(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 February 2014 (13.02.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/023739 A1

(51) International Patent Classification:
F03D 1/06 (2006.01)

(21) International Application Number:
PCT/EP2013/066495

(22) International Filing Date:
6 August 2013 (06.08.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
S2012/0347 9 August 2012 (09.08.2012) IE
13/897,766 20 May 2013 (20.05.2013) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: A BLADE FOR A ROTARY MACHINE

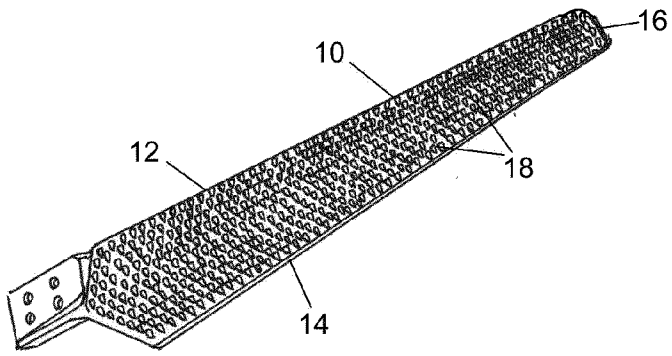

Fig. 1

(57) **Abstract**: A blade for use in rotary machines such as a wind turbine blade (10) has a plurality of dimples (18) distributed over an area of a low pressure or suction surface of the blade (10) which preferably extends from immediately adjacent to a leading edge (12) of the blade at least partially towards a rear or trailing edge (14) of the blade.

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A Blade For a Rotary Machine

Field of the invention

The present invention is concerned with a blade for a rotary machine, which in use undergoes driven or driving rotation, and is particularly but not exclusively concerned with such blades when used in air or gas driven applications such as a wind turbines, or air or gas driving or displacing applications such as fans, compressors, and blowers, and in particular blades having improved flow characteristics, for example reduced boundary layer separation, reduced turbulence, etc.

Background of the invention

Rotating blades are used in a large number of applications and in particular rotary machines as described above, and in many of those applications it is desirable to improve the efficiency and/or performance of the blade through various means. In one application aerofoil blades are utilised in augmented wind turbine systems, for example comprising a shroud surrounding a set of aerofoil blades such as to take advantage of the higher velocity profile. By improving the performance and/or efficiency of such blades a greater power output can be achieved and/or the turbines can be located in a more diverse range of locations. It will also be appreciated that the invention can be used in conventional wind turbine systems or other rotational blade applications or machines.

As a further example, blades of various size, shape and design are used in air displacers such as fans, compressors, blower based applications, for example HVAC applications, refrigeration applications, or any other applications requiring air or other fluid such as gas to be displaced. Such blades may have a full or partial aerofoil section, or may define a simple paddle/vane style blade design

It is therefore an object of the present invention to provide a blade or set of blades for a rotary machine having improved performance and/or efficiency.

Summary of the invention

According to the present invention there is provided a blade having a plurality of dimples distributed over an area of at least one surface of the blade which extends from at or adjacent a leading edge of the blade at least partially towards a rear edge of the blade.

Preferably, the blade comprises an aerofoil blade.

Preferably, the aerofoil comprises a low pressure or suction surface and an opposed high pressure or pressure surface, and the dimples are distributed over at least an area of the low pressure surface.

Preferably, the aerofoil is asymmetric.

Preferably, the leading edge is rounded and the trailing edge is sharp.

Preferably, the area of dimples extends along at least a major part of the length of the blade.

Preferably, the dimples are generally teardrop-shaped with a wider end facing towards the leading edge of the blade.

Preferably, the dimples vary in distribution density.

Preferably, the dimples vary in depth.

Preferably, the dimples vary in cross section with depth.

Preferably, the plurality of dimples comprises dimples of different size.

Preferably, the trailing edge of the blade has a localised rearward or downstream extension.

Preferably, the localised rearward extension is at a free end of the blade.

Preferably, the blade is a wind turbine blade.

Preferably, dimples are also provided on the pressure surface of the blade.

As used herein, the term “dimple” is intended to mean a localised depression in a surface, and which may vary in cross section with depth, and may be of any suitable shape and orientation.

Brief description of the drawings

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of an embodiment of aerofoil blade according to the invention, having particular application in a wind turbine;

Figure 2 is a schematic partial cross section through the blade of Figure 1;

Figure 3 is a partial top view of the blade of Figure 1; and

Figure 4 is a perspective view of a modification of the aerofoil blade of Figure 1.

