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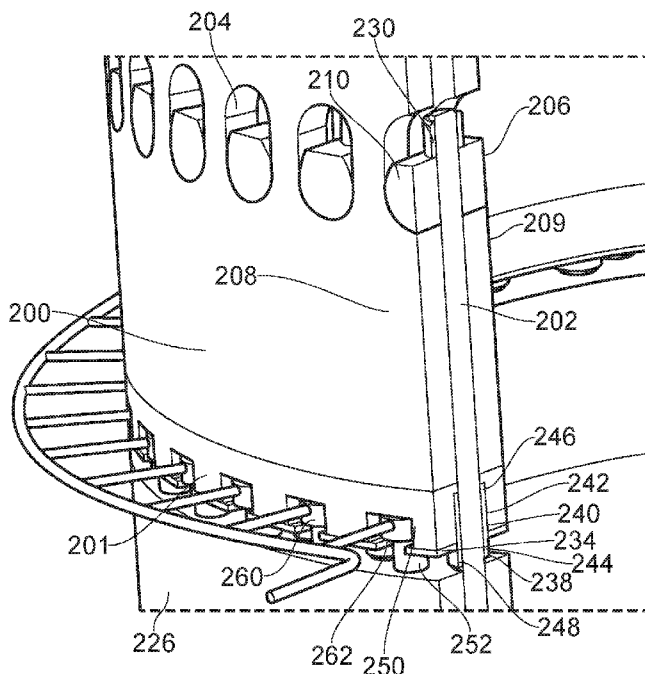


FIG. 2

(57) Abstract: A rotor blade comprises a blade portion and a root portion extending from the blade portion to a free end for attachment, in use, to a blade mounting. The root portion comprises a plurality of apertures. Each aperture has a bore extending through the thickness of the root in a direction substantially perpendicular to the longitudinal axis of the root portion. The rotor blade further comprises a plurality of discrete root fittings, each associated with one of the apertures, for attachment to a blade mounting. Each root fitting comprises an elongate member which extends from a first end, proximal to the free end of the root portion and for attachment to a blade mounting, to a second end which is located within the respective aperture of the root portion. Each root fitting further comprises a barrel shaped and dimensioned to be received within the respective aperture of the root portion. The axial direction of the barrel being substantially aligned with the bore of the aperture. The barrel having a transversely extending bore through which the elongate member extends. Each root fitting further comprises a first tensioning fastener arranged to engage the second end of the elongate member. The aperture is sized and dimensioned such that the second end of the elongate member may project beyond the barrel and be engaged by the first tensioning fastener located within the aperture.

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## ROTOR BLADE

The present invention relates to a rotor blade for use in underwater tidal power generation installations.

### **BACKGROUND OF THE INVENTION**

- 5 There is increasing interest in the use of underwater power generating equipment that makes use of the energy of tidal flows. Such equipment is secured to the bed of a body of water, such as a sea, estuary or river, and makes use of a rotary generator to generate electricity. The generator is driven by a number of rotor blades placed in the water flow.

10 Rotor blades for underwater use generate large bending moments about the root fitting and so this component must be large in order to be able to carry the large loads placed upon it. The fitting is typically a single metallic casting. Such existing root fitting components have several disadvantages. Firstly, the component is very heavy and cumbersome, which limits the number fabricators that are able to produce such a part, and the process of fitting the blade to the root fitting is complex and requires specialist heavy lifting equipment. Secondly, the  
15 root fitting must be of the highest quality in order that it does not fail under the high loads. As such, even the smallest fault in the casting, machining, and finishing processes would result in the scrapping of the entire root fitting.

20 Alternatively, the blade may comprise adhesively bonded joints between a plurality of iron fittings and the carbon/epoxy spar. These fittings are then bolted to the bearing. This arrangement also has a number of disadvantages. Firstly, due to the use of bonded joints there are practical problems associated with scaling the fitting with the size of the blade. As the industry requires blades of increased length the diameter of the blade root would need to increase disproportionately in order to achieve the necessary strength. Secondly, adhesively bonded joints are prone to degradation when immersed in water, especially when the metallic  
25 component is cathodically protected. It is therefore vital to keep the joints dry by means of waterproof covers. This represents a significant additional cost and complexity both at the development and production stages. The reliability of the covers needs to be verified for the operational lifetime of the blade and quality tests need to be performed in order to guarantee a seal.

30 It is, therefore, desirable to provide a rotor blade having a root fitting that can overcome the disadvantages of the known root fittings.

## SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided a rotor blade comprising a blade portion, and a root portion extending from the blade portion to a free end for attachment, in use, to a blade mounting, the root portion comprising a plurality of apertures each having a bore extending through the thickness of the root in a direction substantially perpendicular to the longitudinal axes of the root portion, and a plurality of discrete root fittings, each associated with one of the apertures, for attachment to a blade mounting, wherein each root fitting comprises an elongate member which extends from a first end, proximal to the free end of the root portion and for attachment to a blade mounting, to a second end which is located within the respective aperture of the root portion, a barrel shaped and dimensioned to be received within the respective aperture of the root portion, the axial direction of the barrel being aligned with the bore of the aperture, the barrel having a transversely extending bore through which the elongate member extends, and a first tensioning fastener arranged to engage the second end of the elongate member, wherein the aperture is sized and dimensioned such that the second end of the elongate member may project beyond the barrel and be engaged by the first tensioning fastener located within the aperture.

According to a second aspect of the invention, there is provided a method of assembling a rotor blade, in which the method comprises connecting a root portion of the blade to a blade mounting with a plurality of root fittings, providing at least one tension adjuster such that it is arranged to exert a force between the blade mounting and the root portion of the blade so as to place the root fittings under a desired amount of tension, adjusting at least one tensioning fastener to abut the surface of the blade mounting, and removing the at least one tension adjuster such that the desired tension is maintained by the at least one tensioning fastener.

