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EP 2048393 A **EP 1178231 A**
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Other: **Online: WPI, EPODOC & TXTE**

(54) Title of the Invention: **Drivetrain Connections**
Abstract Title: **A power transmission connector suitable for a turbine main shaft and planet carrier**

(57) A power transmission system of a wind turbine has a main shaft 2 configured to be driven by the rotor about a main axis 11, a gearbox 25 having a gearbox input element 7, and a coupling element 208 connecting the gearbox input element to the main shaft, where the coupling element comprises a first mating surface associated with the main shaft and a second mating surface associated with the gearbox input element such that one of the mating surfaces comprises axially-extending protrusions, and the other of mating surface comprises axially-extending indentations. In use, these mating surfaces interlock to transmit torque between the main shaft and the gearbox input member. The coupling element may be an intermediate element between the main shaft and gearbox element

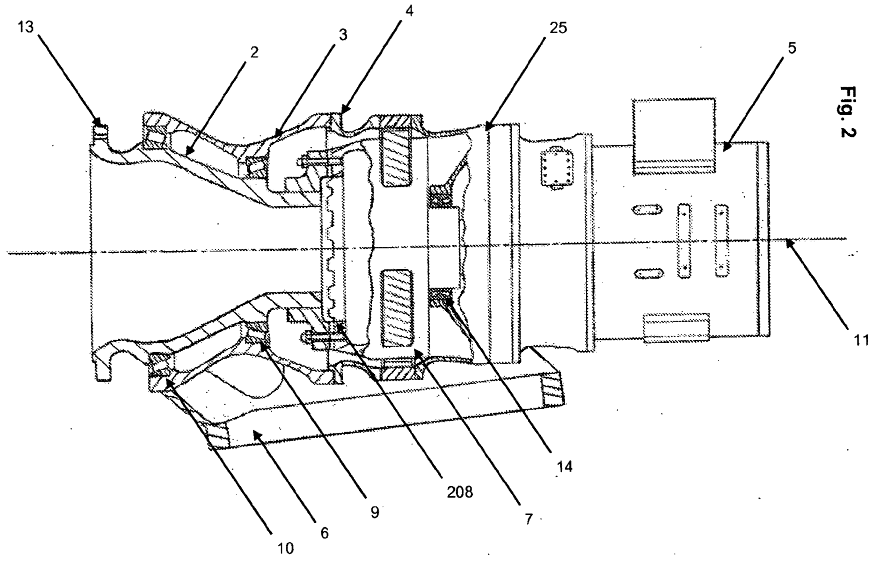

Fig. 2

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Fig. 1

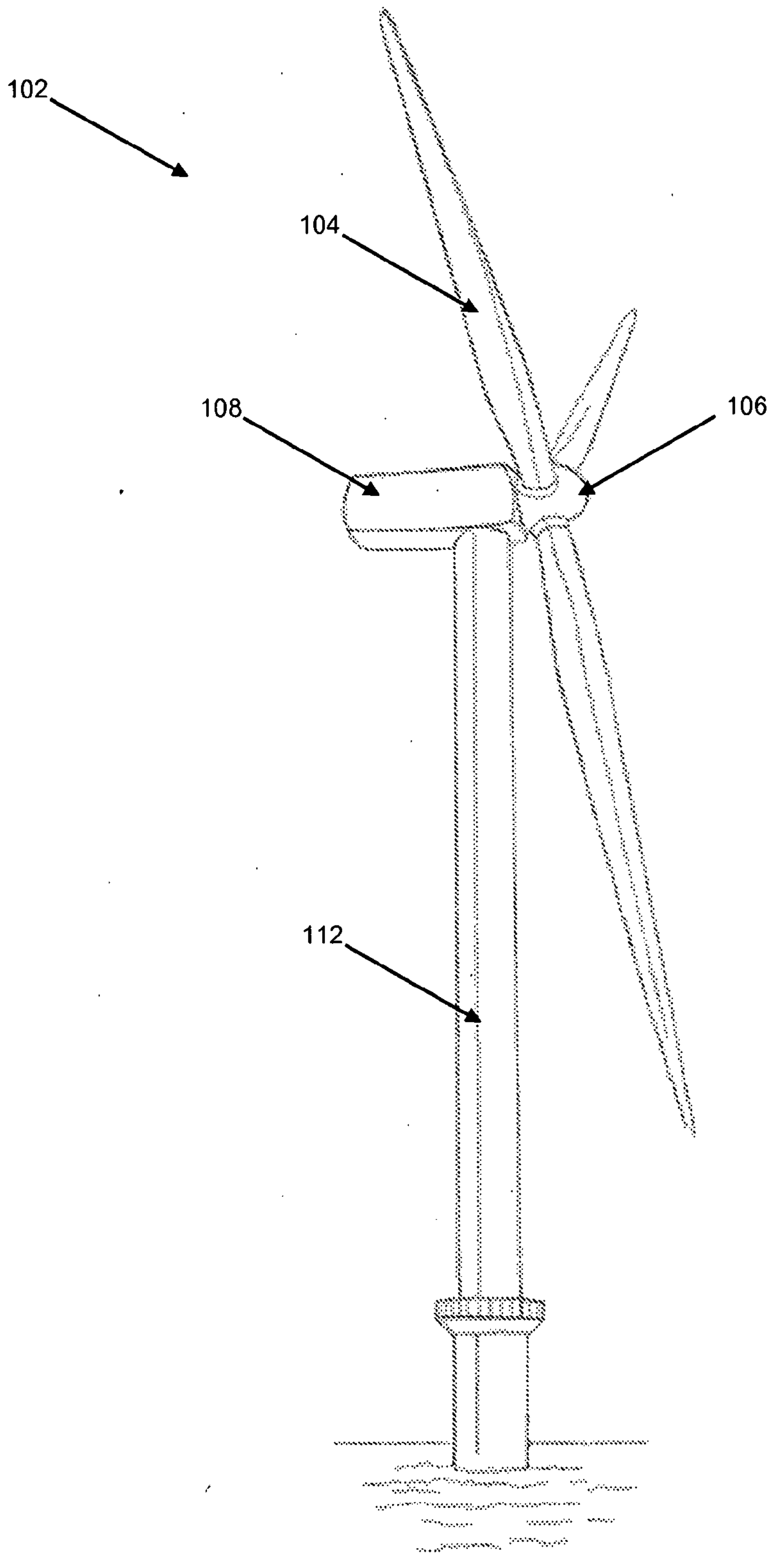


Fig. 2

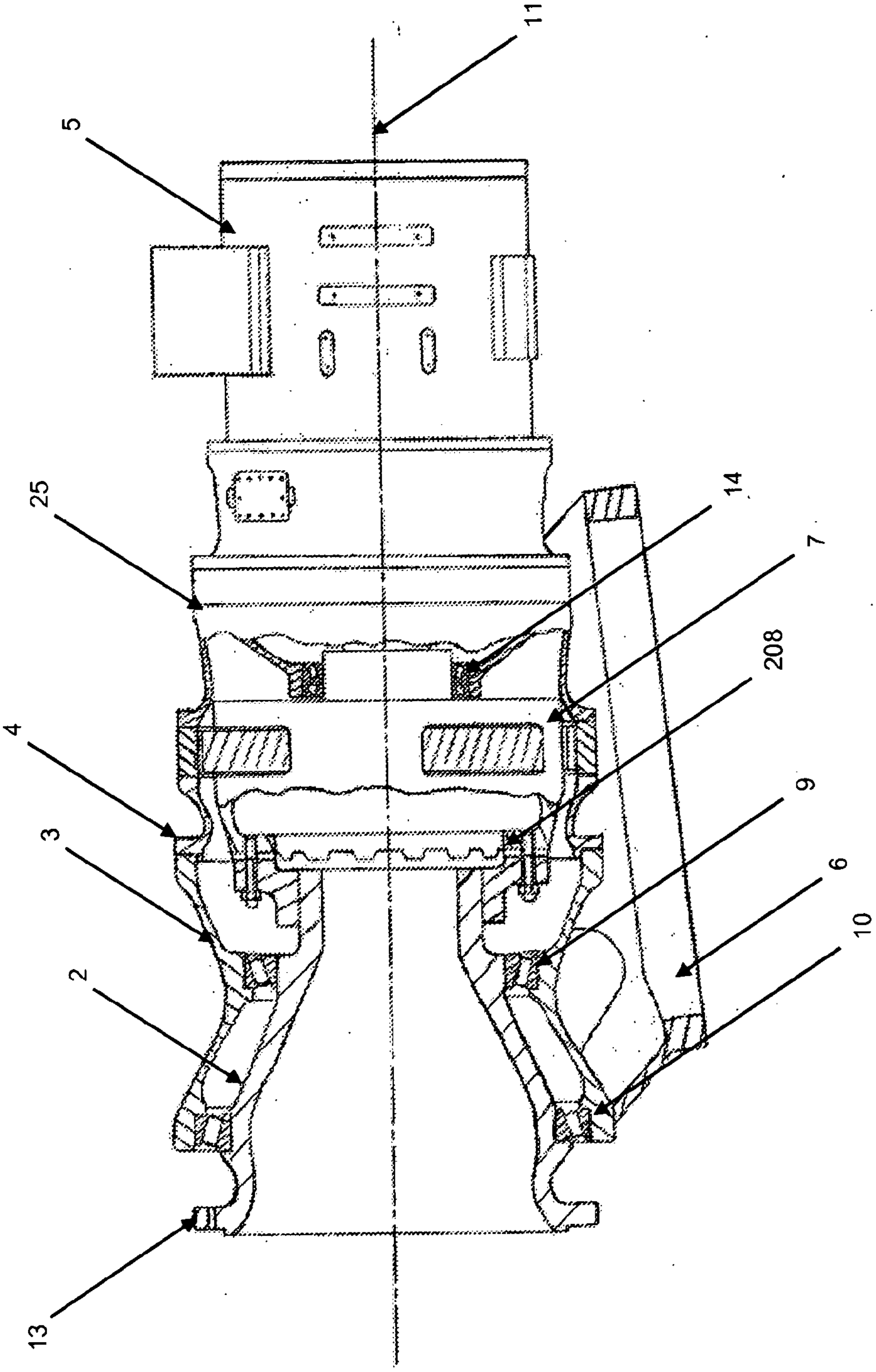


Fig. 3A

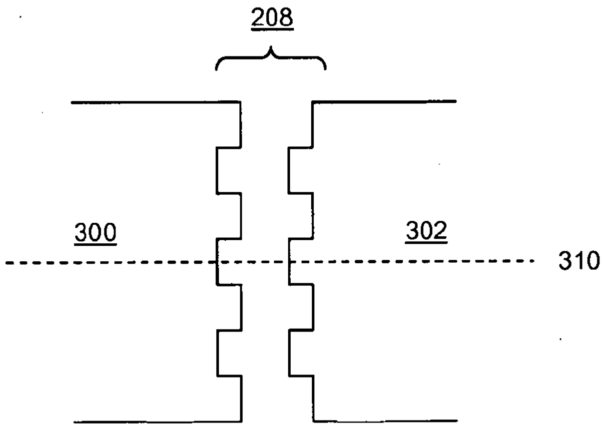


Fig. 3B

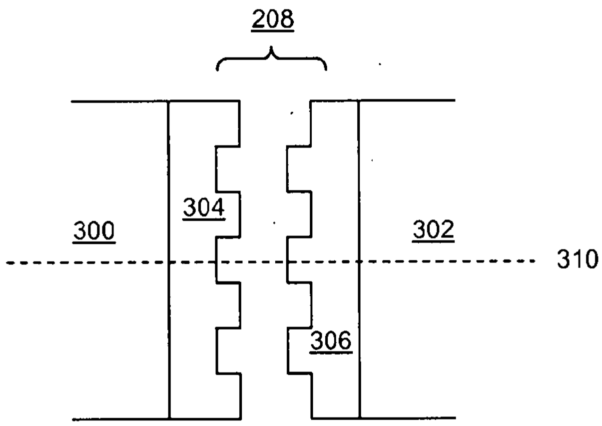


Fig 4A

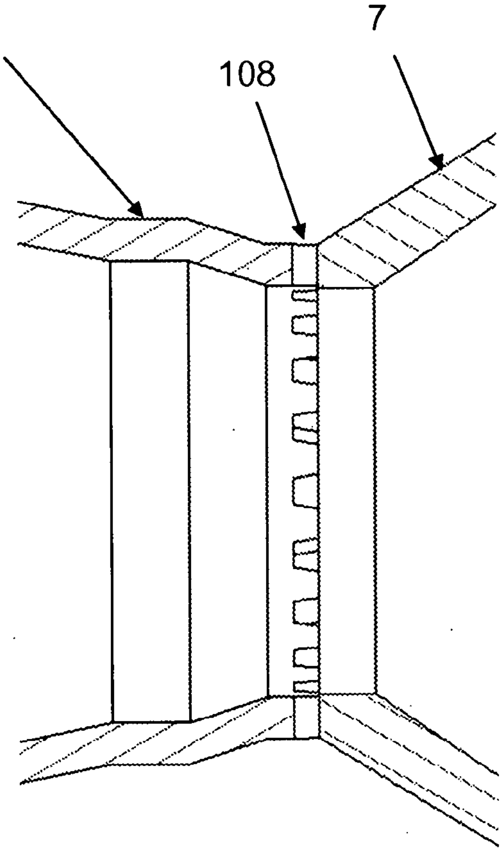


Fig. 4B

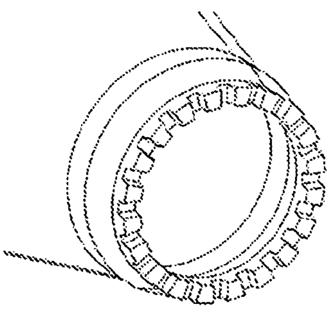


Fig. 4C

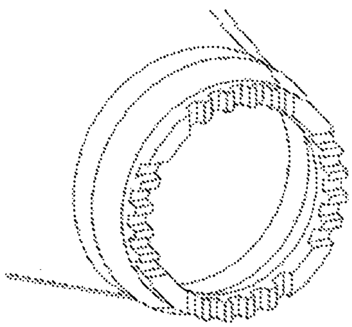


Fig. 4D

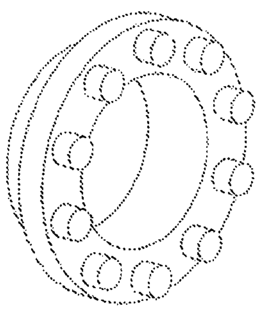


Fig. 5

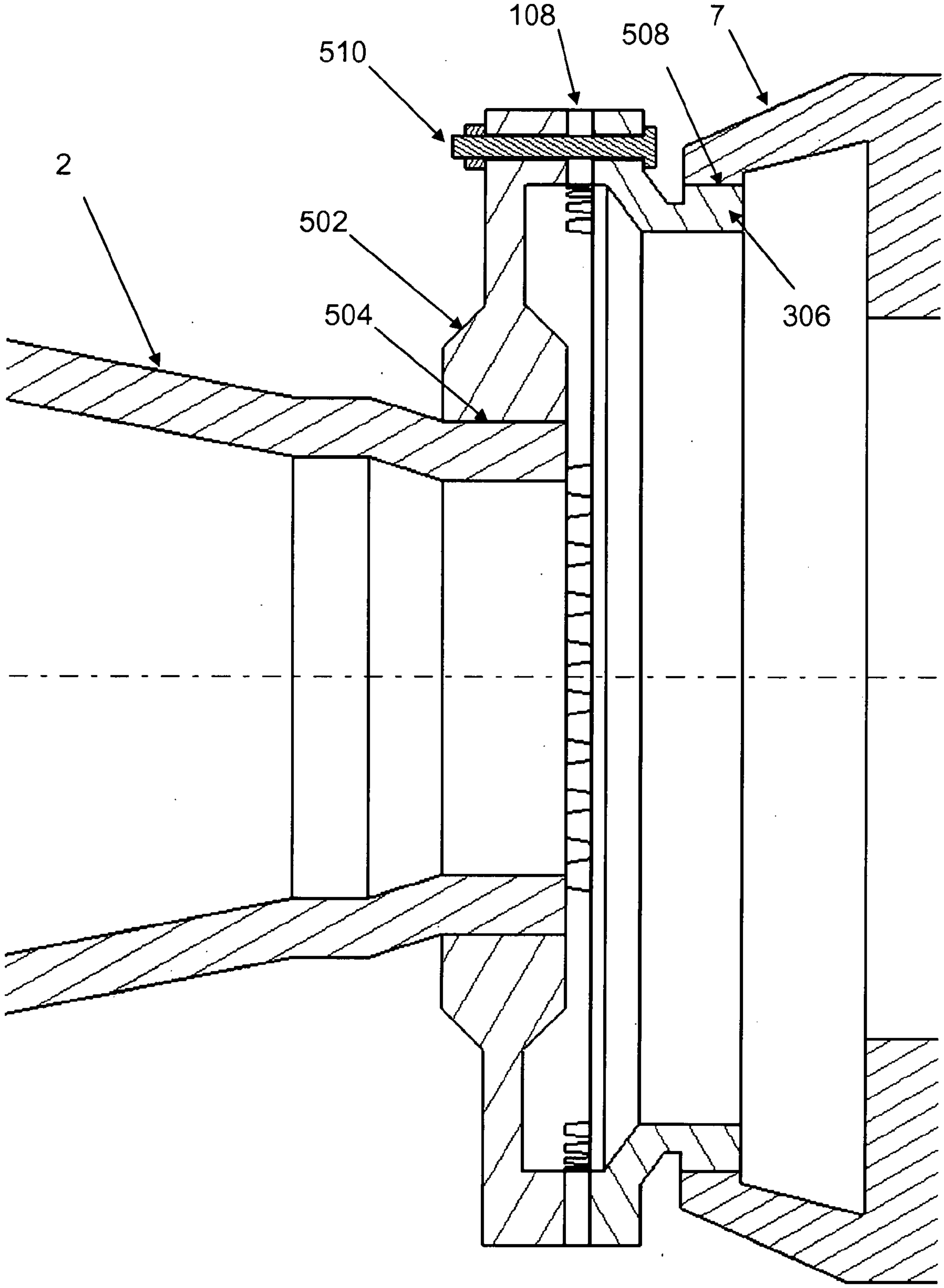


Fig. 6

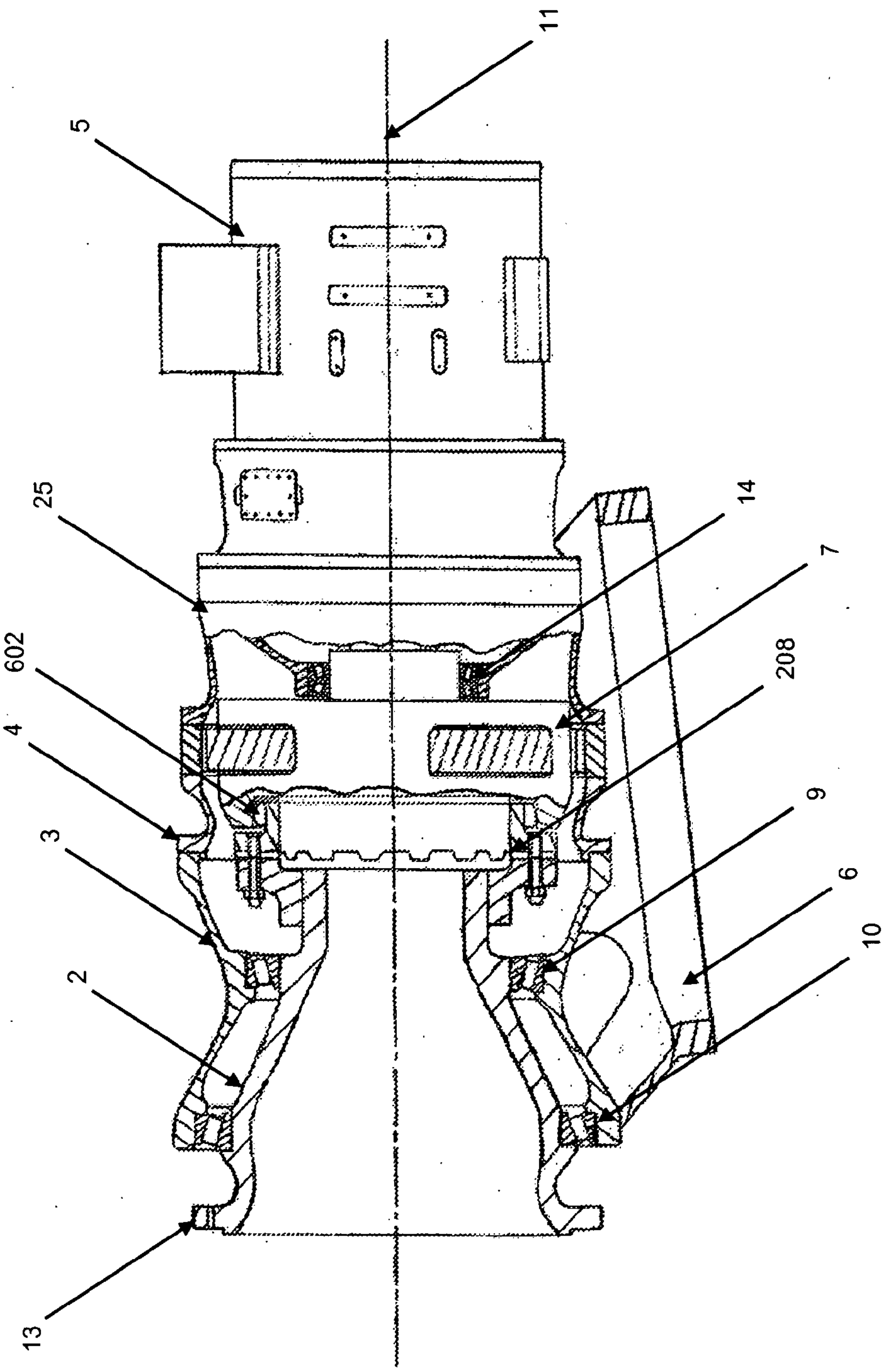


Fig. 7

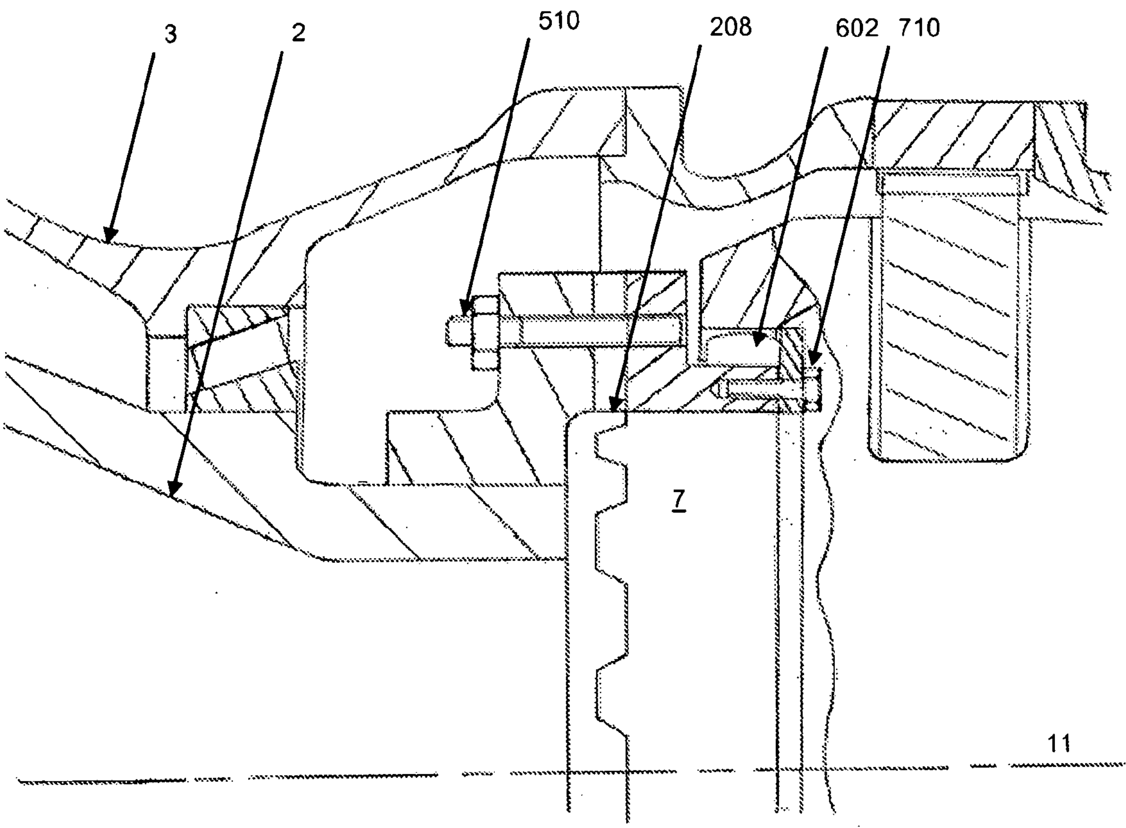


Fig. 8

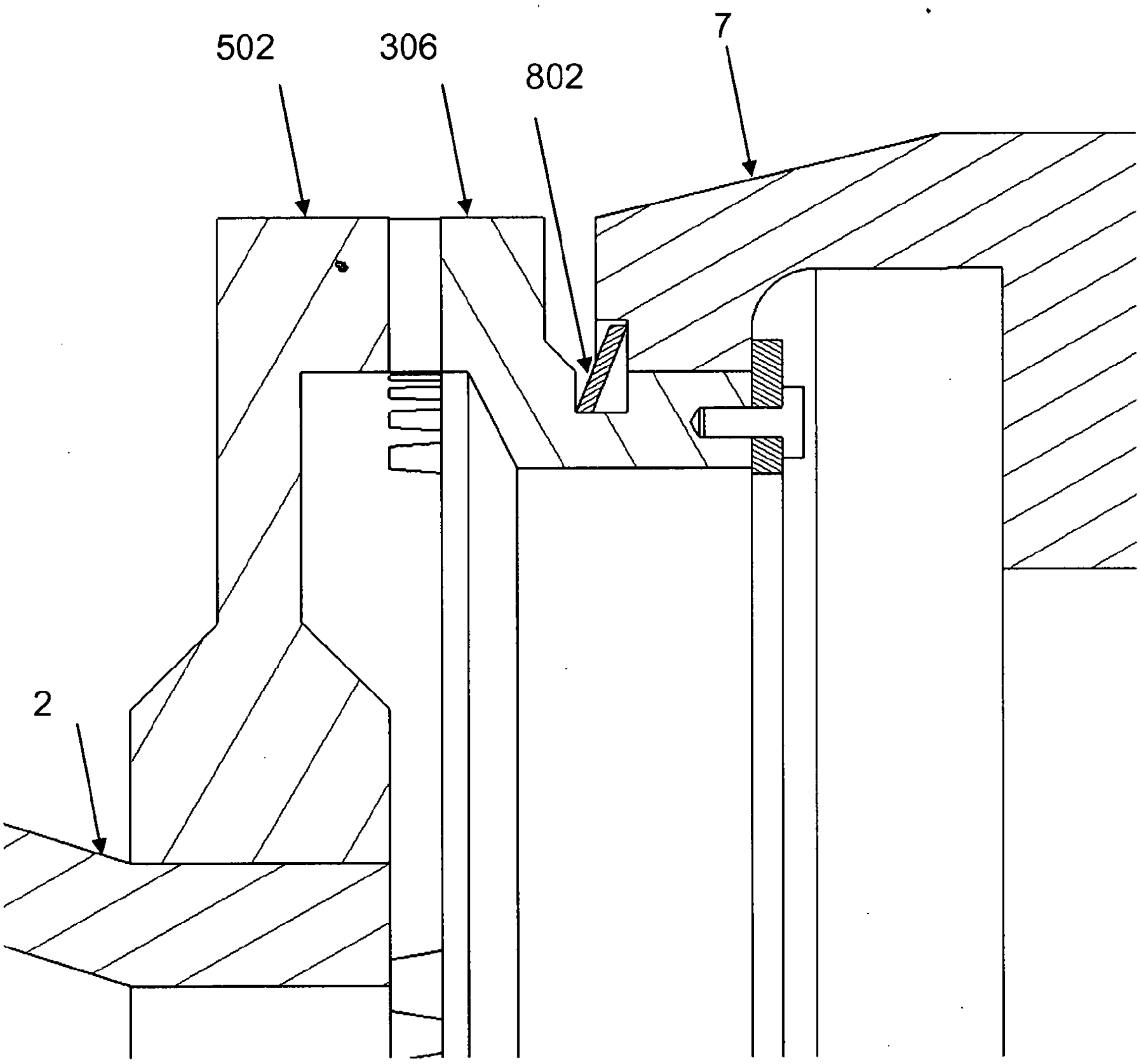
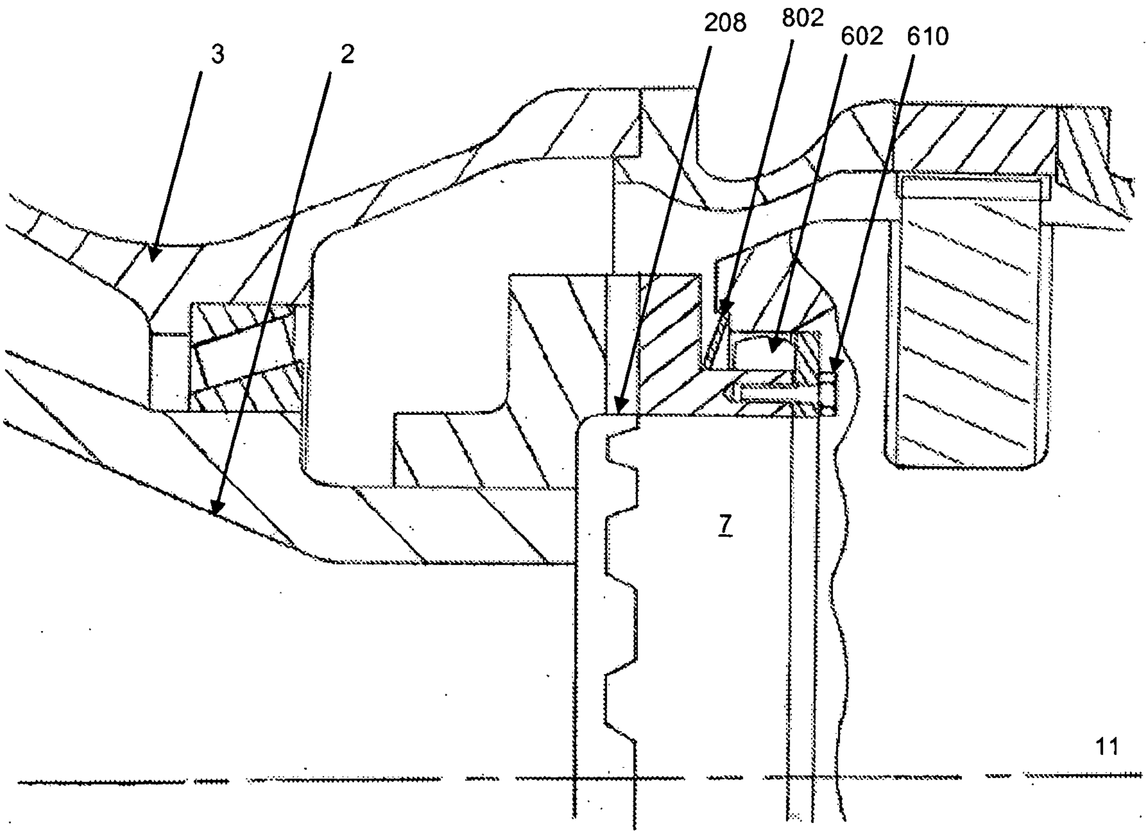


Fig. 9



Drivetrain connections

The present invention relates to power transmission systems for wind or water turbines. More particularly, the present invention relates to connections between a turbine main shaft and a gearbox input member.

