

30. Use of a wind turbine (1) according to any of claims 1 to 28, wherein said wind turbine (1) is a variable speed pitch wind turbine (1).

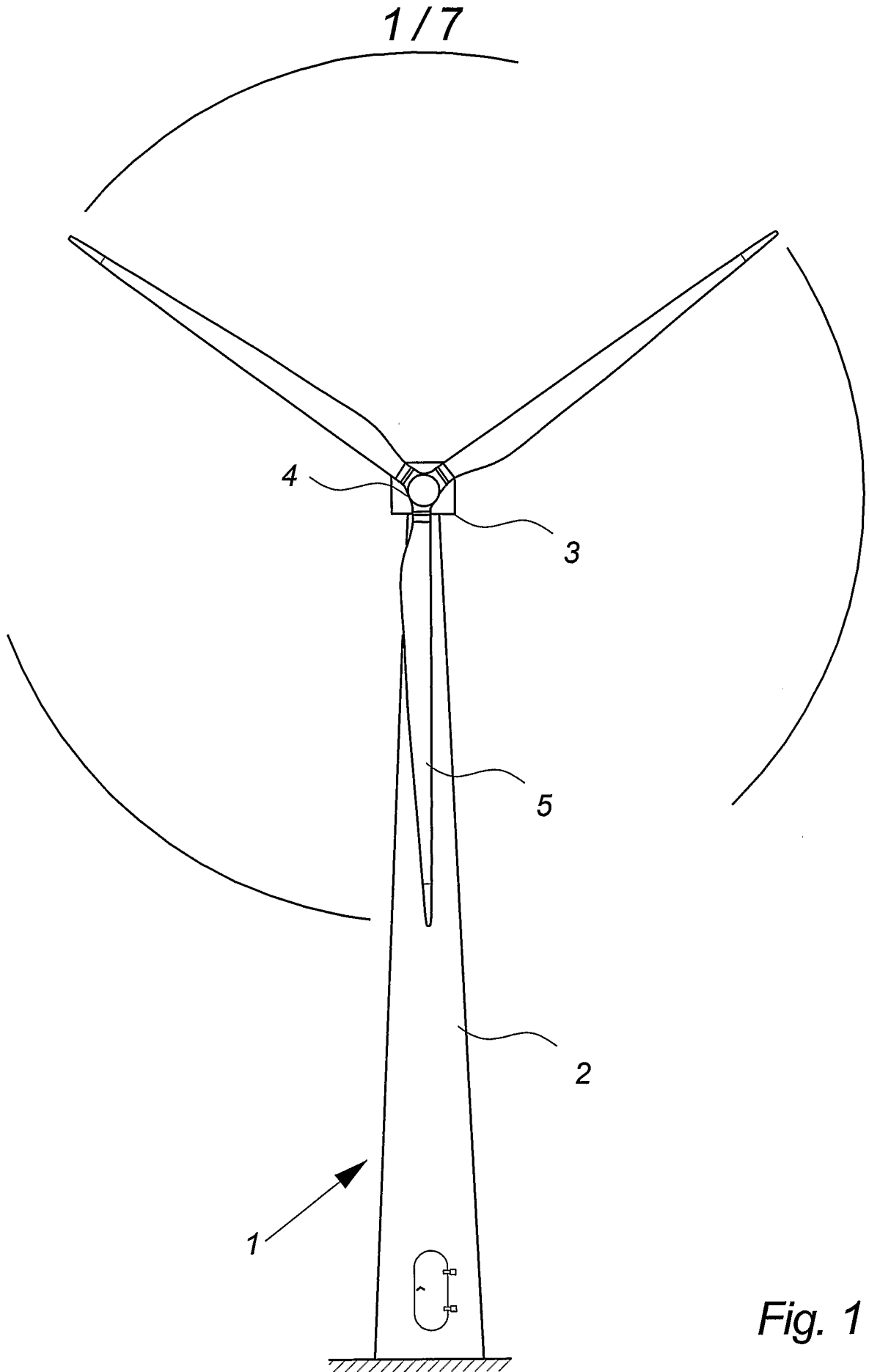


Fig. 1

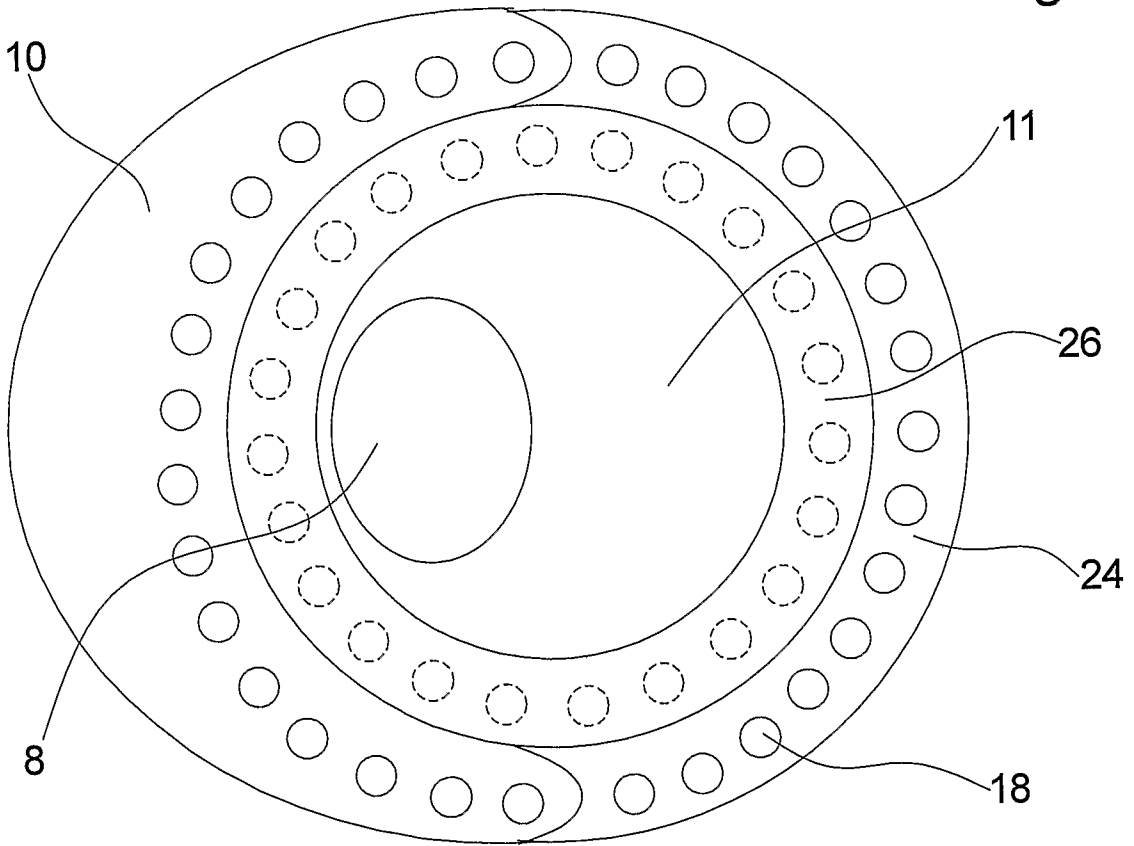
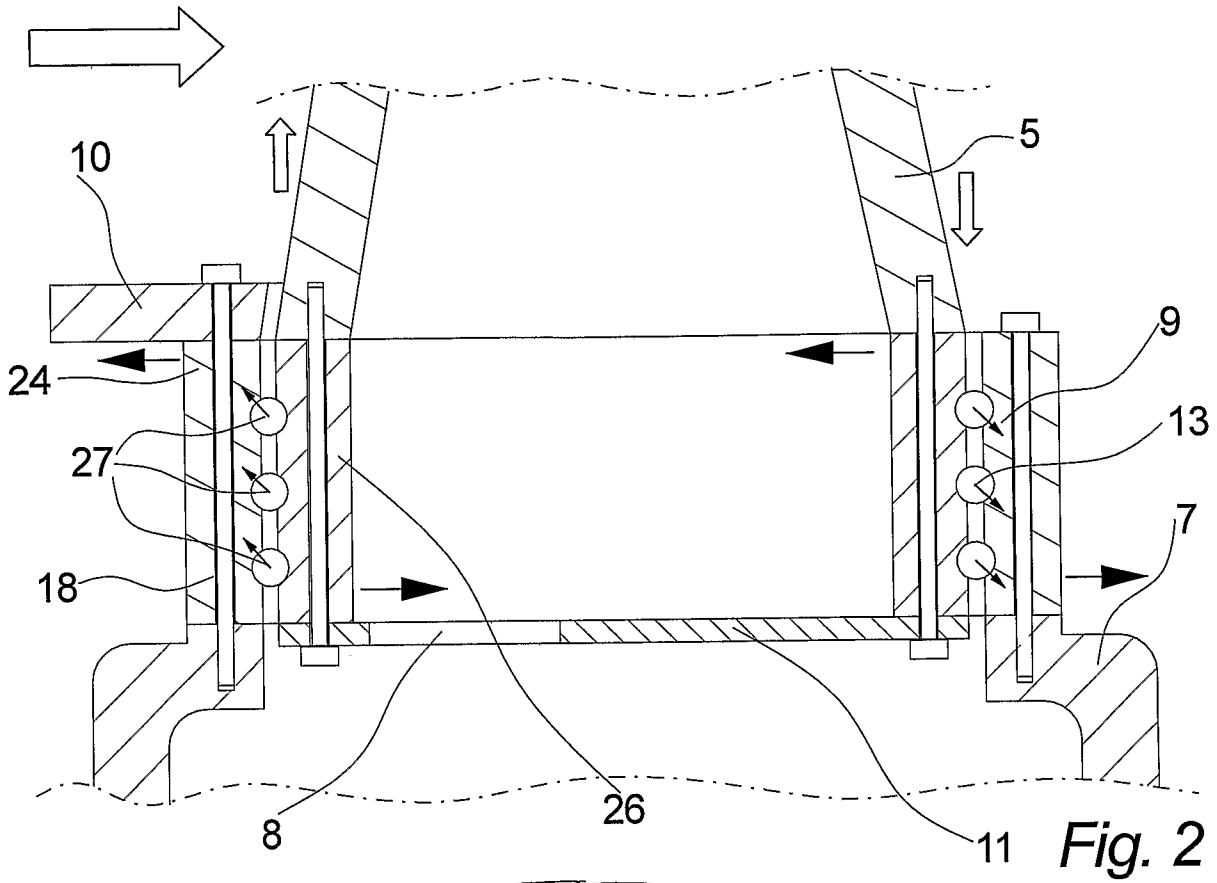