The rotor blade of the present invention has the advantage that the root fitting does not require any adhesive bonds to be made to metallic parts. The root fittings can also be tensioned outside of the hub and as such does not require regular recovery and maintenance. As such, the rotor blade is well suited to the marine environment. The rotor blade of the present invention does not require the use of additional protective covers in order to protect the root fitting from degradation in the water. Furthermore, the root fitting of the rotor blade of the invention can achieve a significantly higher loading per unit spar circumference which will enable more slender blades to be used. The root fitting of the rotor blade can also be scaled

to the length of the blade and as such the blade root thickness can advantageously remain in proportion with the length of the blade.

The root portion may define first and second root surfaces. The first root surface is preferably an outer surface of the root portion and the second root surface is preferably an inner surface of the root portion that bounds an interior volume thereof. The apertures may extend through both the first and second root surfaces. The barrel may engage both the first and second root surfaces in order to distribute the load evenly. A cavity may be provided between the outer surface and the inner surface of the root portion. The first and second root surfaces may be substantially parallel to one another. Alternatively, portions of the first and second root surfaces may converge towards the end of the root portion. Portions of the first and second root surfaces may diverge towards an end region of the root portion. The free end of the root portion may further define an abutment surface extending in a direction between said first and second root surfaces.

The apertures may have any suitable shape and dimensions for receiving the barrel and the first tensioning fastener. The apertures are preferably sufficiently dimensioned so as to receive and allow access to the first tensioning fastener when engaged to the second end of the elongate member. The apertures may for example be circular, or elongated such as for example oval shaped. Preferably, the portion of the aperture arranged to be aligned with the barrel is substantially arcuate in shape so as to compliment the shape and allow rotation of the barrel within the aperture. The apertures are preferably provided in an annular configuration about the root portion. The apertures are preferably aligned so as to be provided at a uniform distance from the free end of the root portion.

The apertures may be shaped and dimensioned to receive at least part, for example the whole, of a first tension adjuster within the aperture for engagement with the first tensioning fastener. The first tensioning fastener may be adjusted by any suitable tension adjuster. Examples of suitable tension adjusters include manual adjustment using fingers or a spanner or by a hydraulic tensioner. It can be understood that in order to accommodate the first tension adjuster, the apertures may be elongated apertures, such as for example oval shaped apertures. The apertures may be elongated in any suitable direction in order to receive the first tension adjuster, for example the apertures may be elongated in a direction extending substantially parallel to the longitudinal axis of the root portion. It will be understood that the dimensions of the apertures will depend on the size of the first tension adjuster.

The barrel may have any suitable shape for alignment within the apertures. For example, the barrel may have a predominantly circular cross-section to be aligned with predominantly circular regions of the aperture. The barrel may provide a flattened surface adjacent an opening to the transversely extending bore. The flattened surface may be arranged to engage or abut the first tightening fastener so that the fastener can be tightened against the flattened surface. The bore is preferably a smooth or plain bore. The barrel is preferably received within the aperture and arranged such that the longitudinal axis of the bore is aligned with and extends substantially parallel to the longitudinal axis of the elongate member. The barrel is preferably rotatable within the aperture so as to enable the axes of the bore and the elongate member to be aligned.

The first end of the elongate member preferably comprises a threaded portion for threaded engagement with a portion of the blade mounting. For example, the blade mounting preferably provides a plurality of threaded bores arranged to engage the threaded portion of the first ends of the elongate member. Furthermore, the second end of the elongate member preferably comprises a threaded portion for threaded engagement with a threaded portion of the first tensioning fastener. The first tensioning fastener preferably comprises a threaded portion for engagement with the elongate member. For example the first tensioning fastener may be a nut for threaded engagement with the second end of the root portion.

In one embodiment, the rotor blade preferably comprises a plurality of second tensioning fasteners. The second tensioning fastener may be located at or adjacent the free end of the root portion. The root portion preferably comprises a plurality of second tensioning fasteners. Preferably a second tensioning fastener is associated with each root fitting. Each second tensioning fastener may engage the elongate member of a root fitting. The second tensioning fastener preferably comprises a threaded portion for threaded engagement with the elongate member.

The abutment surface at the free end of the root portion preferably provides a plurality of recesses. Each recess is preferably shaped and dimensioned to receive and engage a second tensioning fastener. The axial direction of each recess is preferably aligned with the longitudinal axis of the root portion. The second tensioning fastener preferably comprises a first end arranged to be received within the recess of the root portion and a second end located at or adjacent the free end of the root portion. The second end of the second tensioning fastener may be arranged in use to provide a blade mounting abutment surface.

The inner surfaces of the recess may comprise a threaded portion for threaded engagement with the second tensioning fastener, for example the second tensioning fastener may comprise a threaded portion. The second tensioning fastener may have any suitable shape for being received within the first recess, for example the second tensioning fastener may have a substantially circular cross-section. The second tensioning fastener may be an elongate barrel. The second tensioning fastener may provide a channel for receiving an elongate member. The channel may be axially extending through the second tensioning fastener. The location and axial direction of the recess may be arranged so as to align the longitudinal axis of the channel of the second tensioning fastener with the longitudinal axis of the elongate member. The cross-section of the second tensioning fastener may comprise a flattened portion to facilitate rotation of the second tensioning fastener.