Detailed description of the drawings

Referring to Figures 1 to 3, an aerofoil blade for use with a wind turbine is illustrated, and comprises an outwardly tapered blade 10 with a rounded leading edge 12, and a sharp or narrow trailing edge 14 and an outer free end or tip 16. It will however be appreciated that the size, shape and profile of the blade 10 may be varied as required, depending on the particular application with which the blade 10 is to be employed. A large number or array of dimples 18 are distributed over a lower pressure or "suction" surface 20 of the blade 10, and as will be described in detail hereinafter, are arranged to augment the flow of air around the blade 10 in order to improve the performance and/or efficiency of the blade 10.

In this particular embodiment the dimples 18 extend fully from the leading edge 12 of the blade to the trailing edge 14 and from the root to the tip of the blade 10, i.e. they cover substantially the entire suction surface 20. In general, however, the dimpled area of the upper or suction surface 12 may extend rearwardly from immediately adjacent to the leading edge 12 of the blade 10 only partially to the trailing edge 14, preferably at least one quarter the way to the trailing edge. In addition the dimples may not extend all the way to the root or the tip, and further alternatively the suction surface 12 may have one or more regions devoid of dimples.

Also, the dimpled area does not necessarily need to extend along the full length of the leading edge 12 of the blade 10, although it preferably extends along at least a major part of the length of the leading edge.

In this embodiment the dimples 18 are generally concave teardrop-shaped depressions aligned with their wider ends facing upstream towards the leading edge 12 of the blade, as shown in Figure 3, and the narrow or tapered ends facing downstream towards the trailing edge 14. The dimples 18 are preferably closely spaced, but their distribution density may vary over the dimpled area. The dimples may also vary in depth, and may vary in cross section with depth. It will also be appreciated that the dimples 18 may be of any other suitable shape or size in order to generate a desired augmentation

of the air flowing around the blade 10. In addition dimples 18 of different size, shape and/or depth may be used on the same blade 10.

The dimples 18 can be created directly in the upper or suction surface 20 of the blade, or by using blade protection tape 22 (Figure 2) or any other suitable carrier (not shown) which is embossed with the teardrop or other shaped dimples 18 and applied to the upper surface 20. This allows the array of dimples 18 to be quickly and easily retrofitted to an existing blade.

In the embodiment shown in Figures 1 to 3 the length of the blade 10 was 2.45m with an average chord of 300mm. The dimples are 15mm long by 9mm wide at their widest part, with a maximum depth of 0.33mm. These particular dimensions are suited to wind turbine blades, and may of course be varied to suit the intended application. For example in HVAC or refrigeration applications, the blade 10 may be employed with refrigeration fans, blowers and/or compressors (not shown) and will therefore be dimensioned accordingly, with the profile of the blade 10 being altered to suit the velocity profile of the gas being displaced.

The above turbine blade design serves to accelerate airflow, increase lift, reduce the wake created and/or increase the air displaced by the blade 10. The dimples 18 serve to create a micro-turbulent layer across the blade 10 which in turn causes the wind-force acting on the blade to be greater. The dimples delay boundary layer separation thereby reducing the wake of the blade 10. The dimples 18, when in an inverted teardrop shape, may also act as mini-augmenters and give the air direction. The depth, size, shape and distribution density of the dimples 18 may vary with blade characteristics or other system parameters.

In a modification of the above embodiment, Figure 4, the trailing edge 14 of the blade 10 has a localised rearward or downstream paddle-like extension 24, preferably at its free end or tip 16. The extended paddle-like tip 24 of the blade 10 serves to increase the surface area. However the dimples 18 can still work effectively on a conventional aerofoil blade which does not have the projection, i.e. as shown in Figure 1.

If desired, similar dimples may be provided on the “high pressure” surface of the blade (not shown), again extending rearwardly from the leading edge.

Claims

1. A blade having a plurality of dimples distributed over an area of at least one surface of the blade which extends from at or adjacent a leading edge of the blade at least partially towards a rear edge of the blade.

2. A blade according to claim 1 comprising an aerofoil blade.

3. A blade as claimed in claim 1 or 2 comprising a low pressure or suction surface and an opposed high pressure or pressure surface, and the dimples are distributed over at least an area of the low pressure surface.

4. A blade as claimed in claim 2 or 3 in which the aerofoil is asymmetric.

5. A blade as claimed in any preceding claim in which the leading edge is rounded and the trailing edge is sharp.

6. A blade as claimed in any preceding claim, wherein the area of dimples extends along at least a major part of the length of the blade.

7. A blade as claimed in any preceding claim, wherein the dimples are generally teardrop-shaped with a wider end facing towards the leading edge of the blade.

8. A blade as claimed in any preceding claim wherein the dimples vary in distribution density.

9. A blade as claimed in any preceding claim wherein the dimples vary in depth.

10. A blade as claimed in any preceding claim wherein the dimples vary in cross section with depth.

11. A blade as claimed in any preceding claim wherein the plurality of dimples comprises dimples of different size.

12. A blade as claimed in any preceding claim, wherein the trailing edge of the blade has a localised rearward or downstream extension.

