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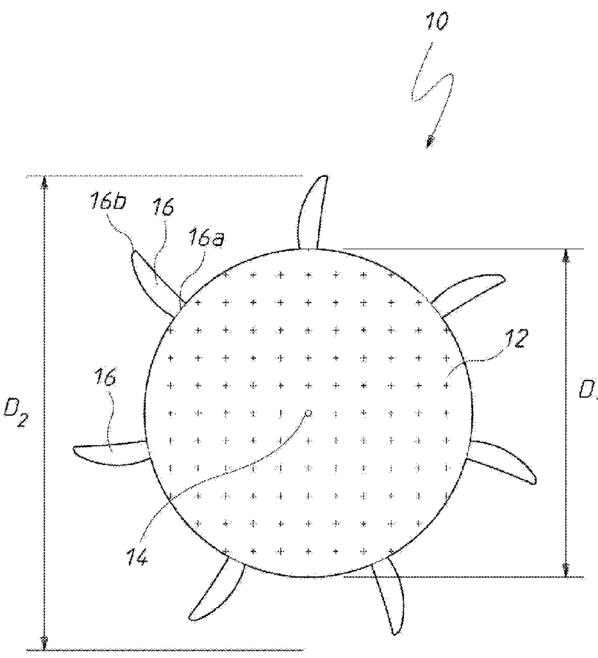

FIG. 1

(57) Abstract: A rotor (10) for a hydro-powered electricity generator. The rotor (10) includes a hub (12) and a plurality of blades (16). The hub (12) has a circular cross sectional shape and a longitudinal rotational axis (14). The plurality of blades (16) each have a proximal root (16a) and a distal tip (16b). Each of the blade roots (16a) are mounted to the hub (12) at the widest part thereof (D1). The ratio between the diameter of the tips (16b) of the blades to the diameter of the widest part (D1) of the hub (12) is less than about 2:1.

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A ROTOR FOR AN ELECTRICITY GENERATOR

Field of the Invention

[0001] The present invention relates to a rotor for an electricity generator.

[0002] The invention has been primarily developed for use in a rotor for a hydro-powered electricity generator. Such generators are used to convert kinetic energy from flowing fluids, such as water and wind, to electrical power.

Background of the Invention

[0003] Kinetic energy in flowing fluids, such as water and wind, is a known alternative to energy sources such as bio-fuels and fossil fuels for generating power. Unlike, for example, bio- and fossil fuels which, when used in electrical power generation, go hand-in-hand with emission of harmful combustion gasses into the atmosphere, generation of power by using flowing fluids has no or very little adverse effects on the atmosphere.

[0004] Known installations for harvesting wind power generally have low running costs, however they tend to be expensive to install and have relatively low generation capacity. Known installations for harvesting hydropower, for example tidal power, on the other hand, have relatively higher generation capacity.

[0005] Known hydro-powered electricity generators typically have a rotor comprising a central hub to which is attached two or more outwardly extending blades. The rotor is connected by a drive shaft to a rotary work to electrical power converter (i.e. a generator). Fluid flowing past the rotor blades causes it to rotate which in turn causes the rotation in the converter and the generation of electrical power.

[0006] Known rotors have a relatively small diameter hub and relatively long and slender blades. The blades also have a relatively high aspect ratio (being the ratio of the blade length to the blade width). Such blades are prone to high operating loads and subject to extreme bending moments in turbulent fluid flow. This typically results in broken blades.

Object of the Invention

[0007] It is an object of the present invention to substantially overcome, or at least ameliorate, the above disadvantage.

Summary of the Invention

[0008] In a first aspect, the present invention provides a rotor for a hydro-powered electricity generator, the rotor including:

a hub with a circular cross sectional shape and a longitudinal rotational axis,

a plurality of blades, each having a proximal root and a distal tip, each of the blade roots being mounted to the hub at the widest part thereof,

wherein the ratio between the diameter of the tips of the blades to the diameter of the widest part of the hub is less than about 2:1.

[0009] Preferably, the ratio between the diameter of the tips of the blades to the diameter of the widest part of the hub is between about 1.2:1 and 2:1.

[0010] Preferably, the ratio between the diameter of the tips of the blades to the diameter of the widest part of the hub is about 1.5:1 or 1.6:1.