Fig. 3

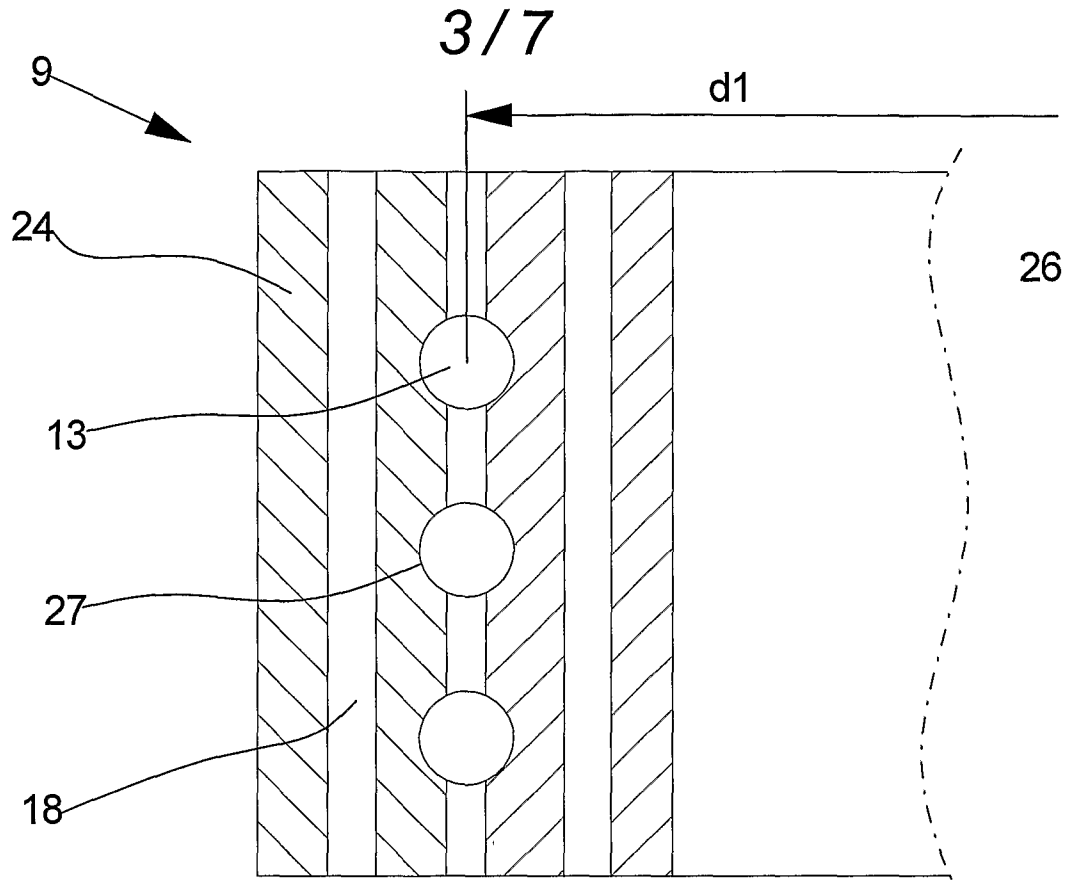


Fig. 4

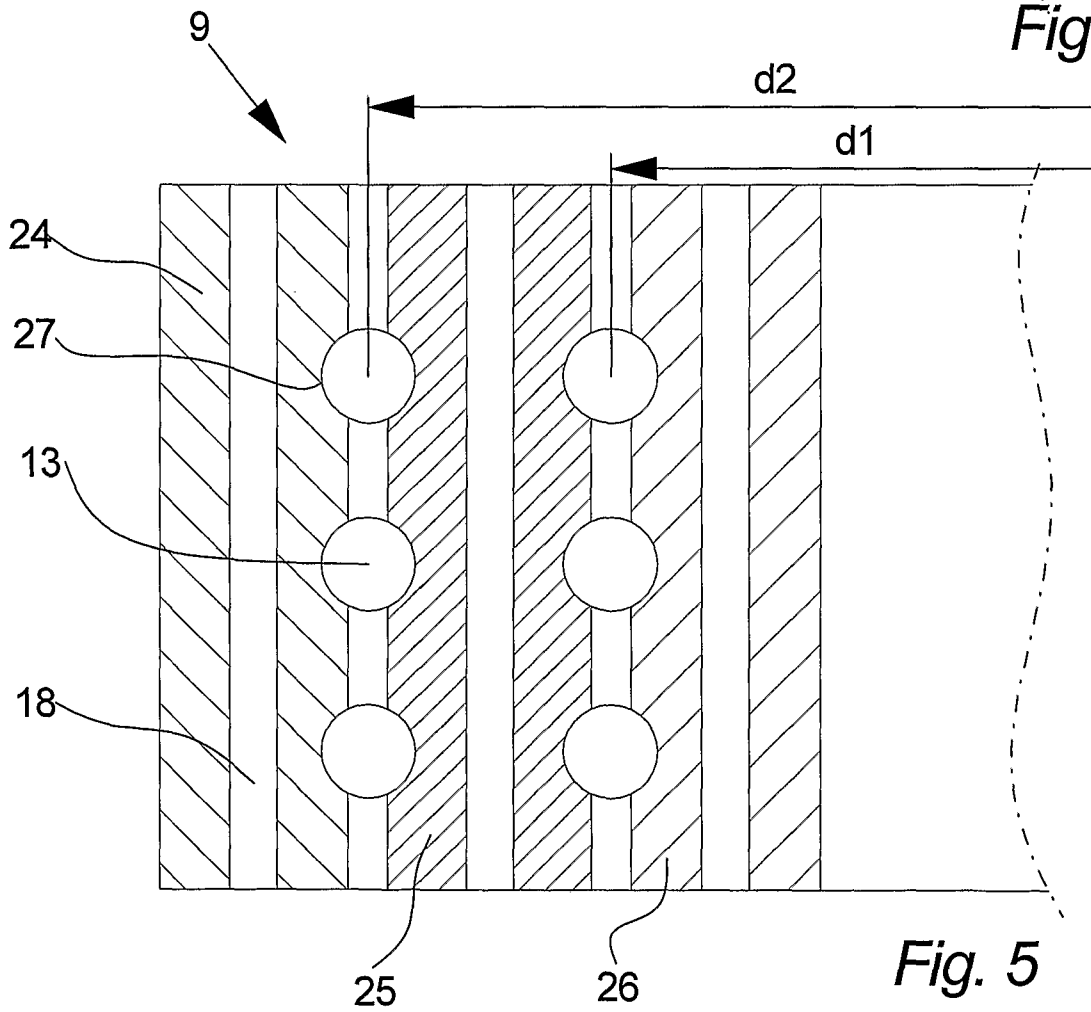