The root portion may further provide at least one chamber located at or adjacent the free end of the root portion, for example the at least one chamber may be provided on an abutment surface of the root portion. A chamber is preferably located at or adjacent a root fitting. Preferably, the root portion provides a chamber located at or adjacent each root fitting. The chamber is preferably located adjacent a second tensioning fastener. The at least one chamber is preferably shaped and dimensioned to receive a second tension adjuster. An example of a suitable second tension adjuster is a hydraulic tensioning mechanism, such as for example a hydraulic jack.

The chamber(s) is preferably provided by the root portion at a location such that the second tension adjuster is received within the chamber so as to be arranged in use to contact and exert a compressive force against the blade mounting. The chamber(s) is preferably provided by the root portion such that the second tension adjuster is located to be opposed to the blade mounting, for example the second tension adjuster may be located to be extendable in a direction to contact and to exert a compressive force against the blade mounting. Preferably, the abutment surface of the root portion provides the chamber(s). Preferably, at least one of the first and second surfaces of the root fitting provides an additional opening into said at least one recess. The additional opening may be shaped and dimensioned to allow the second tension adjuster to be inserted into said chamber. The chamber preferably comprises an annular flange extending inwardly from the periphery of the chamber and arranged in use to contact the second tension adjuster and to secure the second tension adjuster in place within the second recess.

In use, the barrel is rotated within the aperture such that the axial direction of the bore and the longitudinal axis of the elongate member are aligned. The root portion is fitted onto the root fitting. The elongate member extends through a channel provided by the second tensioning fastener. The second end of the elongate member(s) is received within the aperture(s) of the root portion. The second end of the elongate member(s) extends through the bore provided by the barrel. The first tensioning fastener engages the second end of the elongate member. The first tensioning fastener is threaded onto the second end of the elongate member until the fastener tightly abuts the barrel. A hydraulic jack is inserted within the chamber provided by the root portion. The hydraulic jack exerts a compressive force on the blade mounting causing the abutment surface of the root portion and the blade mounting to separate. The second tensioning fastener is then rotated as required to bring the second tensioning fastener into contact with the blade mounting.

The rotor blade may be subject to creep deformation under compressive loading. The creep deformation may be associated with movement in the resin matrix as opposed to the fibres. This effect may be most prevalent at or near the bearing surface. Fibres within the carbon spar laminate of the blade would be orientated in the four principal directions (0, 90, +45, -45) and as such will constrain the matrix in these directions. There are however no fibres in the through thickness direction. As such, creep under axial compressive loading may be accompanied by local thickening of the laminate.

In a further embodiment, the root blade further comprises at least one compressive clamp for exerting a compressive force on said root portion, in which the compressive force extends in a direction substantially perpendicular to the longitudinal axes of the root portion. Preferably, the at least one compressive clamp is arranged to engage the root portion and optionally at least one first tensioning fastener. Preferably, the rotor blade comprises at least one compressive clamp, with each being arranged to engage a root portion and a first tensioning fastener.

The compressive clamp preferably comprises a first clamping portion for engagement with an outer surface of the root portion. The compressive clamp may further comprise a second clamping portion for engagement with an inner surface of the root portion. The compressive clamp may further comprise at least one collar portion for locating within the cavity provided between the inner and outer surfaces of the root portion. The at least one collar portion is located within the cavity and engages the internal surfaces of the outer and inner surfaces of the root portion. The first and second clamping portions and the collar are arranged in use to

be aligned, for example within a plane extending substantially perpendicular to the longitudinal axis of the root fitting or root portion. The first and second clamping portions and the collar are arranged to engage axially aligned surfaces of the root portion. As described herein, the first root fitting preferably comprise a barrel. The barrel preferably comprises a first surface arranged to be located at or near the outer surface of the root portion and a second surface arranged to be located at or near the inner surface of the root portion. Each of the first and second surfaces of the barrel preferably provides a threaded bore extending substantially perpendicular to the longitudinal axis of the root portion. The threaded bores may extend from the first or second surface within the barrel in a direction substantially parallel to and may be aligned with the longitudinal axis of the barrel. Each of the clamping portions may provide a threaded aperture for alignment with the threaded bores provided by the barrel. The first threaded aperture of the first clamping portion may be aligned in use with the threaded bore provided on the first surface of the barrel. The second threaded aperture of the second clamping portion may be aligned in use with the threaded bore provided on the second surface of the barrel. The clamping portions may further comprise a threaded member, for example a bolt, for threaded engagement with the bores provided by the barrel. A first threaded member is inserted through the first threaded aperture into the threaded bore provided on the first surface of the barrel. A second threaded member is inserted through the second threaded aperture into the threaded bore provided on the second surface of the barrel. The first and second threaded members are tightened until the compressive clamps place the barrel and the collar and the adjacent root portion under the desired amount of compression in the through direction. In one embodiment, at least one of the compressive clamps further comprises a compression tube located between the bolt and the threaded aperture of the clamp. The compression tube advantageously reduces the variability in preload which could be caused due to external factors such as for example variation in temperatures in an underwater location.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an embodiment of a root fitting of the present invention;

Figure 2 illustrates a further embodiment of a root fitting of the present invention; and

Figure 3 illustrates a further embodiment of the root fitting of Figure 2.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a cross-sectional view of a rotor blade, and illustrates the principles underlying rotor blades embodying the present invention. As described above a rotor blade comprises a blade portion and a root portion which extends from the blade portion. The root portion may be provided by an end region of a spar of the blade, which spar extends along the length of the blade, as is well known in blade design. Embodiments of the present invention are concerned with the design of rotor blades and root fittings which enable the blade to be attached to a blade mounting. In the following examples, the root portion of the blade is provided by a free end of the spar of the rotor blade, but could be provided by any suitable part of the blade.