[0011] In one embodiment, the diameter of the tips of the blades is between 3.6 and 4.8 metres and the diameter of the widest part of the hub is 2.4 metres.

[0012] In another embodiment, the diameter of the tips of the blades is between 30 and 32 metres and the diameter of the widest part of the hub is 20 metres.

[0013] The profile radius of the hub surface, in the region where each of the blade roots are mounted to the hub, is preferably between 1/6th of and equal to the radius of the widest part of the hub.

Brief Description of the Drawings

[0014] Preferred embodiments of the invention will now be described, by way of examples only, with reference to the accompanying drawings in which:

[0015] Fig. 1 is a front view of a first embodiment of a rotor;

[0016] Fig. 2 is a perspective view of the rotor shown in Fig. 1 with stream lines; and

[0017] Fig. 3 is cross sectional side view of a hydro-powered electricity generator with a second embodiment of a rotor.

Detailed Description of the Preferred Embodiments

[0018] Figs. 1 and 2 show a rotor 10 for a hydro-powered electricity generator suitable for installation in a tidal flow environment. The rotor 10 includes a hub 12 with a circular cross sectional shape and a longitudinal rotational axis 14. The rotor 10 also includes 7 equiangularly spaced apart blades 16. The hub 10 is formed from glass reinfornced plastic (GRP) or metal skins and the blades 16 are formed from carbon fibre metal composites.

[0019] Each of the blades 16 has a proximal root 16a and distal tip 16b. Each of the blades 16 are mounted to the hub 14, at their roots 16a, at the widest part of the hub 14. The diameter of the widest part of the hub 14 is shown as diameter D1. The diameter of the tips 16b of the blades 16 is shown as diameter D2. In the embodiment shown, the ratio between diameters D2:D1 is about 1.4:1.

[0020] Fig. 2 shows the rotor 10 relative to fluid flow stream lines 18 which demonstrate that as the fluid flows around the hub 12 its velocity increases. As the fluid accelerates and the local velocity increases, the local pressure decreases. This pressure reduction causes the fluid to remain concentrated around the hub 12. As a result, the energy in a free stream of the fluid is concentrated in the region of the blades 16.

[0021] Another way of describing the above D2:D1 ratio is that the diameter of the hub 12 is relatively large compared to the length of the blades 16. The relatively large hub diameter D1 advantageously serves the dual function of: 1. concentrating the energy in the passing water stream; and 2 supporting a relatively greater number of smaller and stronger blades 16, which each have a lower aspect ratio.

[0022] In relation to the latter issue, the bending moment at the root is a function of the aspect ratio of the blade. For example, a blade with an aspect ratio of 8:1 will have a stress value in the root that is 16 times higher than the same blade with an aspect ratio of 4:1. In a known 3-blade rotor with a relatively small diameter hub, the blades can only have a limited chord length at the root due to the diameter restriction of the hub. This restriction of chord length means that the blade root thickness must be increased, to provide sufficient strength, over that otherwise required for an ideal foil section.

[0023] A relatively longer blade mounted to a relatively smaller hub also results in a lower apparent velocity for a given RPM and a lower torque radius.

[0024] A thicker root, especially in the lower $1/3^{rd}$ of the blade, combined with the lower apparent velocity and the lower torque radius, results in a lowered contribution to the total power of such a (known) 3-blade rotor. This is due to the fact that the outer $1/3^{rd}$ of the blade in the smaller hub/larger 3-blade configuration does 63% of the work. This is a combination of the swept area of the outer 30% of the blade, which constitutes 56% of the total surface area, and the inner 30% of the blade producing negligible power.

[0025] In contrast, the configuration of the rotor 10 (i.e. relatively larger hub 14, relatively shorter blades 16, relatively large number of blades 16) redirects and concentrates the fluid flow in the inner 2/3 region and accelerates it through the outer $1/3^{rd}$ region where 100% of the power can be extracted. This advantageously means that the blades 16 are operating at maximum capacity, while also experiencing a lower stress loading.

[0026] Put another way, the D2:D1 ratio of the rotor 10 places the blades 16 in a zone of acceleration around the hub 12 with an ideal blade length for the blades 16 to operate in that zone. If the blades are too long relative to the hub diameter then the blades tips instead operate in a region with no fluid acceleration and therefore do not contribute positive torque.