Fig. 5

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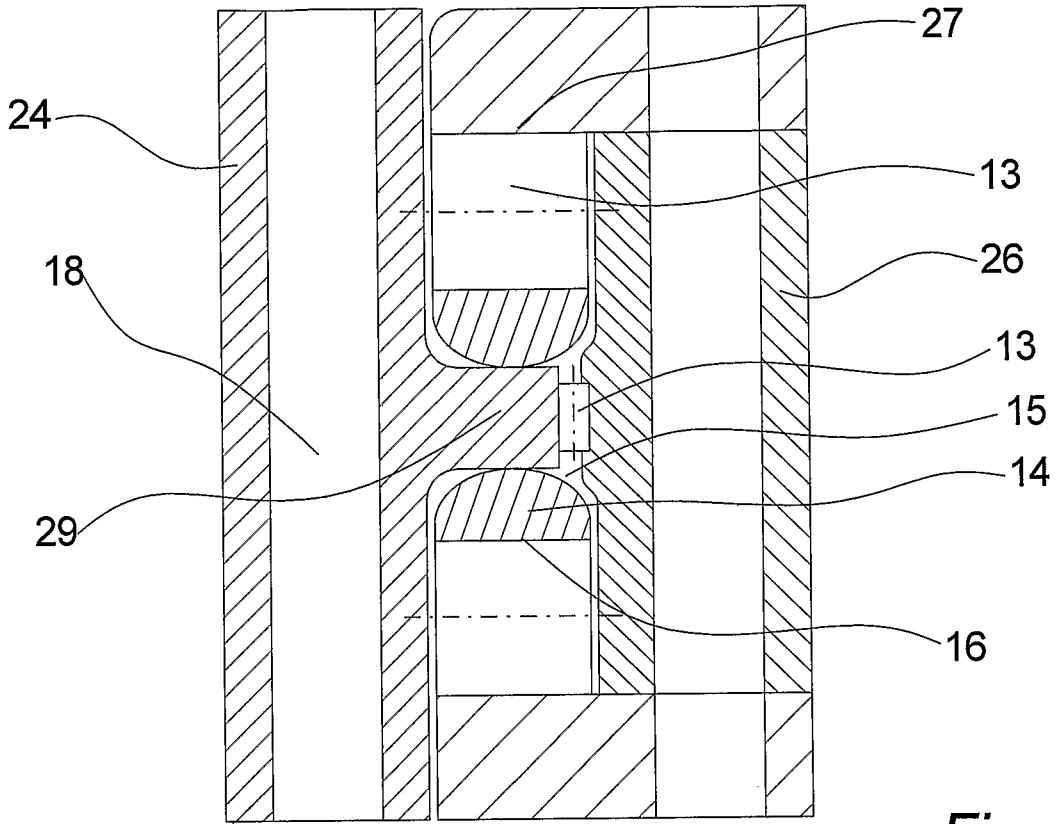