In the example shown, in Figure 1, the root portion 100 is annular in cross-section. Alternatively, the root portion 100 could be of any tubular cross section, such as ovoid, square or rectangular, depending upon design considerations. A root fitting technique embodying the principles of the present invention comprises a plurality of discrete elongate members 102, a plurality of discrete apertures 104 and a plurality of discrete first tensioning fasteners 106 for engagement with the elongate members 102. For the sake of clarity, only three elongate members 102, three apertures 104 and three first tensioning fasteners 106 are illustrated in Figure 1. It will be readily appreciated that a root fitting technique embodying the present invention can have any number of root fittings, apertures and first tensioning fasteners, and that, in practice, the number is likely to far exceed three. The precise number of fittings 102, apertures 104 and tensioning fasteners 106 provided, however, does not affect the underlying principles of the present invention.

The root portion 100 defines first and second root surfaces. The first root surface is the outer surface 108 of the root portion 100 and the second root surface (not shown) is the inner surface of the root portion 100 that bounds an interior volume thereof. The inner and outer surfaces of the root portion 100 extend substantially parallel to one another and define a cavity extending therebetween. The root portion 100 provides a plurality of apertures 104 arranged to be located in an annular arrangement about the root portion 100. The apertures 104 are provided at a uniform distance from the free end of the root portion 100. The apertures 104 each have a bore extending through the thickness of the root portion 100 in a direction extending substantially perpendicular to the longitudinal axis of the root portion 100.

The rotor blade comprises a plurality of first tensioning fastener 106. Each first tensioning fastener 106 comprises a barrel 110 having a circular cross-section and dimensioned to be received within an aperture 104 provided by the root portion 100. The barrel 110 provides a transversely extending smooth bore 120. The bore 120 extends substantially perpendicular to the longitudinal axis of the barrel 110. The barrel 110 has a flattened surface 112.

The root fitting 102 comprises a first end 122 having a first threaded portion for threaded engagement with a threaded hole 124 provided by the blade mounting 126. The root fitting 102 comprises a second end 128 having a second threaded portion for threaded engagement with the first tensioning fastener 106.

In use, each first end 122 of a elongate member 102 is threadingly engaged within a threaded hole 124 provided by the blade mounting 126. The blade is then lowered into position over the elongate members 102. Each elongate member 102 extends into the cavity extending between the outer surface 108 and the inner surface (not shown) of the root portion 100. The second end 128 of the elongate member 102 extends into the apertures 104 provided by the root portion 100. A barrel 110 is located within each aperture 104. Each barrel 110 is rotatable within the aperture 104. The barrel 110 may be rotated within the aperture 104 such that the longitudinal axis of the bore 120 extends parallel to and is aligned with the longitudinal axis of the root fittings 102. The second end 128 of the elongate member 102 is received within and extends through the bore 120 provided by the barrel 110. A threaded nut 130 is placed in threaded engagement with the second end 128 of the elongate member 102 within the aperture 104. A tension adjuster 132 is received within the aperture 104. The nut 130 is tightened using the tension adjuster 132, in this embodiment a hydraulic tensioner. The nut 130 is tightened by the adjuster 132 until the nut 130 sits flush against the flattened surface 112 of the barrel 110. The apertures 104 are shaped and dimensioned to receive the hydraulic tensioner 132. In this embodiment, the apertures 104 are elongated oval in shape so as to provide sufficient space for the tensioner 132.

Figure 2 illustrates a second embodiment of the present invention. As before, the spar of the rotor blade provides the root portion 200 to which the elongate members 202 are connected. The first root surface is the outer surface 208 of the root portion 200 and the second root surface is the inner surface 209 of the root portion 200 that bounds an interior volume thereof. The root portion 200 provides a plurality of apertures 204 arranged to extend in an annular arrangement about the root portion 200. The apertures 204 are located at a uniform distance from the free end of the root portion 200. The apertures 204 each have a bore extending

through the thickness of the root portion 200 in a direction substantially perpendicular to the longitudinal axis of the root portion 200. A first tensioning fastener 206 comprising a barrel 210 is received within the apertures 204 provided by the root portion 200. The barrel 210 has the same features as discussed in relation to Figure 1. The first tensioning fastener 206 further  
5 comprises a threaded nut 230 for threaded engagement with the second end of the root fitting 202 as discussed in relation to Figure 1.

The free end 201 of the root portion 200 provides a plurality of recesses 234. Each recess 234 has a threaded inner surface is are shaped and dimensioned for receiving a second tensioning fastener 238. Each second tensioning fastener 238 is predominantly cylindrical in  
10 shape comprising an elongate barrel. The outer surface 242 of each second tensioning fastener 238 comprises a threaded portion for mutual engagement with the threaded portion of the first recess 234. The elongate barrel of each second tensioning fastener 238 provides a channel 244 for receiving the elongate member 202. Each recess 234 is located so as to align the longitudinal axis of the channel 244 of the second tensioning fastener 238 with the  
15 longitudinal axis of the elongate member 202.

Each second tensioning fastener 238 comprises a first end 246 arranged to be received within the recess 236 of the root portion 200 and a second end 248 located at or adjacent the free end of the root portion 200. Each second end 248 of the second tensioning fastener 238 may be arranged in use to provide a blade mounting abutment surface. Each second tensioning  
20 fastener 238 may be rotated within the recess 234 in order to selectively displace the second tensioning fastener 238 from the recess such that the second end 248 is brought into contact with the blade mounting 226.

The root portion 200 further provides a plurality of chambers 250 located at the free end of the root portion 200. Each chamber 200 is located adjacent an elongate member 202 and a  
25 second tensioning fastener 238. The chambers 250 are shaped and dimensioned to receive a second tension adjuster 252. In this embodiment, the second tension adjuster 252 is a hydraulic jack.