[0027] Fig. 3 shows a hydro-powered electricity generator 30 with a second embodiment of rotor 32. The rotor 32 has a hub 34 and ten blades 36. Fig. 3 also shows blade root mounting beams 38, a blade mounting hub 40, a fixed main spindle 42, a drive shaft 44, a gear box 46, a support beam 48, a water seal 50, bearings 52 and a rotary electrical generator 54. The beam 48 is used to connect the generator 30 to a floating deployment rig (not shown).

[0028] Also shown on Fig. 3 is radius R, being the profile radius hub 34 in the region where the hub 34 and the blades 36 are connected. In the preferred configuration shown, the radius R is

1/6 the radius of the hub 34. This particular ratio maximises flow acceleration while avoiding turbulence.

[0029] One preferred form of the generator 30 has the following specifications:

Hub diameter D1: 2.4 meters

Blade tip diameter D2: 4.8 to 3.6 meters

Power generation range: 50 to 300 kWs

Flow velocity range: 1.2 to 4.2 m/sec

Blade tip diameter to hub diameter ratio: 2:1 to 1.5:1

[0030] Another preferred form of the generator 30 has the following specifications:

Hub diameter D1: 20 meters

Blade tip diameter D2: 32 to 30 meters

Power generation range: 0.5 to 5 MWs

Flow velocity range: 1.2 to 4.0 m/sec

Blade tip diameter to hub diameter ratio: 1.6:1 to 1.5:1

[0031] There are several advantages for hydro-powered generators due to the (relatively larger) diameter hub to (relatively smaller) diameter blade ratios described above.

[0032] Firstly, the energy in the fluid stream is concentrated and accelerated across a set of small blades, which improves the efficiency of the rotor.

[0033] Secondly, the total volume of the multiple (e.g. 7) smaller blades is less than the volume of a small number of (e.g. 3) large blades, which lowers manufacturing cost.

[0034] Thirdly, the smaller blades have a lower aspect ratio, which equates to a lower bending moment in the blade root, and a lower probability of blade breakage.

[0035] Fourthly, the incident velocity and the incident angle of the flow onto the smaller blades is closer to a uniform value across the span of the blades. This equates to near zero twist in the blade across its span, and allows the blades to be articulated in pitch control without any performance losses induced by blade twist. Further, the ability to adjust the pitch during operation means the rotor can be run at a constant rpm independent of the flow stream velocity.

This allows the generator to be run at a constant rpm connected directly to the electrical grid thereby negating the cost of an electrical frequency inverter drive system.

[0036] Fifthly, rotors operating in fast flowing tidal flows are subject to high levels of turbulence in the stream. The action of the flow acceleration of the water around the larger hub reduces the level of turbulence into the blade region. This improves the survivability of the blades in highly turbulence environments.

[0037] Although the invention has been described with reference to preferred embodiments, it will be appreciated by person skilled in the art that the invention may be embodied in other forms.

CLAIMS:

1. A rotor for a hydro-powered electricity generator, the rotor including:

a hub with a circular cross sectional shape and a longitudinal rotational axis,

a plurality of blades, each having a proximal root and a distal tip, each of the blade roots being mounted to the hub at the widest part thereof,

wherein the ratio between the diameter of the tips of the blades to the diameter of the widest part of the hub is less than about 2:1.

2. The rotor as claimed in claim 1, wherein the ratio between the diameter of the tips of the blades to the diameter of the widest part of the hub is between about 1.2:1 and 2:1.

3. The rotor as claimed in claim 1, wherein the ratio between the diameter of the tips of the blades to the diameter of the widest part of the hub is about 1.5:1 or about 1.6:1.

4. The rotor as claimed in claim 1, wherein the diameter of the tips of the blades is between 3.6 and 4.8 metres and the diameter of the widest part of the hub is 2.4 metres.

5. The rotor as claimed in claim 1, wherein the diameter of the tips of the blades is between 30 and 32 metres and the diameter of the widest part of the hub is 20 metres.

6. The rotor as claimed in any one of claims 1 to 5, wherein the profile radius of the hub surface, in the region where each of the blade roots are mounted to the hub, is between 1/6th of and equal to the radius of the widest part of the hub.