Fig. 6

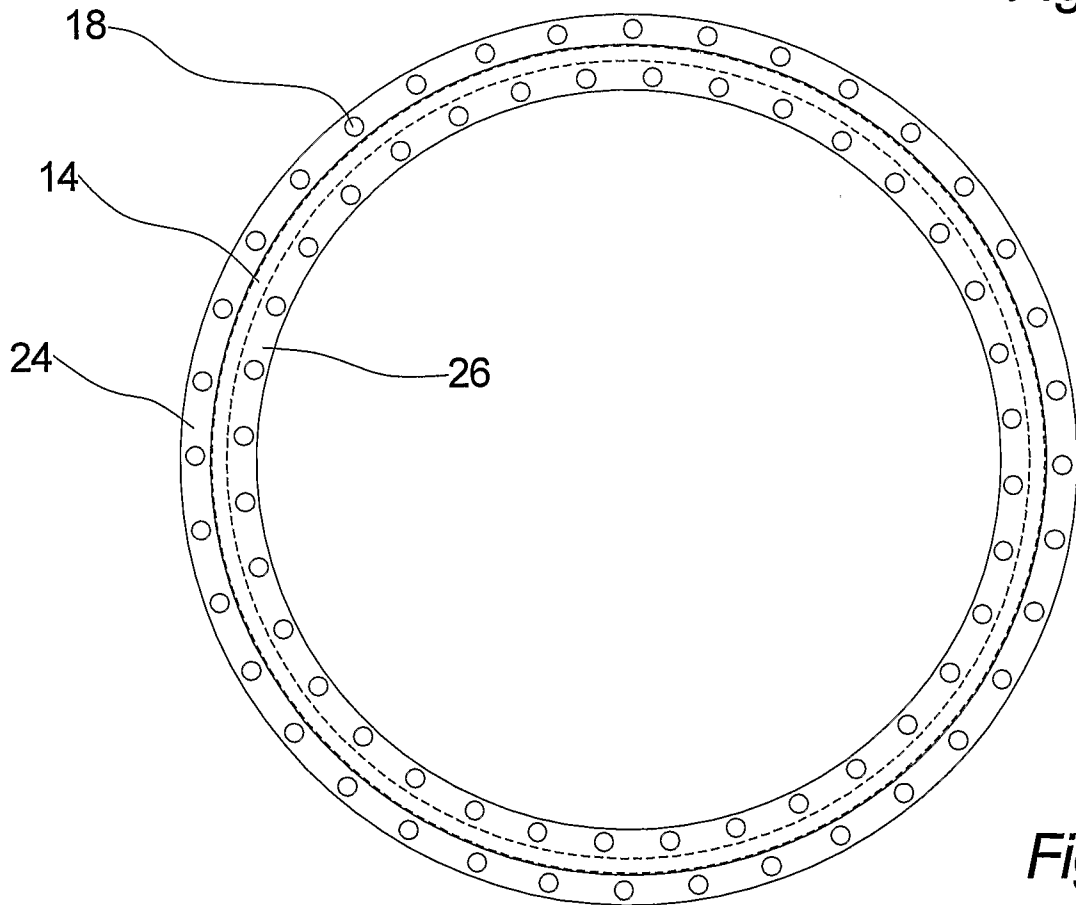


Fig. 7

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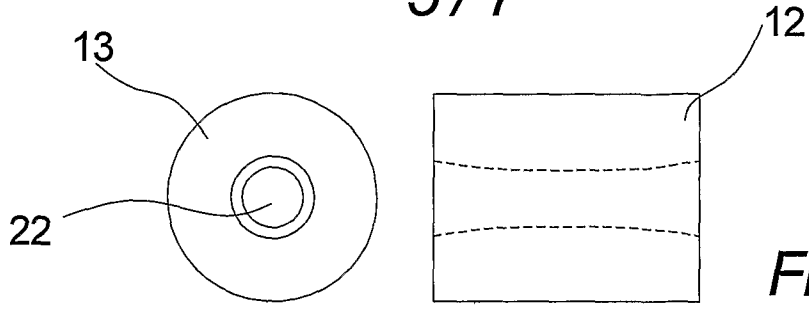


