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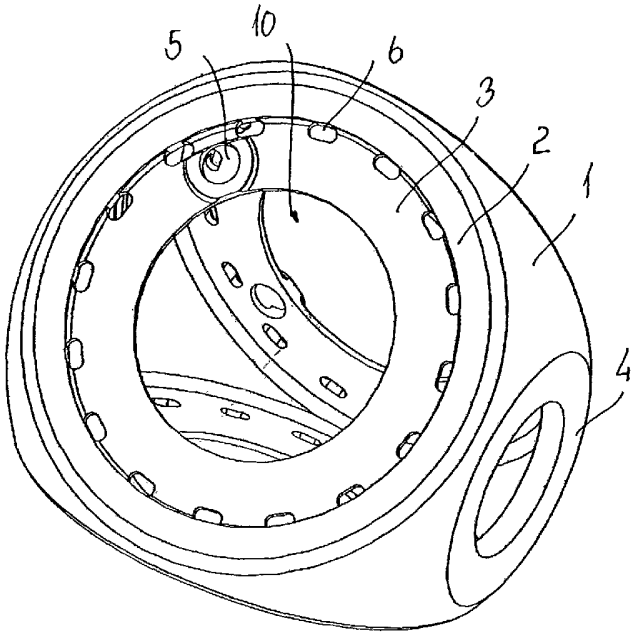
(54) Title: BLADE-HUB FOR A WIND TURBINE



(57) Abstract: The invention relates to a blade-hub for a wind turbine. The blade-hub is provided with rib-stiffeners, which extend from a flange of the blade hub and inwardly along the plane of a hole delimited by the flange. The rib-stiffeners aid in providing a sufficient stiffness of the blade-hub, especially large hollow blade-hubs for the constantly increasing size of wind turbines. The rib-stiffeners are sized according the need for proper stiffness of the blade-hub, but also in consideration of the needs for proper access to the blades attached to the blade-hub, i.e. access to bearing bolts and access to the interior of the blades.

WO 03/064854 A1

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

BLADE-HUB FOR A WIND TURBINE

The present invention relates to a blade-hub for a wind turbine, where the design of the blade-hub results in significant stress reduction and reduced deformations.

BACKGROUND FOR THE INVENTION

The development in the wind energy industry has led to the manufacturing of larger wind energy conversion systems. One of the results of this is that the wind turbine blades become longer and heavier, and stronger and larger blade-hubs are therefore needed.

For smaller wind turbines, welded constructions have been used for blade-hubs. However, in order to obtain stronger blade-hubs for larger wind turbines, they are generally designed as a hollow body defined between two spheres, an inner and an outer sphere, often with their centres slightly displaced to get the optimal distribution of the stress introduced in the blade-hub by the turbine blades. The blade-hub is designed as a hollow body construction to reduce the weight of it and to optimise the strength thereof.

Turbine blades are attached to the blade-hub via flanges and bearings to allow for pitching of the blades. In order to reduce weight and to be able to attach the blades and tighten the bearing bolts, the flanges are designed with an opening within each of them. Furthermore, this opening is used to provide access for pitching means for pitching the turbine blades. Due to the openings in the blade-hub the area between these openings is small and therefore large stress concentrations may occur in the material in this area during operation of the wind turbine, and deformations may arise as consequence thereof.

The area between the openings may be enlarged and the stress thus lowered by increasing the diameter of the blade-hub as the dimensions of the turbine blades are increased. However, the costs of manufacture of the larger structure increases more than proportional with the size, in particular for cast-iron structures, and the greater weight causes the problems discussed above. Another solution is to use blade-hubs with larger material thickness. This will however have the negative side effect of increasing the weight of the blade-hub and tests have shown that the problems are not solved satisfactory.

Thus, the object of the present invention is to provide a blade-hub design for larger wind turbines, in which the stresses during operation are kept at an acceptable level without increasing the weight of the blade-hub excessively.

This objective is met by the present invention according to which rib-stiffeners are added to the hollow body blade-hub flanges substantially in the plane of the flanges to provide a larger area for the stresses and thus prevent excessive stress concentrations.

Furthermore, the design of providing the rib-stiffeners substantially in the plane of the flanges increases the stiffness of these flanges and prevents deformation of the flanges, thus preventing deformation of the blade bearings attached to the flange. A deformation of the bearings is disadvantageous and results in an excessive wear of the bearing and lowering of the durability of the bearings.