The chambers 250 are provided by the abutment surface at the free end of the root portion 200. The chambers 250 are arranged such that the second tension adjuster 252 is extendable  
30 in a direction to contact and to exert a compressive force against the blade mounting 226.

The outer 208 surface of the root portion 200 provides additional openings 260 in communication with the chambers 250. The additional openings 260 are shaped and

dimensioned to allow the insertion and removal of the second tension adjuster 252 into the chamber 250. The chamber 250 further comprises an annular flange 262 arranged to support the second tension adjuster 252 within the chamber 250.

In use, each first end 222 of an elongate members 202 is threadingly engaged within a threaded hole 224 provided by the blade mounting 226. The blade is then lowered into position over the elongate members 202. Each elongate members 202 extends into the through the second tensioning fastener and into the cavity extending between the outer surface 208 and the inner surface 209 of the root portion 200. The second end 228 of the elongate members 202 extends into the apertures 204 provided by the root portion 200. A barrel 210 is located within each aperture 2. The nut is threadingly engaged with the second end 224 of the elongate members 202. The nut is tightened until it abuts the flattened surface of barrel 110. The hydraulic tension adjuster 252 is switched on and portion of the adjuster 252 extends from the chamber 250 so as to exert a compressive force against the blade mounting causing the free end of the root portion 200 and the blade mounting to separate from each other. The hydraulic tension adjuster 252 therefore subjects the adjacent elongate member(s) to increased tension. The second tensioning fastener 238 is rotated within the first recess 236 of the root portion 200 in a direction such that the proximal end 248 of the second tensioning fastener 238 extends from the recess 236. The second tensioning fastener 238 is rotated until the second end 248 of the second tensioning fastener abuts the blade mounting abutment surface. The hydraulic tension adjuster 252 is switched off and is removed from the chamber.

Figure 3 illustrates a further embodiment, in which the rotor blade as described in relation to Figure 2 further comprises compressive clamp 270 for exerting a compressive force on the root portion 200. Each root fitting is associated with a compressive clamp 270. The compressive clamp 270 is arranged to exert a compressive force in a direction substantially perpendicular to the longitudinal axis of the root portion 200. In particular, the compressive clamp 270 is arranged to exert a compressive force in a direction substantially perpendicular to the longitudinal axis of the elongate member 202. As shown in Figure 3, the compressive clamp 270 is arranged to engage the root portion 200 and the barrel 210 of the root fitting.

The compressive clamp 270 comprises a first clamping portion 271 for engagement with an outer surface 208 of the root portion 200 and a second clamping portion 272 for engagement with an inner surface 209 of the root portion 200. The compressive clamp 270 also comprises two collar portions 273 for locating within the cavity provided between internal surfaces of the

inner and outer surfaces 208,209 of the root portion 200. The collar portions 273 are arranged to engage the internal surfaces of the root portion 200. The first and second clamping portions 271,272 and the collars 273 are aligned, for example to extend within a plane extending substantially perpendicular to the longitudinal axis of the root portion 200, and to engage axially aligned surfaces of the root portion 200. The barrel 210 preferably comprises a first surface 275 arranged to be located at or near the outer surface 208 of the root portion 200 and an second surface 276 arranged to be located at or near the inner 209 surface of the root portion 200. Each of the first and second surfaces 275, 276 of the barrel 210 provides a threaded bore 278,279 extending substantially perpendicular to the longitudinal axis of the root portion 200. The threaded bores 278,279 extend from the first and second surfaces 275,276 within the barrel 210 in a direction substantially parallel to and are be aligned with the longitudinal axis of the barrel 210. Each of the clamping portions 271,272 provide a threaded aperture 280,281 in a location to align with the threaded bores 278,279 provided by the barrel 210. The first threaded aperture 280 of the first clamping portion 271 is aligned in use with the threaded bore 278 provided on the external face of the barrel 275. The second threaded aperture 281 of the second clamping portion 272 is aligned in use with the threaded bore 279 provided on the internal face 276 of the barrel 210. A first bolt 282 is inserted through the first threaded aperture 280 into the threaded bore 278 provided on the external face of the barrel 210. A second bolt 284 is inserted through the second threaded aperture 281 into the threaded bore 279 provided on the internal face of the barrel 210. The compressive clamp further comprises a compression tube 290 located between the bolt 284 and the threaded aperture 281 of the clamp. The compression tube 290 advantageously reduces the variability in preload which could be caused due to external factors such as for example variation in temperatures in an underwater location. The first and second bolts 282,284 are tightened until the compressive clamps place the barrel 210 and the collar 270 and the adjacent root portion 200 under the desired amount of compression in the through direction.

**CLAIMS:**

1. A rotor blade comprising:  
a blade portion, and  
a root portion extending from the blade portion to a free end for attachment, in use, to  
5 a blade mounting, the root portion comprising a plurality of apertures each having a bore  
extending through the thickness of the root in a radial direction; and  
a plurality of discrete root fittings, each associated with one of the apertures, for  
attachment to a blade mounting, wherein each root fitting comprises:  
10 an elongate member which extends from a first end, proximal to the free end  
of the root portion and for attachment to a blade mounting, to a second end which is  
located within the respective aperture of the root portion,  
a barrel shaped and dimensioned to be received within the respective  
aperture of the root portion, the axial direction of the barrel being aligned with the  
15 bore of the aperture, the barrel having a transversely extending bore through which  
the elongate member extends; and  
a first tensioning fastener arranged to engage the second end of the elongate member,  
wherein the aperture is sized and dimensioned such that the second end of the  
elongate member may project beyond the barrel and be engaged by the first tensioning  
20 fastener located within the aperture.
2. A rotor blade as claimed in claim 1, in which the plurality of apertures are elongated.
3. A rotor blade as claimed in any preceding claim, in which the second end of the  
elongate member comprises a threaded portion, and in which the first tensioning fastener  
25 comprises a threaded portion for threaded engagement with the second end of the elongate  
member.
4. A rotor blade as claimed in any preceding claim, further comprising a first tension  
adjuster, in which the first tension adjuster is received in use within the aperture and arranged  
for engagement with the first tensioning fastener.
- 30 5. A rotor blade as claimed in any preceding claim, in which the root portion further  
comprises a plurality of second tensioning fasteners located at or adjacent the free end of the  
root portion for engagement with the root fittings.