Fig. 8

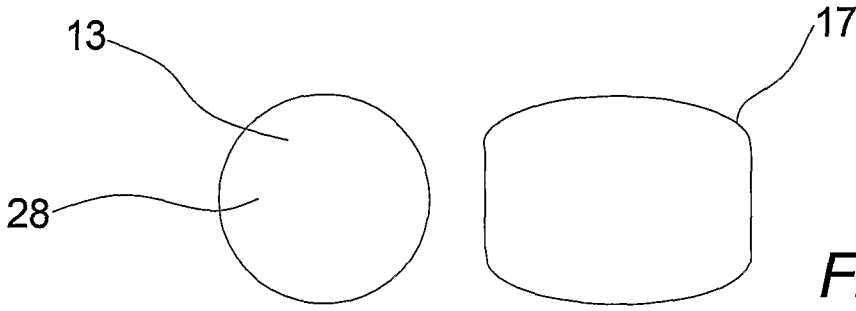


Fig. 9

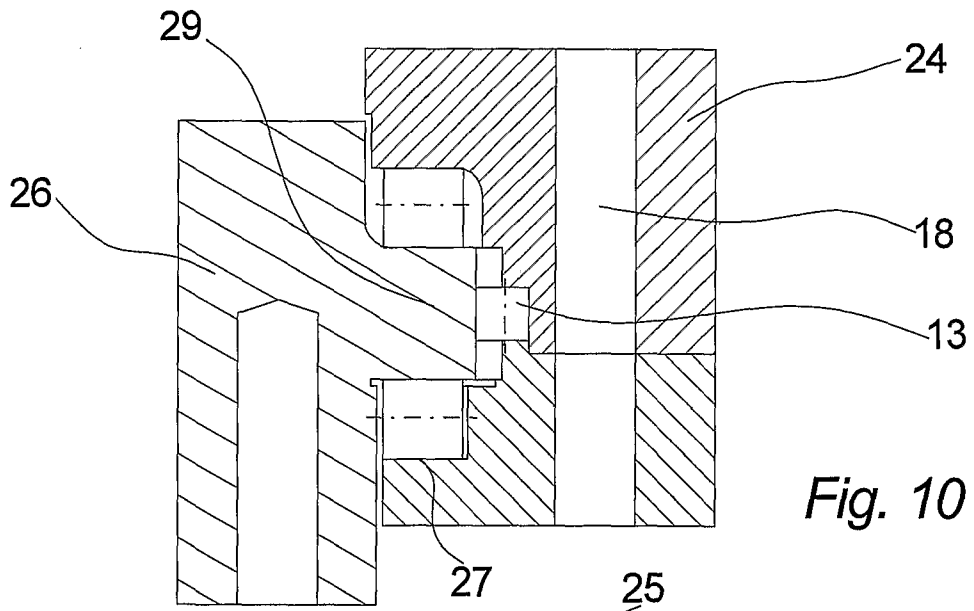


Fig. 10

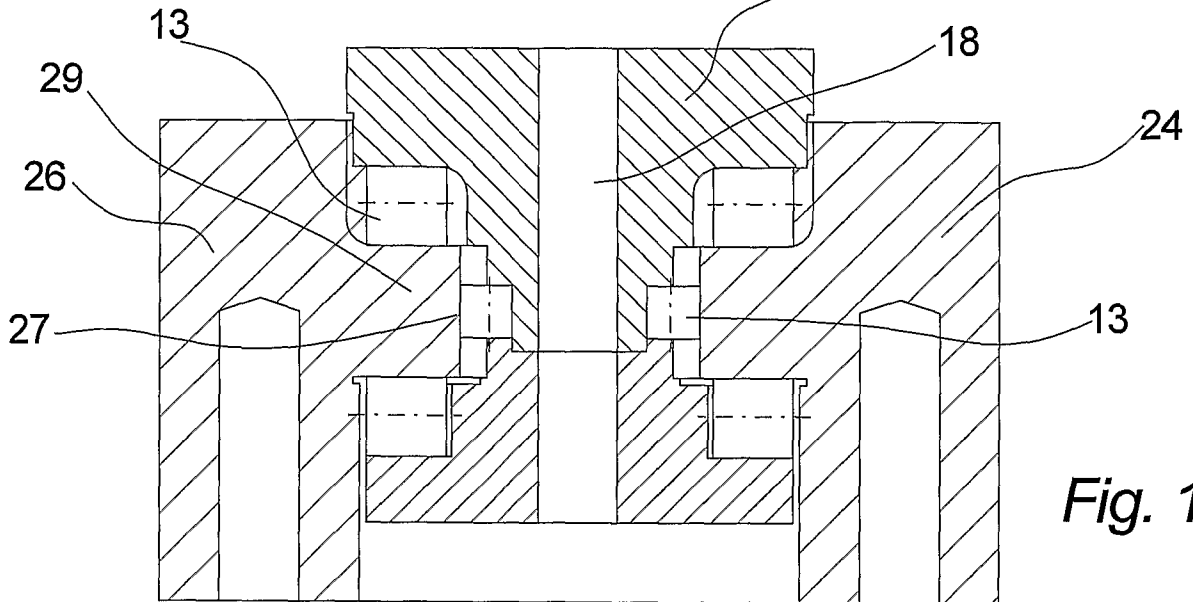