BRIEF DESCRIPTION OF THE INVENTION

The present invention relates to a blade-hub for a wind turbine, where the blade-hub is a hollow body having blade flanges for the attachment of wind turbine blades. For each of the flanges a rib-stiffener is extending substantially in the plane of the flange, so as to increase the area affected by stresses and thus preventing stress concentration as well as to gain stiffness of the blade-hub in the planes of the flanges, thus preventing deformation of the flanges and the bearings attached thereto.

In a preferred embodiment the area of the rib-stiffener in the plane of the flange is within the range of 30 to 80% of the cross-sectional area of the wind turbine blade root, preferably in the range of 40-60% of the cross-sectional area.

The outer shape of the hollow body blade-hub is generally defined by revolution of a smooth curve. Said curve may be substantially normal to the axis of rotation at the intersections of the two at the front end of the blade-hub and/or at the back end of the blade-hub. By a smooth curve is understood a curve having a substantially continuous derivative. This design ensures optimal distribution of stress introduced in the blade-hub by preventing stress concentrations at sharp bends. However, the shape is only generally defined by the curve revolution and the blade-hub may comprise smaller projection e.g. for the fastening of turbine blades to the hub.

The hollow body may have an opening defined within each of said blade flanges, in which case it is preferred that the rib-stiffeners extend inwardly of the openings of the blade flanges. Alternatively, the rib-stiffeners may extend outwardly from the flanges. A pitching hole may be formed in each of the rib-stiffeners to provide access for a drive means for pitching the turbine blade, such as a toothed wheel attached to the drive shaft of an electric motor and engaging a toothed rim of the part of the bearing attached to the blade root. Furthermore, holes may advantageously be formed in each of the rib-stiffeners to

provide access to tightening wind turbine blade bearing bolts, which are connecting the bearings to the turbine blades.

In one embodiment the blade-hub and the rib-stiffeners are integrally formed using e.g. composite materials or ceramics, however in a preferred embodiment they are cast in one piece e.g. from cast iron.

When the above described blade-hub is used in a wind turbine, the rib-stiffeners should be designed such that the resulting stiffness of the blade-hub will prevent deformations of the diameter of the flanges exceeding a 1% change of diameter under operation of the wind turbine, preferably preventing deformations exceeding a 0.5% change, and most preferred preventing deformations exceeding a 0.1-0.2% change.

According to a second aspect of the present invention, a blade-hub may also be part of a wind turbine blade-hub assembly comprising a hollow body blade-hub and a hollow body main shaft and also comprising adaptation means for a wind turbine main bearing encircling the main shaft. The hollow body blade-hub and the hollow body main shaft being integrally formed or cast in one piece to reduce the number of components. Furthermore, the lack of interface between these two main parts also gives the possibility of reducing the weight due to the reduction of stress introduced in the blade-hub assembly.

In a preferred embodiment the main shaft of the blade-hub assembly extends at least 50% in the orientation of the axis of rotation compared to the size of the blade-hub to ensure optimal operating conditions.

In one embodiment the adaptation means for the main bearing is positioned at the main shaft of the blade-hub assembly at a distance of 20 to 250 cm from the blade-hub, preferable 30-80 cm, also ensuring optimal operating conditions.

The design of the blade-hub may be as the above described hollow body blade-hub with integrated rib-stiffeners, making it possible to combine the new design of the blade-hub with the blade-hub assembly.

BRIEF DESCRIPTION OF THE FIGURES

Embodiments of the present invention are shown in the accompanying drawings, of which

Fig. 1 is a perspective view of a blade-hub according to a first aspect embodiment of the present invention, with rib-stiffeners according to the invention provided

Fig. 2 is a cross-section of a detail of the blade-hub according to the invention as shown in Fig. 1 and a bearing and a wind turbine blade attached thereto, and

Fig. 3 is a perspective view of a second aspect embodiment of the blade-hub and main shaft assembly according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a hollow body blade-hub 1 with blade flanges 2 and integrated rib-stiffeners 3. 1. The figure shows blade flanges 2 for the attachment of three turbine blades and shows the main shaft flange 4 for the attachment of the hub to the main shaft. Rib-stiffeners 3 are added to the flanges 2, said rib-stiffeners 3 extending inwardly of the flanges 2. In each of the rib-stiffeners 3 an opening 5 is formed for the provision of a pitch motor. Furthermore, holes 6 have been formed between the flange 2 and the rib-stiffener 3 for providing access to tightening the bearing bolts of the turbine blades.