Wind turbine drivetrains commonly consist of an aerodynamic rotor, which is supported on a main shaft, and which in turn is connected to a speed-increasing gearbox, commonly comprising a number of planetary and/or parallel gear stages. The output of this gearbox is then connected by a further shaft to a generator which produces the electrical output.

The gearbox is the most complex part of the mechanical drivetrain of the turbine, and thus the likelihood of component failure within the service life of the turbine is significant. Although there are some repair activities which may be carried out in-situ, it will often be advantageous to replace the entire gearbox with another unit. The original gearbox may then be refurbished at the operator's convenience in a facility more suited to such work than a wind turbine nacelle.

Due to the costs of heavy lifting equipment, particularly for offshore installations, it is advantageous to accomplish this exchange of gearboxes with the minimum of time, manpower, and tooling.

As wind turbines increase in size, the connection between the main shaft and the gearbox input member becomes increasingly challenging due to the extremely high torques which must be transmitted. Common methods of connecting these two components require large amounts of space, and are time consuming to assemble.

One common method of making the connection between main shaft and gearbox is with a pair of flanges, which are connected either by bolts, or by a mixture of bolts and dowels. Friction modifying compounds are sometimes used to treat the mating surfaces to increase the torque capacity of the joint.

Another method for transferring torque is by an interference fit. This may be assembled by thermal expansion, the use of high pressure oil, or by use of a 'shrink disc' component, in which the tightening of a number of bolts forces two conical surfaces together to produce a radial force.

Connections in rotating machinery are also commonly made with splines, consisting of a pattern of teeth projecting radially outwards on one component, and a corresponding pattern of teeth projecting radially inwards on the other component, so as to engage with the first set of teeth. Depending on the shape and size of these teeth, such a coupling may be substantially rigid, or it may permit a certain degree of rotation about axes perpendicular to the main axis, and linear movement along the main axis.

In large wind turbines, a bolted connection must comprise a very large number of bolts to achieve the required torque capacity. In addition, these bolts must be tensioned very precisely, typically using a hydraulic tensioning device. This makes the process of connecting or disconnecting the gearbox very time consuming, and introduces a high risk of incorrect tensioning leading to an unsatisfactory connection. Finally, the large diameter required for the bolted flanges may cause packaging difficulties.