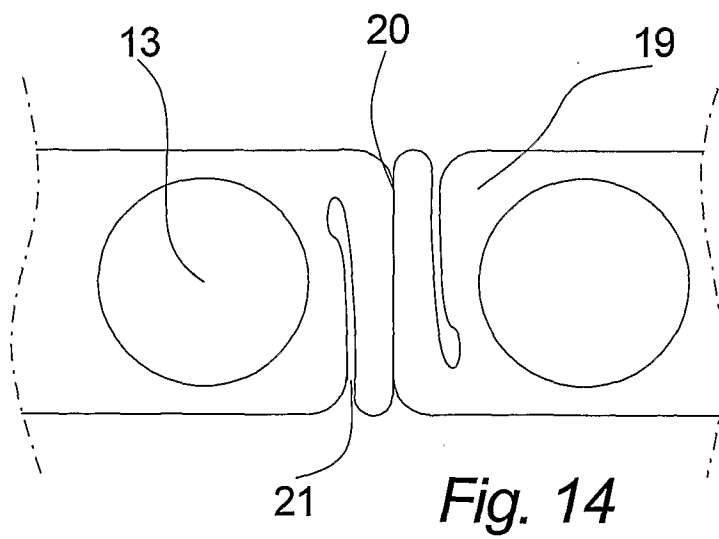
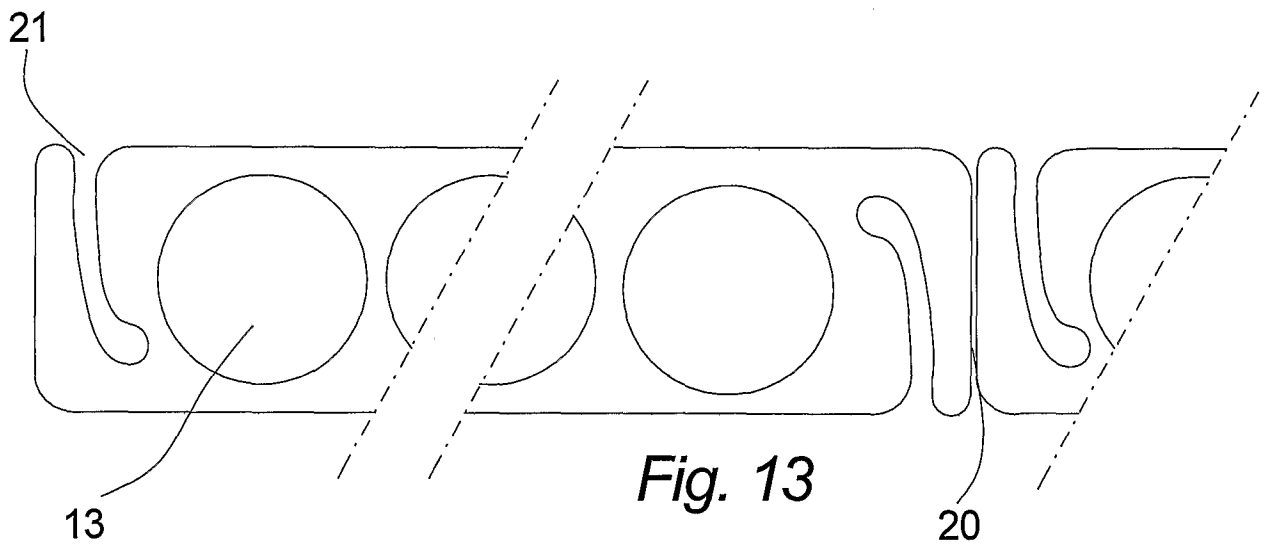
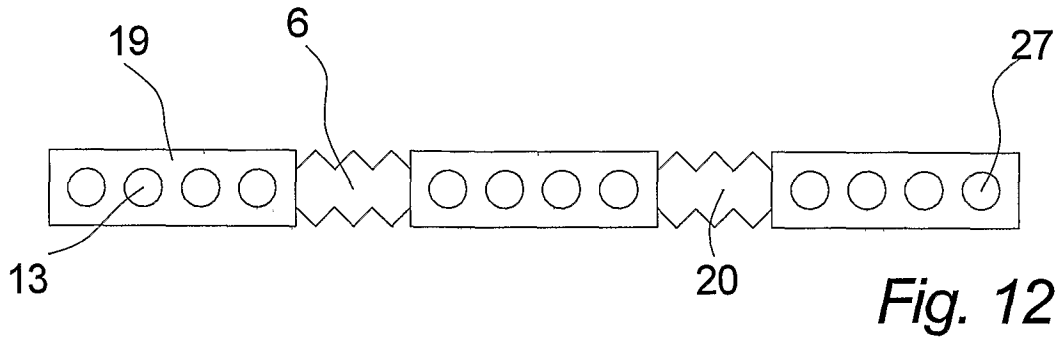