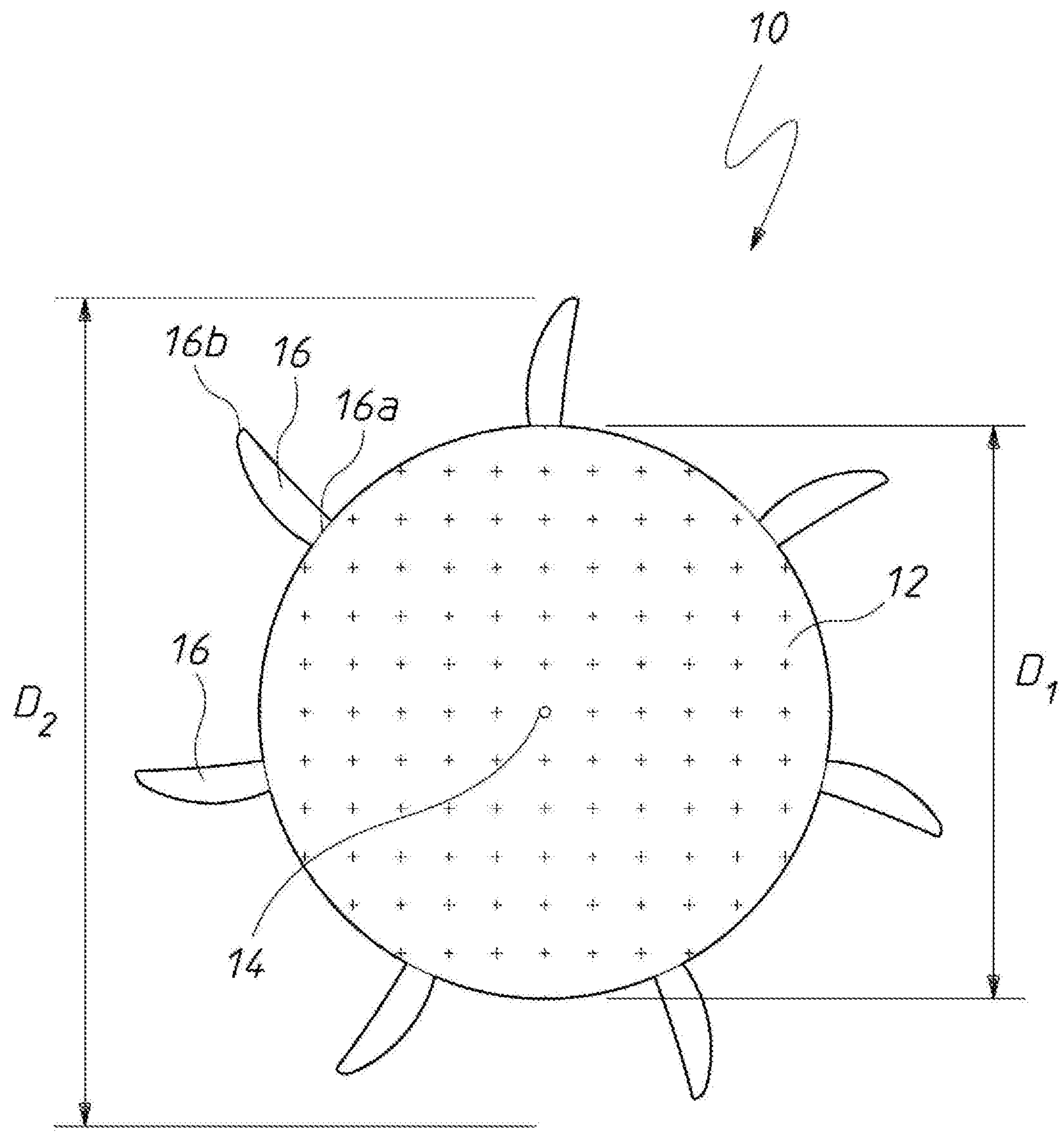

FIG. 1

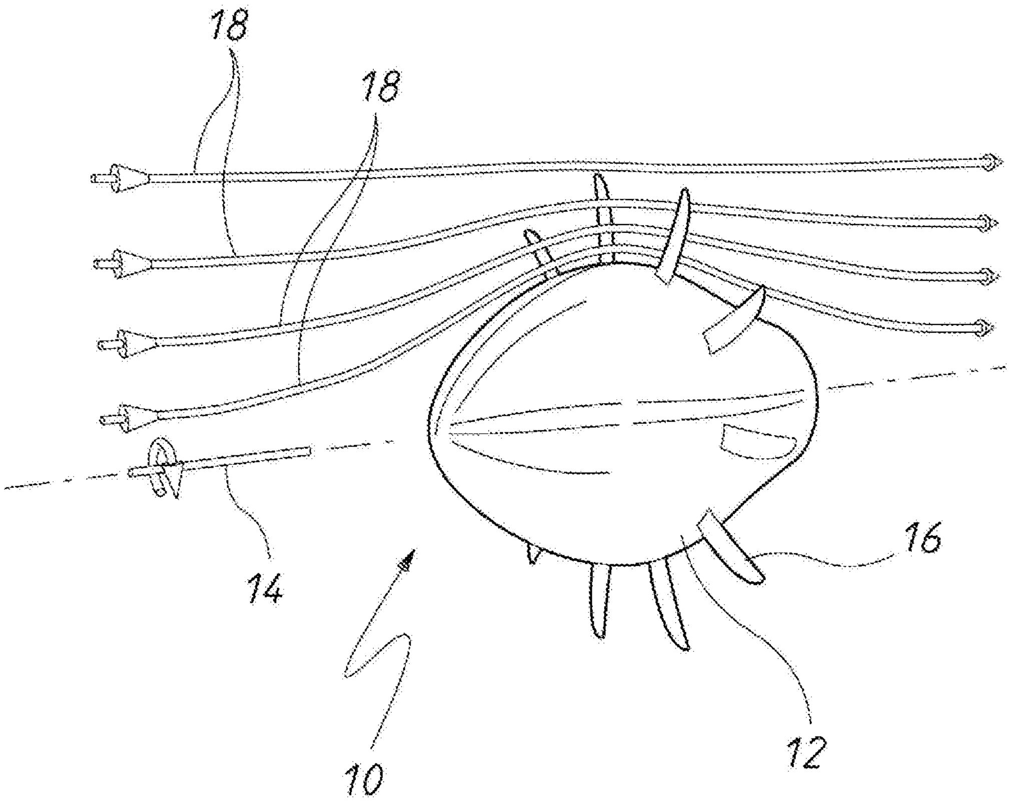

FIG.2

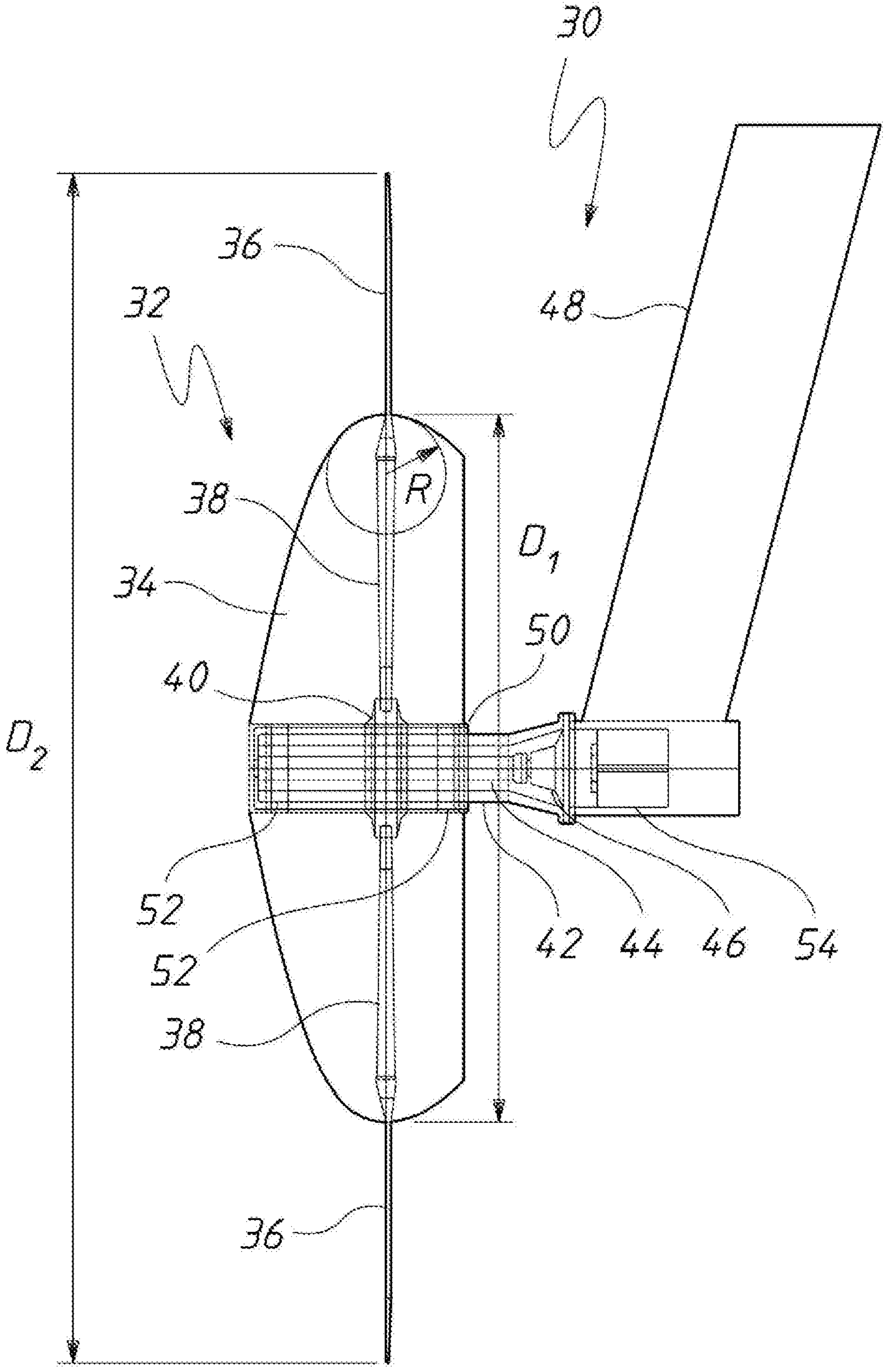

FIG.3

A. CLASSIFICATION OF SUBJECT MATTER

F03B 3/04 (2006.01) F03B 3/12 (2006.01)

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)

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)

WPIAP, EPODOC, TXTE : IPC, CPC: F03B; CPC: Y02E10/20/LOW. keywords: hub, tip, ratio, hydro, Kaplan and similar terms

Google Patents, Google Scholar: hydro, hydraulic, turbine, hub, tip ratio and similar terms

Applicant/Inventor name search in AusPat, Espace

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

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