Connections using interference fits face similar difficulties on assembly, requiring careful alignment and the use of additional equipment. In the case of shrink discs, this will include the requirement to hydraulically tension a ring of bolts.

Similarly, spline couplings require precise alignment to permit assembly without binding.

The invention disclosed provides an alternative arrangement for transmitting torque between the main shaft and the gearbox input member, which may be assembled and disassembled more easily than the arrangements previously described.

According to a first aspect of the invention, there is provided a power transmission system for increasing the rotational speed from a rotor of a wind or water turbine, comprising: a main shaft configured to be driven by the rotor about a main axis; a gearbox comprising a gearbox input member; and a coupling element connecting the gearbox input member to the main shaft. The coupling element comprises: a first mating surface associated with the main shaft and a second mating surface associated with the gearbox input member. One of the mating surfaces comprises axially-extending protrusions, and the other of the mating surface comprises axially-extending indentations, whereby in use the mating surfaces interlock to transmit torque between the main shaft and the gearbox input member. This arrangement means that the main shaft can transmit torque to the gearbox input member and the connection may be assembled and disassembled more easily than the arrangements previously described.

Preferably, the power transmission system additionally comprises one or more intermediary members connected between the main shaft and the gearbox input member. At least one of the mating surfaces is formed on an intermediary member. This advantageously reduces the complexity of forming the mating surface directly onto the end of main shaft or the gearbox input member.

Preferably, pluralities of bolts connect the main shaft and the gearbox input member. The coupling arrangement serves to transmit torque, which means that the number of bolts, and the precision with which they must be tensioned, is reduced compared to a conventional bolted joint, and thus the time to assemble the connection is considerably reduced.

Preferably, the intermediary member is connected to the main shaft by an interference fit. Although assembly of the interference fit join is a complex process, this joint does not need to be disassembled to disconnect the main shaft from the gearbox input member during replacement of the gearbox.

Preferably, the intermediary member is connected to the main shaft by a radial / barrel type spline joint. This permits movement in directions perpendicular to the main axis and angular misalignments about axes perpendicular to the main axis.

Preferably, the intermediary member is connected to the gearbox input member by an interference fit. Although assembly of the interference fit join is a complex process, this joint does not need to be disassembled to disconnect the main shaft from the gearbox input member during replacement of the gearbox.

Preferably, the intermediary member is connected to the gearbox input member by a radial / barrel type spline joint. This permits movement in directions perpendicular to the main axis and angular misalignments about axes perpendicular to the main axis.

Preferably, the power transmission system additionally comprises a support structure including at least one bearing supporting the main shaft for rotation about the main axis, in which the gearbox comprises a gearbox housing rigidly coupled to the support structure, and in which the mating surfaces are maintained in interlock by the supporting structure. This permits some axial movement between the main shaft and the gearbox input member.

Preferably, a resilient member is located between the gearbox input member and the intermediary member, which permits movement in a direction parallel to the drivetrain axis. Movement in this direction is resisted by one or more springing elements which ensure the connection remains engaged regardless of the relative axial position of the main shaft and gearbox input member.

Preferably, one of the mating surfaces comprises a first face spline providing the axially-extending protrusions, and in which the other of the mating surfaces comprises a second face spline providing axially-extending indentations. Preferably the protrusions and the indentations are arranged in a radial pattern or in a chordal pattern.

Preferably, the gearbox input member is a planet carrier.

According to a further aspect of the invention, there is provided a power transmission system for a wind or water turbine, comprising: a main shaft configured to be driven by the rotor about a main axis; a drivetrain member comprising an input member; and a coupling element connecting the input member to the main shaft. The coupling element comprises: a first mating surface associated with the main shaft and a second mating surface associated with the input member. One of the mating surfaces comprises axially-extending protrusions, and the other of the mating surface comprises axially-extending indentations, whereby in use the mating surfaces interlock to transmit torque between the main shaft and the input member. This arrangement means that the main shaft can transmit torque to the input member and the connection may be assembled and disassembled more easily than the arrangements previously described.

Preferably, the drivetrain member is a generator or a hydraulic transmission.

According to a further aspect of the invention, there is provided a wind turbine comprising the power transmission system disclosed above.

The present invention will now be described, by way of example only, with references to the accompanying drawings, in which:

Fig. 1 is a perspective view of an example of a wind turbine;

Fig. 2 is a cross-sectional view of a power transmission system of the present invention;

Figs. 3A and 3B show diagrammatic representations of a power transmission system for a wind or water turbine in which two drive train components are connected via a coupling element;

Fig. 4A is an enlarged view of Fig. 2 showing features of the main shaft, the coupling and the gearbox input member.

Figs. 4B-4C show examples of the protrusions / indentations formed on the end of main shaft;

Fig. 5 shows a more detailed embodiment of the arrangement shown in Fig. 3B;

Fig. 6 is a cross-sectional view of a power transmission system of the present invention permitting movement in directions perpendicular to the main axis;

Fig. 7 shows a more detailed embodiment of the arrangement shown in Fig. 6;

Fig. 8 shows a further embodiment permitting axial movement between the main shaft and the gearbox input member; and

Fig. 9 shows a further embodiment permitting movement in directions perpendicular to the main axis and axial movement between the main shaft and the gearbox input member.

Fig. 1 is a perspective view of an example of a wind turbine. Although an offshore wind turbine is shown, it should be noted that the description below may be applicable to other types of wind turbines. The wind turbine 102 includes rotor blades 104 mounted to a hub 106, which is supported by a nacelle 108 on a tower 112. Wind causes the rotor blades 104 and hub 106 to rotate about a main axis 11 (not shown; see Fig. 2). This rotational energy is delivered to a power transmission system (or "power train") of the type shown in Fig. 2 housed within the nacelle 108.

Fig. 2 shows an example of a power transmission system for increasing the rotational speed from a rotor of a wind turbine of the type shown in Fig.1. The power transmission system typically includes main shaft 2 and configured to be driven by hub 106 (see Fig. 1) about a main axis 11, and gearbox 25 having gearbox input member 7. In the example shown, main shaft 2 is supported by upwind rotor bearing 10 and downwind rotor bearing 9, and is connected to hub 106 via flange 13. The terms “upwind” and “downwind” in the context of the present invention assume that main axis 11 is orientated with the wind direction; thus rotor hub 106 and flange 13 are at the “upwind” end of the drivetrain, and generator 5 is at the “downwind” end of the drivetrain. Main shaft housing 3 is connected to supporting structure 6, and supporting structure 6 is connected to a tower via a yaw mechanism (tower and yaw mechanism are not shown). Main shaft 2 is connected to gearbox input member 7 via coupling element 208.

Fig. 3A shows a diagrammatic representation of two drive train components 300, 302 which are connected via a coupling element 208. A plurality of protrusions is formed on component 300, and the corresponding plurality of indentations is formed on component 302 so that each have a mating surface. Thus one of the mating surfaces comprises axially-extending protrusions, and the other mating surface comprises axially-extending indentations, or a different way of saying it is that both parts have alternating protrusions and indentations.