Fig.2 shows in cross-section a detail of the hollow body blade-hub 1. The turbine blade 7 is attached to the blade-hub 1 by means of bearing bolts 9. The rib-stiffener 3 is extending inwardly of the flange 2. Furthermore, the bearing 8 and the bearing bolts 9 for the attachment of the turbine blade 7 to the blade-hub 1 can also be seen. The rib-stiffeners extend inwardly to an extend so that the area of the rib-stiffeners 3 cover a large portion of an opening 10 in the hub, said opening 10 being delimited by the blade flange 2. The rib-stiffeners cover in the range of 30-80% of the entire area of the opening 10, preferably in the range of 40-60% of the area of the opening 10. The thickness of the rib-stiffeners may be in the range of 5-100 mm, possibly in the range of 10-50 mm. The thickness of the rib-stiffeners 3 very much depend on the size of the blade-hub 1 and the desired stiffness of the blade-hub 2 in comparison with the design and the dimensioning of the different parts of the blade-hub 2.

The extension of the rib-stiffeners 3 of course has an effect on the stiffness obtained of the entire hollow body 1. However, the rib-stiffeners should not cover too much of the area of the opening 10, because access should still be possible to the interior of the blades, when

being mounted to the flange 2 along the bearing 8. Therefore, a balancing between the stiffening effect of the rib-stiffeners and the limited accessibility to the interior of the blades must be made, when designing how much of the area of the opening 10 that the rib-stiffeners 3 should cover. The demand for accessibility is also prevailing, when taking the holes 6 in view. These holes 6 are just the point of obtaining accessibility to the tightening the bearing bolts 9.

The rib-stiffeners 3 are provided for obtaining a reduction of the deformations of the hub 1 during operation of the wind turbine. Preferably, the rib-stiffeners 3 should result in an decrease in deformation of the blade-hub preventing deformation of the diameter of the flanges exceeding a 1% change of diameter under operation of the wind turbine, preferably preventing deformations exceeding a 0.5% change, and most preferred preventing deformations exceeding a 0.1-0.2% change.
In the figure shown, the flange 2 and the rib-stiffener 3 is shown as one and the same member. Preferably, the flange and the rib-stiffeners are integrally formed, perhaps by being cast in one piece. Provision of hole 5 for the pitch motor and holes for accessibility to the bearing bolts are made after casting. However, it will be possible to join together a separate hub with separate rib-stiffeners, said joining preferably being made by welding. Due to the stresses and tension occurring in the hub during operation, there may however be a risk of crack formation leading to the rib-stiffeners not providing the proper stiffening, and in worst cases resulting in the rib-stiffeners being detached from the flange.

Fig. 3 shows an integrated hollow body blade-hub 1 and hollow body main shaft 11. The integration of the blade-hub and of the main shaft constitutes a second aspect of the invention, primarily differing from the first aspect in the integration of the two wind turbine parts. The figure shows flanges 2 for the attachment of three turbine blades. Rib-stiffeners can be added to the flanges 2 extending inwardly of the flanges 2. This is not shown at the figure. The rib-stiffeners may be integrate with the blade-hub and the main shaft. Alternatively, the rib-stiffeners may be added to the blade-hub by welding or other means of joining a separate rib-stiffeners with the flanges 2 of the blade-hub. The above considerations as mentioned with reference to fig. 1 must also be taken into consideration in the second aspect of the invention

The main shaft 11 has adaptation means 12 for a wind turbine main bearing encircling the shaft 11. The adaptation means may be provided at different distances from the blade hub depending on the desired and obtainable stiffness of the integrated main shaft and blade-hub. Preferably, the adaptation means is positioned at the main shaft at a distance of 20 to 250 cm from the blade-hub, preferable at a distance of 30-80 cm from the blade-hub. Furthermore, because the main shaft constitutes an integrate part together with the blade-

hub, the main shaft contributes to the stiffness of the blade-hub. Accordingly, preferably the main shaft extends at least 50% in the orientation of the axis of rotation compared to the circumferential size of the blade-hub seen in a plane perpendicular to the longitudinal direction of the main shaft.