13. A blade as claimed in claim 12, wherein the localised rearward extension is at a free end of the blade.

14. A blade as claimed in any preceding claim, wherein the blade is a rotary machine blade.

15. A blade as claimed in any preceding claim, wherein the blade is a wind turbine blade.

16. A blade as claimed in claim 3, wherein dimples are also provided on the pressure surface of the blade.

17. A wind turbine comprising at least one blade according to any of claims 1 to 16.

18. An air displacement system comprising at least one blade according to any of claims 1 to 16.

19. An air displacement system according to claim 18 comprising a fan comprising the at least one blade.

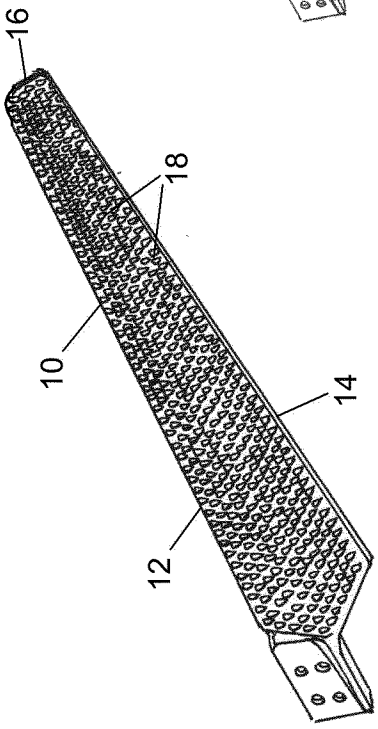

Fig. 1

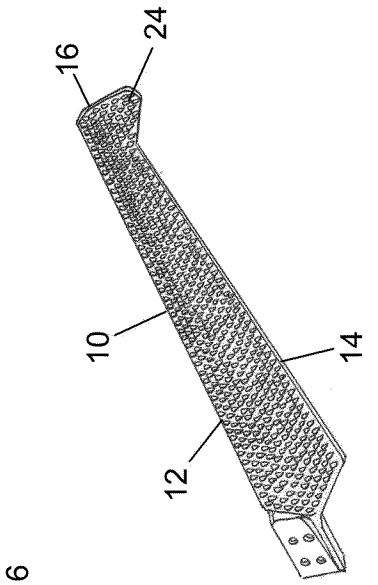

Fig. 4

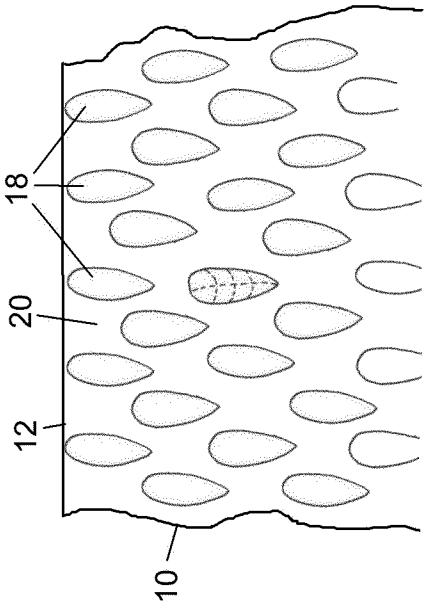

Fig. 3

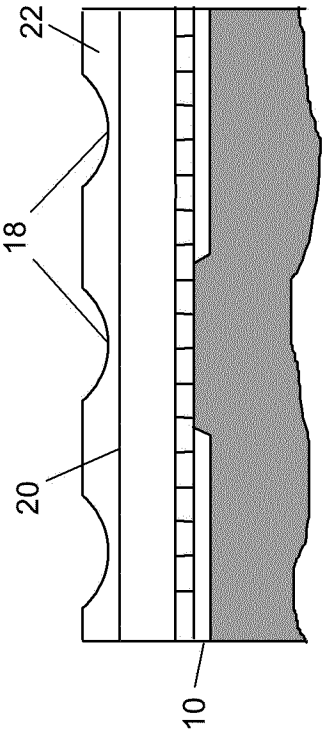

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/066495

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D1/06
ADD.

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

B. FIELDS SEARCHED

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

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2004/038217 A1 (SIEMENS AG [DE]; HERBST MANFRED [DE]) 6 May 2004 (2004-05-06) abstract page 4, line 4 - line 21 page 5, line 1 - line 9 page 6, line 5 - line 24 page 10, line 6 - line 22 figures 1,12 -----	1-17
X	EP 1 469 198 A1 (RADTKE EUGEN [DE]) 20 October 2004 (2004-10-20) paragraph [0006] - paragraph [0007] paragraph [0016] - paragraph [0018] paragraph [0021] paragraph [0023] paragraph [0027] paragraph [0039] - paragraph [0043] figures 1-5 -----	1-17

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 October 2013	07/11/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/066495

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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