One of the components 300,302 is a main shaft 2 of the turbine and the other is a gearbox input member 7, and both rotate about axis 310. The axially-extending protrusions and indentations are adapted to interlock to transfer torque from the main shaft to the gearbox input member.

In use, these mating surfaces interlock to transmit torque between the main shaft and the gearbox input member

Fig. 3B shows an embodiment of the arrangement shown in Fig. 3A, in which components 300,302 are connected respectively and directly to intermediate elements 304,306.

Fig. 4A is an enlarged view of coupling element 208 showing features of main shaft 2 and gearbox input member 7. Adjacent faces of main shaft 2 and gearbox input member 7 are manufactured with a pattern of protrusions and recesses such that, when main shaft 2 and gearbox input member 7 are brought together, the protrusions of one part fit into the recesses in the other part. Protrusions can be formed on main shaft 2 and indentations formed on gearbox input member 7, or vice versa.

Figs. 4B and 4C show examples of the protrusions / indentations formed on the end of main shaft 2. It can be seen that the protruded surface of the end of main shaft 2 has an adjacent indentation or recess.

Coupling element 208 thus has two mating surfaces, a first mating surface associated with main shaft 2 and a second mating surface associated with gearbox input member 7.

Each mating surfaces comprises both axially-extending protrusions and axially-extending indentations, as can be seen in Figs. 4B and 4C. This means that when the mating surfaces are brought together, the protrusions of one surface fit into the indentations in the other surface, and vice versa, and the mating surfaces interlock to transmit torque between the main shaft and the planet carrier.

Coupling element 208 can be comprised of a pair of interlocking face splines, and the protrusions and recesses can take the form of spline teeth which interlock to transmit torsional forces from one to the other. The splines can be radially arranged as in Fig. 4B or they can be arranged chordally, where each set of chords is parallel to a diameter, as shown in Fig. 4C, which shows two sets arranged orthogonally. Other angles are suitable: the objective is that the face splines interlock efficiently via the spline teeth to transfer torque from main shaft 2 to gearbox input member 7.

Coupling element can be formed from other topologies of mating surface. Thus, as is shown in Fig. 4D, one mating surface can have columnar protrusions extending from the mating surface; the other mating surface (not shown) has corresponding columnar recesses or indentations into which the protrusions fit.

Fig.5 shows a more detailed embodiment of the arrangement shown in Fig. 3B, in which the patterns of protrusions and recesses are not integral to the main shaft 2 or gearbox input member 7, but instead form part of an intermediate component 306.

For example, the pattern of protrusions and recesses can be part of flange component 502 attached to main shaft 2 using an interference fit at 504. Although assembly of the interference fit join is a complex process, this joint does not need to be disassembled to disconnect the main shaft from the gearbox input member during replacement of the gearbox. It also advantageously reduces the complexity of forming the face spline directly onto the end of main shaft 2.

For example, the pattern of protrusions and recesses can be part of a flange component 306 attached to gearbox input member 7 using an interference fit at 508. Although assembly of the interference fit join is a complex process, this joint does not need to be disassembled to disconnect the gearbox input member from the main shaft during replacement of the gearbox. It also advantageously reduces the complexity of forming the face spline directly onto the end of gearbox input member 7.

In another embodiment, shown in Fig. 6, the intermediate component or components may be connected to either main shaft 2 or gearbox input member 7 in such a way as to offer flexibility between the main shaft and gearbox input member. For example, instead of an interference joint at 508, a radial / barrel type 602 spline joint comprised of interlocking, radially protruding teeth on each component (7,306), arranged so as to permit movement in directions perpendicular to the main axis, and angular misalignments about axes perpendicular to the main axis can be used. A similar arrangement can be used at 504 between 2 and 502, or at both positions. This is adding a conventional radial/barrel type spline joint additional to the face spline joint. The conventional spline provides flexibility (by crowning one set of teeth) but would be assembled in the factory, the face spline is providing the easy assembly up-tower. Fig. 7 shows this arrangement in greater detail.

Flexibility of this nature can be achieved in other ways, such as the use of polymer, composite, or metallic elements designed to deflect under loads in certain directions.

A number of bolts 510 may be used to ensure the two components 502,306 do not move apart. However, because coupling arrangement 208 serves to transmit torque, the number of bolts, and the precision with which they must be tensioned, is reduced compared to a conventional bolted joint, and thus the time to assemble the connection would be considerably reduced.

Fig. 8 shows a further embodiment of the invention, in which bolts 510 can be eliminated, and which permits some axial movement between the main shaft and the gearbox input member. In this implementation, the patterns of protrusions and recesses associated with main shaft 2 and gearbox input member 7 are maintained in engagement by mounting the main shaft assembly and the gearbox to a common, rigid supporting structure 3 of the type shown in Fig. 2. First and second bearings 9, 10 support main shaft 2, and main shaft housing 3 surrounds the first and second bearings 9, 10. A support structure 6 supports main shaft housing 3, and gearbox 25 is suspended from the main shaft housing 3.

To accommodate manufacturing tolerances and other deflections between the two parts, component 306 can be connected to gearbox input member 7 in such a way as to permit movement in a direction parallel to the drivetrain axis. Movement in this direction is resisted by one or more springing elements 802 which ensure the connection remains engaged regardless of the relative axial position of the main shaft and gearbox input member. A stop prevents excessive axial movement in the direction of hub 306.

Fig. 9 shows a combination of the embodiments shown in Figs. 7 and 8 permitting movement in directions perpendicular to main axis 11 and axial movement between main shaft 2 and gearbox input member 7.

The embodiments described facilitate connection of a gearbox input member to a main shaft by reducing the complexity of the coupling arrangement, whilst preserving an effective means for transmitting torque between the main shaft and the gearbox input member. A face spline connection can be assembled and disassembled more easily than the arrangements previously described. Ease of assembly / disassembly is further enhanced by the use of intermediate elements which can be rigidly joined in the factory to the main shaft and / or the gearbox input member, using for example an interference joint; these joints do not need to be disassembled to disconnect the main shaft from the gearbox input member during replacement of the gearbox. The face spline connection can be achieved in situ in the wind turbine nacelle. Finally, because the face spline serves to transmit torque, the number of bolts, and the precision with which they must be tensioned, is reduced compared to a conventional bolted joint, and thus the time to assemble or disassemble the connection is considerably reduced.

The embodiments describe connection of a drivetrain input member to a drive shaft, and can be applied to a direct drive arrangement in which the connection is between a main shaft and a generator, or between a main shaft and a hydraulic transmission. Thus the power transmission system can include a main shaft configured to be driven by rotor about a main axis; a drivetrain member comprising an input member; and a coupling element connecting the input member to the main shaft. The first drivetrain member can be a generator or a hydraulic transmission.