CLAIMS

1. A wind turbine blade-hub comprising a hollow body having blade flanges for the attachment of wind turbine blades, and for each of said flanges a rib-stiffener extending substantially in the plane of an opening delimited by the flange.

2. A blade-hub according to claim 1, wherein the area of the rib-stiffener in the plane of the flange is within the range of 30-80% of the cross-sectional area of the opening in the flange, preferably 40-60% of the cross-sectional area.

3. A blade-hub according to claim 1 or 2, wherein the outer shape of the hollow body is generally defined by revolution of a smooth curve.

4. A blade-hub according to claim 3, wherein said curve is substantially normal to the axis of rotation at the intersections of the two at a front end of the blade-hub.

5. A blade-hub according to claim 3 or 4, wherein said curve is substantially normal to the axis of rotation at the intersections of the two at a back end of the blade-hub.

6. A blade-hub according to any of claims 1-5, wherein the hollow body has an opening defined within each of said blade flanges, and the rib-stiffeners extend inwardly of said openings of the blade flanges.

7. A blade-hub according to claim 6, wherein a pitching hole is formed in each of the rib-stiffeners, said hole providing access for a drive means for pitching the turbine blade.

8. A blade-hub according to claim 6 or 7, wherein a plurality of holes are formed in each of the rib-stiffeners, said holes intended for providing access to tightening of wind turbine blade bearing bolts connecting the bearings to the turbine blades.

9. A blade-hub according to any of the preceding claims, wherein the blade-hub and the rib-stiffeners are integrally formed, possibly the blade-hub and the rib-stiffeners being cast in one piece.

10. A blade-hub according to claim 9, wherein the blade-hub and the rib-stiffeners constitute separate parts and are joined togteher, said parts preferably being joined by welding.

11. A wind turbine blade-hub assembly comprising a hollow body blade-hub according to any of claims 1-10 and a hollow body main shaft comprising adaptation means for a wind turbine main bearing encircling said main shaft, wherein the hollow body blade-hub and the hollow body main shaft are integrally formed.

12. A blade-hub assembly according to claim 11, wherein the hollow body blade-hub and the hollow body main shaft are cast in one piece.

13. A blade-hub assembly according to claim 11 or 12, wherein the main shaft extends at least 50% in the orientation of the axis of rotation compared to the circumferential size of the blade-hub seen in a plane perpendicular to the longitudinal direction of the main shaft.

14. A blade-hub assembly according to any of claims 11-13, wherein the adaptation means for the main bearing is positioned at the main shaft at a distance of 20 to 250 cm from the blade-hub, preferable at a distance of 30-80 cm from the blade-hub.

15. A wind turbine blade-hub assembly comprising a hollow body blade-hub and a hollow body main shaft comprising adaptation means for a wind turbine main bearing encircling said main shaft, wherein the hollow body blade-hub and the hollow body main shaft are integrally formed.

16. A blade-hub assembly according to claim 15, wherein the hollow body blade-hub and the hollow body main shaft are cast in one piece.

17. A blade-hub assembly according to claim 15 or 16, wherein the main shaft extends at least 50% in the orientation of the axis of rotation compared to the circumferential size of the blade-hub seen in a plane perpendicular to the longitudinal direction of the main shaft.

18. A blade-hub assembly according to any of claims 15-17, wherein the adaptation means for the main bearing is positioned at the main shaft at a distance of 20 to 250 cm from the blade-hub, preferable 30-80 cm.