6. A rotor blade as claimed in claim 5, in which the free end of the root portion provides a plurality of recesses, in which each recess is shaped and dimensioned for engagement with a second tensioning fastener.
7. A rotor blade as claimed in claim 6, in which the recesses are threaded recesses for threaded engagement with a second tensioning fastener.
8. A rotor blade as claimed in either of claims 6 and 7, in which the axial direction of each recess is aligned with the longitudinal axis of the root portion.
9. A rotor blade as claimed in any one of claims 5 to 8, in which each second tensioning fastener is arranged in use to be selectively extendable from the recess to abut the blade mounting in order to adjust the tension within the elongate member.
10. A rotor blade as claimed in any one of claims 5 to 9, in which the second tensioning fastener is a barrel comprising a threaded outer surface for threaded engagement with the recess and an axially extending channel through which the elongate member may extend.
11. A rotor blade as claimed in claim 6 to 10, in which the second tensioning fastener comprises a first end arranged to be received within the recess of the root portion and a second end arranged to be located at or adjacent the free end of the root portion, and in which the second end provides a blade mounting abutment surface.
12. A rotor blade as claimed in any one of claims 5 to 11, in which the root portion further provides at least one chamber located at the free end of the root portion, in which the or each chamber is shaped and dimensioned to receive a second tension adjuster.
13. A rotor blade as claimed in claim 12, in which the at least one chamber is located at or adjacent each root fitting.
14. A rotor blade as claimed in either of claims 12 and 13, in which a second tension adjuster is received in use within each chamber.
15. A rotor blade as claimed in claim 14, in which the second tension adjuster is a hydraulic tensioning mechanism.
16. A rotor blade as claimed in claim 15, in which the second tension adjuster is a hydraulic jack.
17. A rotor blade as claimed in any one of claims 12 to 16, in which the at least one chamber is provide by the root portion at a location such that a second tension adjuster is received within each chamber so as to be arranged in use to contact and exert a tensioning force against the blade mounting.

18. A rotor blade as claimed in any one of claims 12 to 17, in which the abutment surface of the root portion provides the at least one chamber.
19. A rotor blade as claimed in any one of claims 1 to 18, in which the elongate member comprises a first threaded portion at the first end for engagement with the blade mounting, and a second threaded portion at the second end for engagement with the first tensioning fastener.
20. A rotor blade as claimed in any preceding claim, in which the blade further comprises at least one compressive clamp for exerting a compressive force on the root portion, in which the compressive force extends in a direction substantially perpendicular to the longitudinal axis of the root portion.
21. A rotor blade as claimed in claim 20, in which each compressive clamp is arranged to engage the root portion and the barrel of a root fitting.
22. A rotor blade as claimed in either of claims 20 and 21, in which the compressive clamp comprises a first clamping portion for engagement with an outer surface of the root portion and a second clamping portion for engagement with an inner surface of the root portion.
23. A rotor blade as claimed in claim 22, in which the compressive clamp further comprises at least one collar portion for locating within a cavity provided between the inner and outer surfaces of the root portion and for engagement with the internal surfaces of the inner and outer surfaces of the root portion.
24. A rotor blade as claimed in claim 23, in which the first and second clamping portions and the collar are aligned in use in a plane extending substantially perpendicular to the longitudinal axis of the root fitting.
25. A rotor blade as claimed in any one of claims 20 to 24, in which the at least one compressive clamp threadingly engages the barrel of the root fitting.
26. A rotor blade as claimed in claim 25, in which the barrel comprises a first surface located at or near the outer surface of the root portion and a second surface arranged to be located at or near the inner surface of the root portion, and in which each of the first and second surfaces of the barrel provides a threaded bore extending substantially perpendicular to the longitudinal axis of the root portion, and the first and second clamping portions each comprise a threaded member for engaging the threaded bores.
27. A rotor blade as claimed in claim 26, in which at least one of said first and second clamping portions further comprises a compression tube.
28. A method of assembling a rotor blade as claimed in any one of claims 1 to 27, in which the method comprises:

a. connecting the root portion of a blade to a blade mounting with a plurality of root fittings;

b. providing at least one tension adjuster such that it is arranged to exert a force between the blade mounting and the root portion of the blade so as to place the root fittings under a desired amount of tension;

c. adjusting at least one tensioning fastener to abut the surface of the blade mounting; and

d. removing the at least one tension adjuster such that the desired tension is maintained by the at least one tensioning fastener.