Claims

1. A power transmission system for increasing a rotational speed from a rotor of a wind turbine or water turbine, comprising:

   a main shaft configured to be driven by the rotor about a main axis;

   a gearbox comprising a gearbox input member; and

   a coupling element connecting the gearbox input member to the main shaft;

   characterised by the coupling element comprising:

   a first mating surface associated with the main shaft and a second mating surface associated with the gearbox input member;

   wherein one of the mating surfaces comprises axially-extending protrusions, and the other of the mating surface comprises axially-extending indentations, whereby in use the mating surfaces interlock to transmit torque between the main shaft and the gearbox input member.

2. A power transmission system according to claim 1, additionally comprising one or more intermediary members connected between the main shaft and the gearbox input member, wherein at least one of the mating surfaces is formed on the intermediary member.

3. A power transmission system according to claim 1 or claim 2, in which a plurality of bolts connect the main shaft and the gearbox input member.

4. A power transmission system according to claim 3, in which the intermediary member is connected to the main shaft by an interference fit.

5. A power transmission system according to claim 3, in which the intermediary member is connected to the main shaft by a radial / barrel type spline joint.

6. A power transmission system according to claim 3, in which the intermediary member is connected to the gearbox input member by an interference fit.

7. A power transmission system of claim according to 3, in which the intermediary member is connected to the gearbox input member by a radial / barrel type spline joint.

8. A power transmission system according to claim 2, additionally comprising a support structure including at least one bearing supporting the main shaft for rotation about the main axis, in which the gearbox comprises a gearbox housing rigidly coupled to the support structure, and in which the mating surfaces are maintained in interlock by the supporting structure.

9. A power transmission system according to claim 8, comprising a resilient member located between the gearbox input member and the intermediary member.

10. A power transmission system according to any preceding claim, in which one of the mating surfaces comprises a first face spline providing the axially-extending protrusions, and in which the other of the mating surfaces comprises a second face spline providing axially-extending indentations.

11. A power transmission system according to 10, in which the protrusions and the indentations are arranged in a radial pattern.

12. A power transmission system according to claim 10, in which the protrusions and the indentations are arranged in a chordal pattern.

13. A power transmission system according to any preceding claim, in which the gearbox input member is a planet carrier.

14. A power transmission system for a wind or water turbine, comprising:
a main shaft configured to be driven by the rotor about a main axis;
a drivetrain member comprising an input member; and
a coupling element connecting the input member to the main shaft;
characterised by the coupling element comprising:
a first mating surface associated with the main shaft and a second mating surface associated with the input member;
wherein one of the mating surfaces comprises axially-extending protrusions, and the other of the mating surface comprises axially-extending indentations, whereby in use the mating surfaces interlock to transmit torque between the main shaft and the input member.

15. A wind turbine comprising the power transmission system according to claim 14, in which the drivetrain member is a generator or a hydraulic transmission.

16. A power transmission system substantially as described herein with reference to the accompanying drawings.

17. A wind or water turbine comprising the power transmission system according to any preceding claim.

18. A wind or water turbine substantially as described herein with reference to the accompanying drawings.

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Amendment to the claims have been filed as follows

Claims

1. A power transmission system for a wind turbine or water turbine, comprising:

   a main shaft configured to be driven by the rotor about a main axis;

   a gearbox comprising a gearbox input member; and

   a coupling element connecting the gearbox input member to the main shaft;

   characterised by the coupling element comprising:

   a first mating surface associated with the main shaft and a second mating surface associated with the gearbox input member;

   wherein one of the mating surfaces comprises axially-extending protrusions, and the other of the mating surface comprises axially-extending indentations, whereby in use the mating surfaces interlock to transmit torque between the main shaft and the gearbox input member.

2. A power transmission system according to claim 1, additionally comprising one or more intermediary members connected between the main shaft and the gearbox input member, wherein at least one of the mating surfaces is formed on the intermediary member.

3. A power transmission system according to claim 1 or claim 2, in which a plurality of bolts connect the main shaft and the gearbox input member.

4. A power transmission system according to claim 3, in which the intermediary member is connected to the main shaft by an interference fit.

5. A power transmission system according to claim 3, in which the intermediary member is connected to the main shaft by a radial / barrel type spline joint.

6. A power transmission system according to claim 3, in which the intermediary member is connected to the gearbox input member by an interference fit.

7. A power transmission system of claim according to 3, in which the intermediary member is connected to the gearbox input member by a radial / barrel type spline joint.

8. A power transmission system according to claim 2, additionally comprising a support structure including at least one bearing supporting the main shaft for rotation about the main axis, in which the gearbox comprises a gearbox housing rigidly coupled to the support structure, and in which the mating surfaces are maintained in interlock by the supporting structure.

9. A power transmission system according to claim 8, comprising a resilient member located between the gearbox input member and the intermediary member.

10. A power transmission system according to any preceding claim, in which one of the mating surfaces comprises a first face spline providing the axially-extending protrusions, and in which the other of the mating surfaces comprises a second face spline providing axially-extending indentations.

11. A power transmission system according to 10, in which the protrusions and the indentations are arranged in a radial pattern.

12. A power transmission system according to claim 10, in which the protrusions and the indentations are arranged in a chordal pattern.

13. A power transmission system according to any preceding claim, in which the gearbox input member is a planet carrier.

14. A power transmission system for a wind or water turbine, comprising:
a main shaft configured to be driven by the rotor about a main axis;
a drivetrain member comprising an input member; and
a coupling element connecting the input member to the main shaft;
characterised by the coupling element comprising:
a first mating surface associated with the main shaft and a second mating surface associated with the input member;
wherein one of the mating surfaces comprises axially-extending protrusions, and the other of the mating surface comprises axially-extending indentations, whereby in use the mating surfaces interlock to transmit torque between the main shaft and the input member.

15. A wind turbine comprising the power transmission system according to claim 14, in which the drivetrain member is a generator or a hydraulic transmission.

16. A power transmission system substantially as described herein with reference to the accompanying drawings.

17. A wind or water turbine comprising the power transmission system according to any preceding claim.

18. A wind or water turbine substantially as described herein with reference to the accompanying drawings.

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Application No: GB1307275.6 **Examiner:** Mr Robert Arnold

Claims searched: 1-15 **Date of search:** 13 June 2013

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-4, 8, 10-15	CN102817786 A (HE) - See whole document, especially the abstract and figure reference 7.
X	1, 3, 4, 8 & 10-15	WO2009/052825 A (VESTAS WIND SYS) - See whole document, especially page 15 line 6 to page 17 line 15 and the figures.
X	1, 2, 8 & 10-15	FR2327441 A (RENAULT) - See whole document, especially the abstract and figure reference 7.
X	1-4, 10, 11, 14 & 15	EP1178231 A (GEN ELECTRIC) - See whole document, especially paragraphs 2, 9 & 12 and the figures.
X	1, 2, 10, 11, 14 & 15	EP2048393 A (ENPLAS CORP) - See whole document, especially paragraphs 30-42 and the figures.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

F03B; F03D; F16D

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC & TXTE

International Classification:

Subclass	Subgroup	Valid From
F03D	0011/02	01/01/2006
F03B	0011/00	01/01/2006
F16D	0001/02	01/01/2006