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"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
20 June 2016	20 June 2016

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SIMPSON R. et al., *"Design of propeller turbines for pico hydro"* April 2011. Retrieved from internet on 08 June 2016, <URL: http://herehydro.weebly.com/uploads/9/3/9/1/93913/pico_propeller_guidelines_apr_2011_v11c.pdf> pp 4-7, Figs 3, 8	1-6
X	ADHIKARI P. et al., *"A Study on Developing Pico Propeller Turbine for Low Head Micro Hydropower Plants in Nepal"*. Published in Journal of the Institute of Engineering, Vol. 9, No. 1 (2013). Retrieved from internet on 08 June 2016, <URL:http://www.nepjol.info/index.php/JIE/article/view/10669> pp. 40-42; Figures 2.3, 2.5	1-6
X	CA 2643587 A1 (ORGANOWORLD INC.) 10 May 2010 page 1, lines 5-7; page 12, lines 14-15; Figures 5A-8	1, 2, 6
P,X	GB 2530048 A (ROLLS-ROYCE PLC) 16 March 2016 page 5, lines 24-25.	1, 2, 6

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2016/000091**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
CA 2643587 A1	10 May 2010	CA 2643587 A1	10 May 2010
		EP 2394052 A1	14 Dec 2011
		WO 2010051647 A1	14 May 2010
GB 2530048 A	16 March 2016	GB 2530048 A	16 Mar 2016

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

摘要

一种用于水力发电机的转子(10)。所述转子(10)包括轮毂(12)和多个叶片(16)。所述轮毂(12)具有圆形截面形状和纵向旋转轴(14)。所述多个叶片(16)各自具有近端叶根(16a)和远端叶尖(16b)。叶片叶根(16a)中的每个安装到所述轮毂(12)的最宽部分(D1)。所述叶片的所述叶尖(16b)的直径与所述轮毂(12)的所述最宽部分(D1)的直径之比小于约 2:1。