Fig. 11

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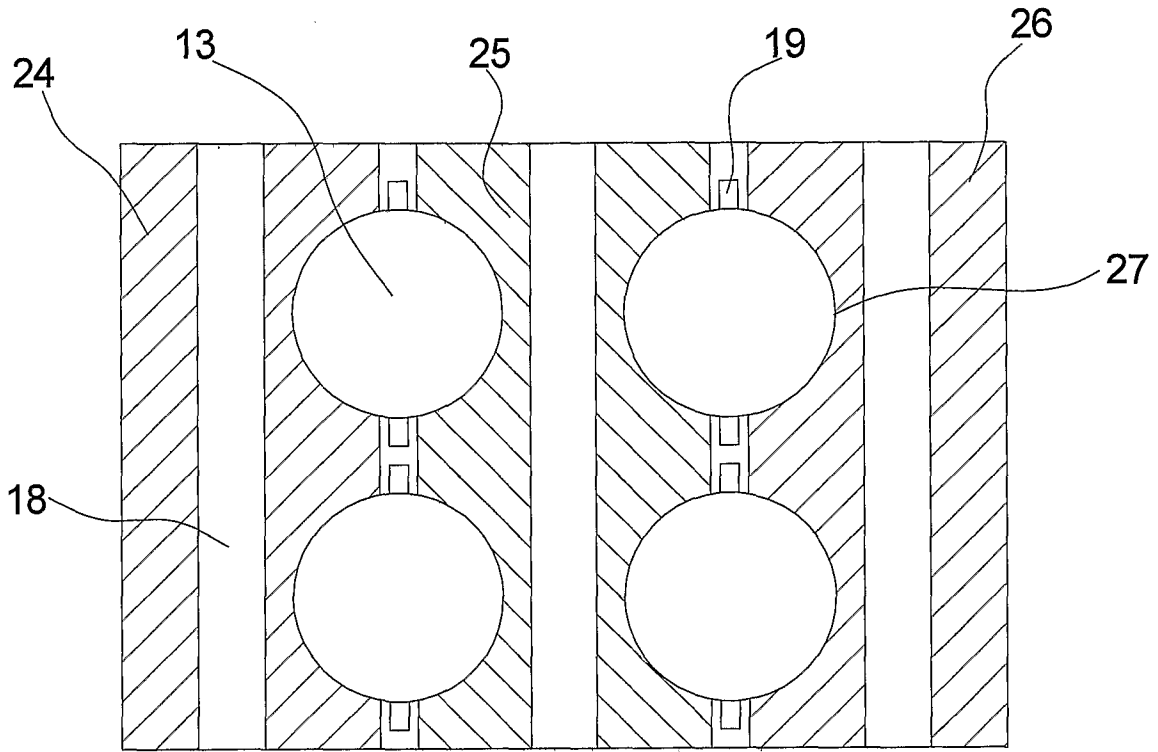


Fig. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2005/002612

A. CLASSIFICATION OF SUBJECT MATTER
F03D1/06 F03D7/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 431 375 A (CARTER, JR. ET AL) 14 February 1984 (1984-02-14) column 5, line 21 - column 8, line 50; figures 5-14	1-27, 30
X	US 4 364 708 A (DAVID ET AL) 21 December 1982 (1982-12-21) the whole document	1-27
X	FR 2 291 378 A (CARRE JEAN) 11 June 1976 (1976-06-11) abstract; figures 1-3	1-27
X	SE 416 990 B (* SAAB-SCANIA) 16 February 1981 (1981-02-16) abstract; figures 1-5	1-7
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Further documents are listed in the continuation of Box C.

See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search

23 February 2006

Date of mailing of the international search report

03/03/2006

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2005/002612

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 668 109 A (BASSO ET AL) 26 May 1987 (1987-05-26) the whole document	1-8, 28-30
A	US 4 201 514 A (HUETTER, ULRICH) 6 May 1980 (1980-05-06) the whole document	1-30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2005/002612

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US 4668109	A	26-05-1987	NONE	
US 4201514	A	06-05-1980	DE 2655026 B1 FR 2372971 A1 GB 1573687 A SE 7713525 A	18-05-1978 30-06-1978 28-08-1980 05-06-1978