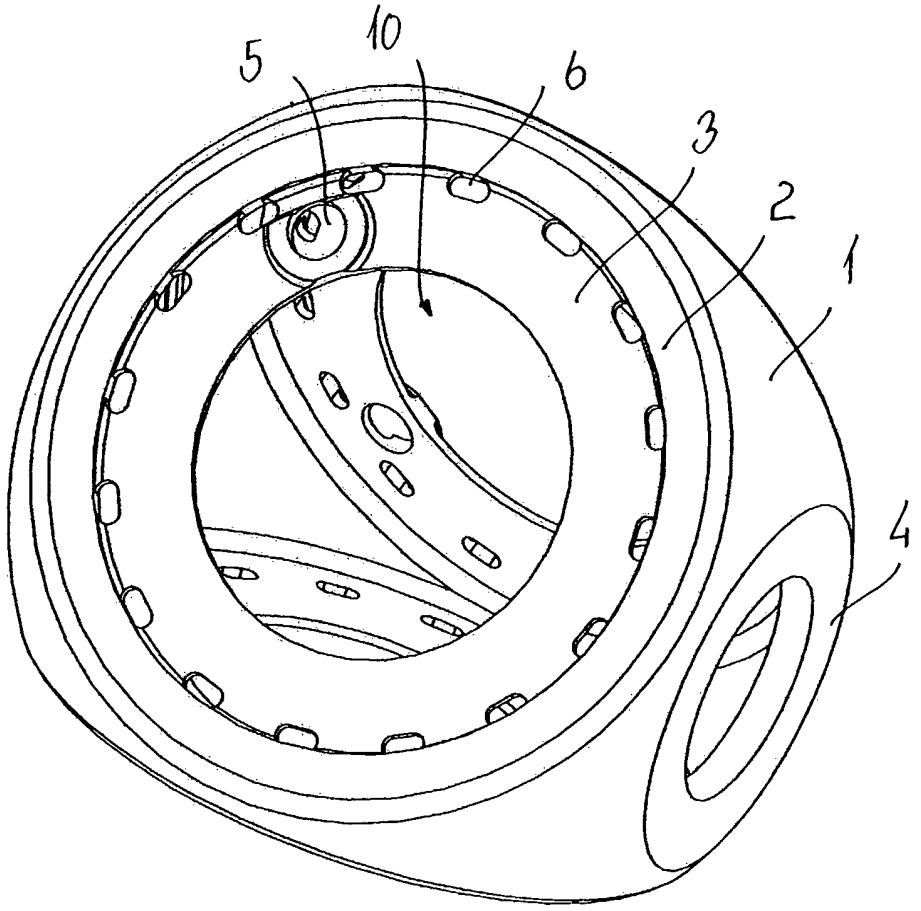


Fig. 1

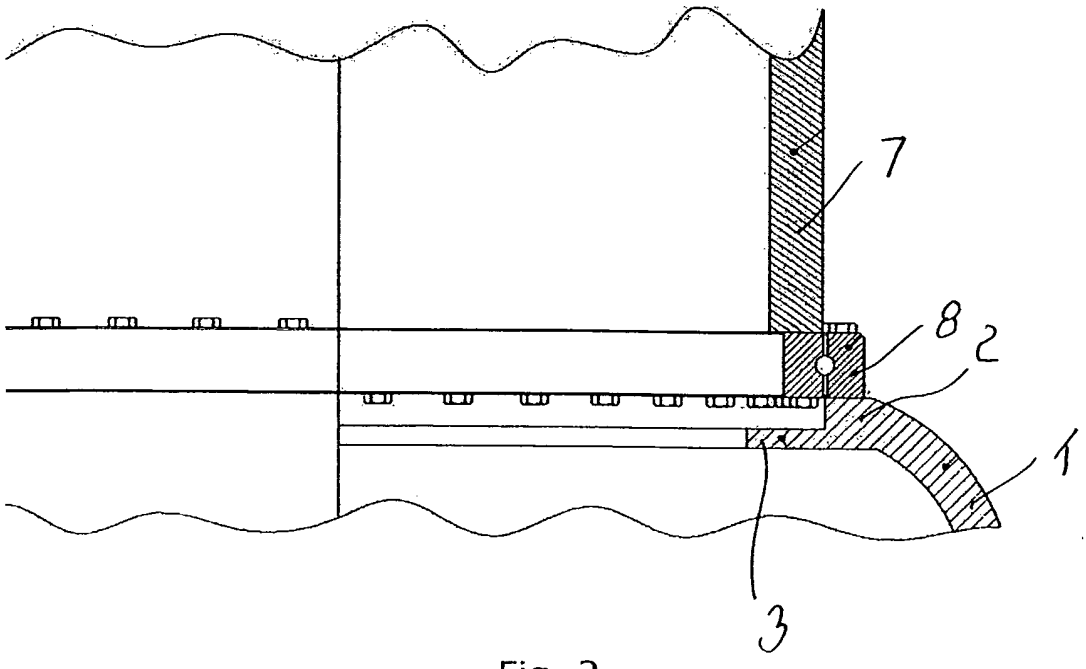


Fig. 2

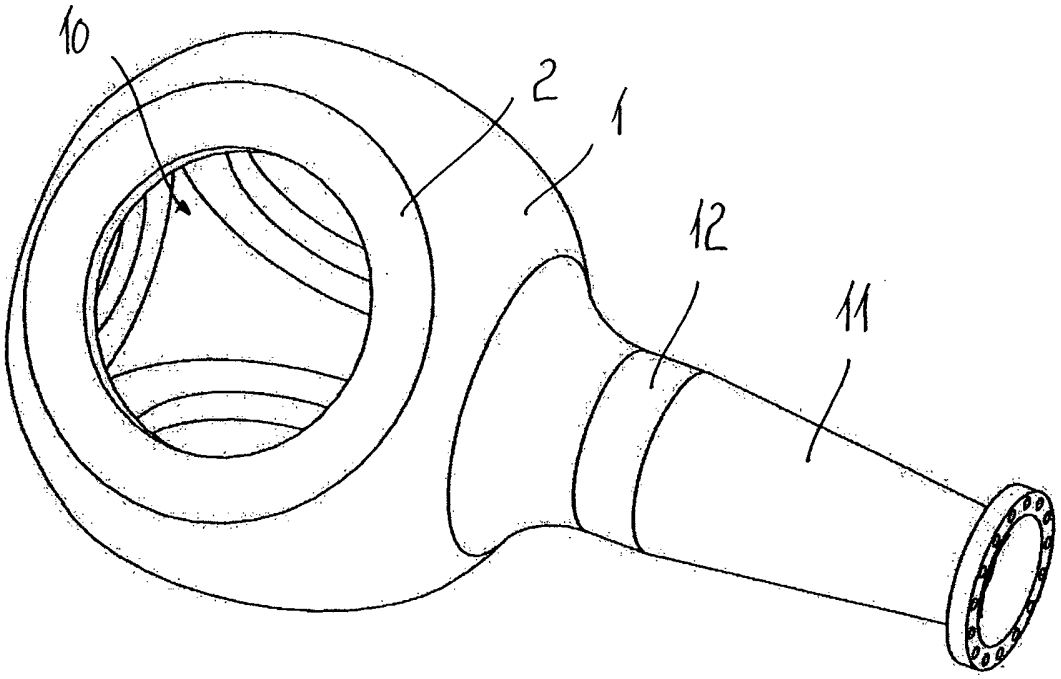


Fig. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/DK 03/00064

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F03D11/04

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)
IPC 7 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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ERICH HAU: "Windturbines Fundamentals, Technologies, Application and Economics" , SPRINGER-VERLAG , GERMANY XP002240153 ISBN: 3-540-57064-0 page 213 -page 215 page 219 -page 222 page 238 -page 242	15-18
A	---	1-14
A	WO 02 06667 A (WOBBEN ALOYS) 24 January 2002 (2002-01-24) abstract; figures 1-4	1-14

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 May 2003	06. 06. 2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	ANNA R-SALOMONSSON/JA

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 03/00064

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-10

Claims 1-10 relate to a wind turbine blade-hub comprising a hollow body having blade flanges for the attachment of wind turbine blades, and where the flanges are provided with rib-stiffener in order to reduce stress and deformation of the blade-hub.

2. Claims: 11-14