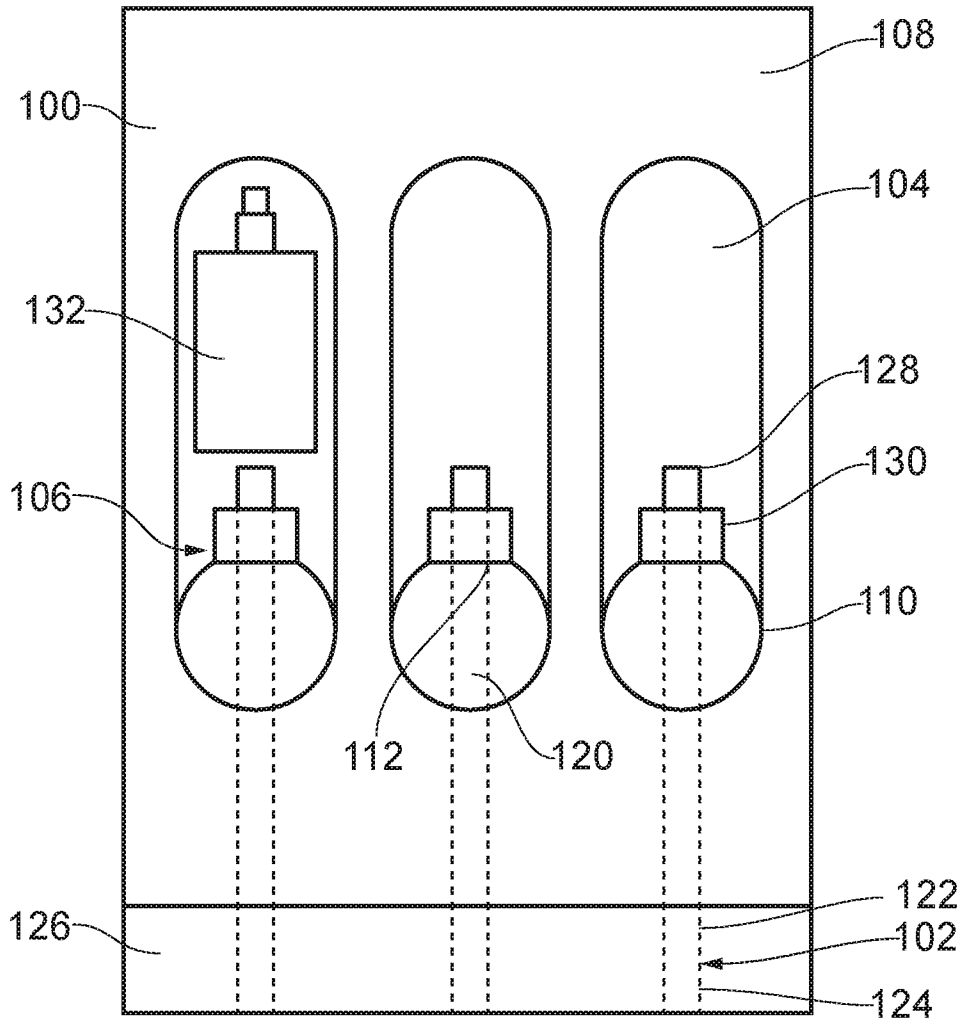


FIG. 1

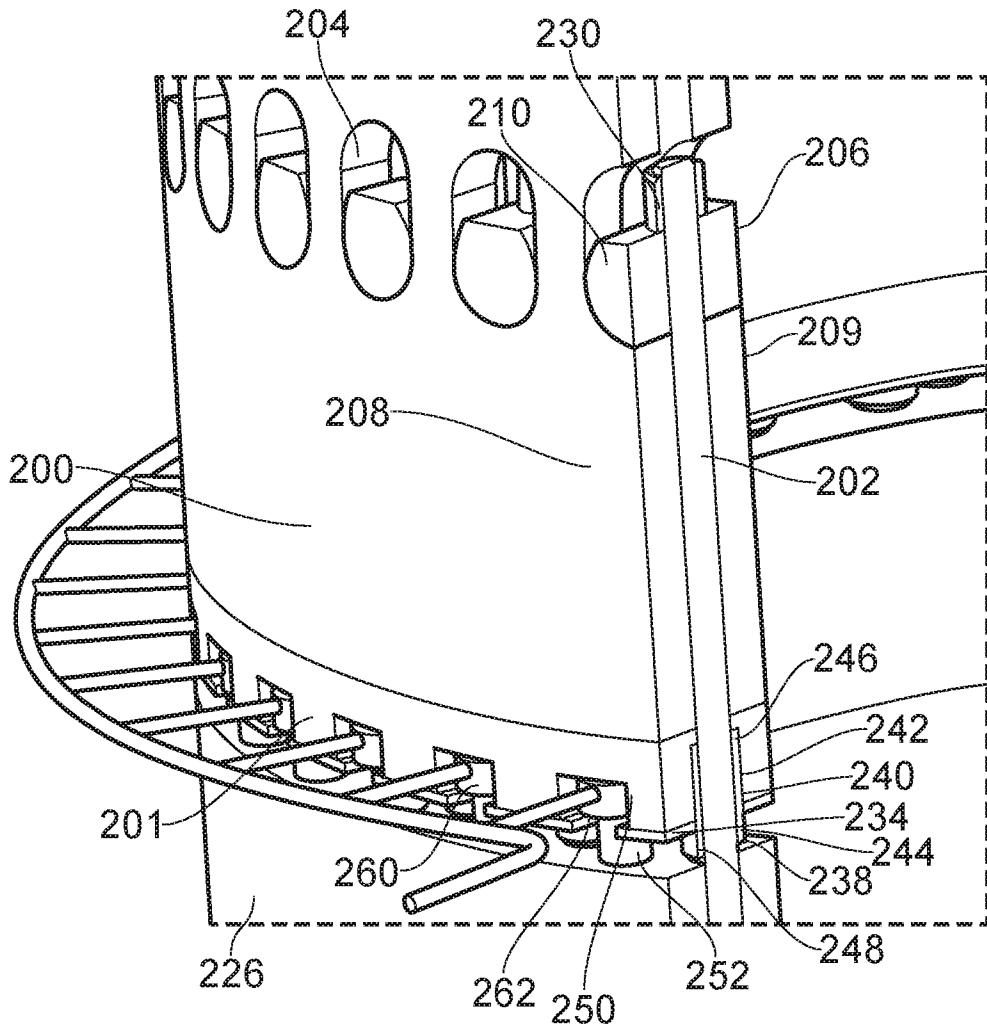


FIG. 2

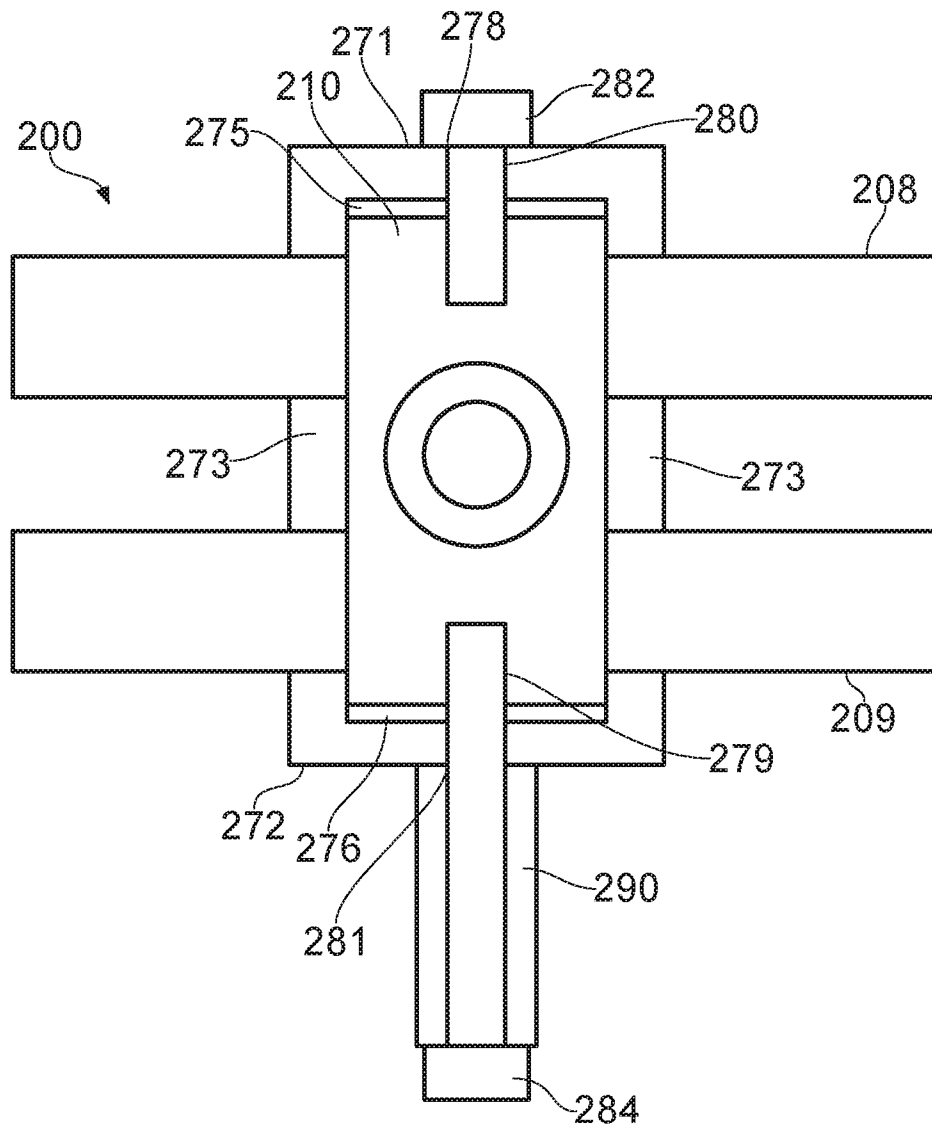


FIG. 3

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/GB2014/050995

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> INV. F03D1/06 F03B3/12 ADD.				
According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b>				
Minimum documentation searched (classification system followed by classification symbols) F03D F04D F03B				
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 practicable, search terms used) EPO-Internal, WPI Data				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X  Y A	EP 1 234 984 A2 (AIRBUS FRANCE [FR]) 28 August 2002 (2002-08-28)  abstract paragraph [0003] paragraphs [0036] - [0038] paragraphs [0050] - [0051]; figures 2,3,4,5,7  ----- WO 01/42647 A2 (AERPAC HOLDING B V [NL]; HEERKES HENDRIK JAN [NL]; SCHERER RALF ROGER) 14 June 2001 (2001-06-14) abstract page 10, lines 6-18 figures 3-7  ----- -/--	1-6,8,9, 12-17, 19-25,28 26,27 7,10,11, 18           1-4,28           7,10,11, 18		
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.</td> <td style="width: 50%; border: none;"><input checked="" type="checkbox"/> See patent family annex.</td> </tr> </table>			<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> See patent family annex.
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> See patent family 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 application or patent 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  <p style="text-align: center; font-weight: bold;">7 August 2014</p>	Date of mailing of the international search report  <p style="text-align: center; font-weight: bold;">14/08/2014</p>			
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  <p style="text-align: center; font-weight: bold;">Cabrele, Silvio</p>			

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International application No  
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	<p style="text-align: center;">-----</p> EP 2 187 069 A1 (GEN ELECTRIC [US]) 19 May 2010 (2010-05-19) abstract paragraph [0001] paragraph [0015] paragraph [0018] paragraph [0021] figures 1-11 <p style="text-align: center;">-----</p>	1-28

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