Claims 11-14 relate to a wind turbine blade-hub assembly comprising a hollow body blade-hub according to any of the claims 1-10 and a hollow body main shaft comprising adaptation means for a wind turbine main bearing encircling said main shaft, said hollow body blade-hub and hollow body main shaft being integrally formed.

3. Claims: 15-18

Claims 15-18 relate to a wind turbine blade-hub assembly comprising a hollow body blade-hub and a hollow body main shaft comprising adaptation means for a wind turbine main bearing encircling said main shaft, said hollow body blade-hub and hollow body main shaft being integrally formed.

The inventions according to claims 1-10 and 11-14 and the invention according to claims 15-18 are not so linked as to form a single general inventive concept (Rule 13.1 PCT) for the following reasons: The inventions according to claims 1-14 relate to a wind turbine blade-hub which reduces stress and deformation of the blade-hub while the invention according to claims 15-18 relate to a hollow body blade-hub provided with a hollow body main shaft.

The invention according to claims 15-18 could be searched without effort justifying an additional fee.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/DK 03/00064

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0206667 A	24-01-2002	DE 10034958 A1	07-02-2002
		AU 8387101 A	30-01-2002
		WO 0206667 A1	24-01-2002
		EP 1303698 A1	23-04-2003
		NO 20030236 A	05-02-2003