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Hotto

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(54) **ROTATABLE BLADE APPARATUS WITH INDIVIDUALLY ADJUSTABLE BLADES**

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**

F03D 11/00 (2006.01)
F01D 5/30 (2006.01)
F03D 1/06 (2006.01)
F03D 7/00 (2006.01)
F03D 7/02 (2006.01)

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CPC ***F01D 5/30*** (2013.01); ***F03D 1/0608*** (2013.01); ***F03D 7/00*** (2013.01); ***F03D 7/024*** (2013.01); ***F03D 7/0224*** (2013.01); ***F03D 7/0236*** (2013.01); *F05B 2240/202* (2013.01); *F05B 2240/2021* (2013.01); *F05B 2240/31* (2013.01); *F05B 2240/312* (2013.01); *F05B 2240/313* (2013.01); *Y02E 10/721* (2013.01); *Y02E 10/723* (2013.01)

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CPC ... F03D 1/0675; F03D 7/0224; F03D 7/0236; F03D 7/024; F03D 7/041; F05B 2240/202; F05B 2240/2021; F05B 2240/2023; F05B 2240/31; F05B 2240/312; F05B 2240/3121; F05B 2240/313

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,540,583 A *	6/1925	Williams	.... F03D 3/068	416/113
2,704,128 A *	3/1955	Papadakos	.... B64C 13/30	244/17.21

(Continued)

FOREIGN PATENT DOCUMENTS

EP	0995904	10/1999
WO	2005005824	1/2005

OTHER PUBLICATIONS

E A Bossanyi, Garrad Hassan & Partners Ltd., "Further Load Reductions with Individual Pitch Control", Wind Energy vol. 8, issue 4, pp. 481-485, published online Jul. 7, 2005.

(Continued)

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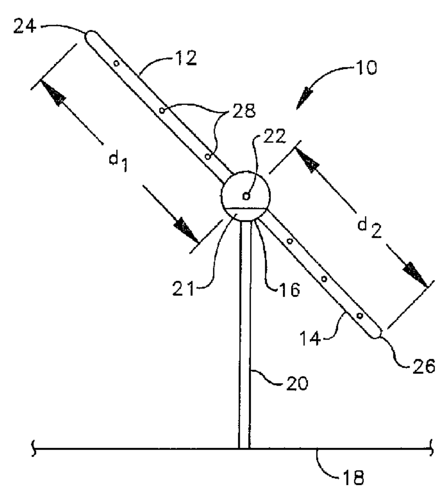
(57) **ABSTRACT**

The lengths and/or chords and/or pitches of wind turbine or propeller blades are individually established, so that a first blade can have a length/chord/pitch that is different at a given time to the length/chord/pitch of a second blade to optimize performance and/or to equalize stresses on the system.

18 Claims, 8 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

3,249,160 A 5/1966 Willy Messerschmitt
3,934,533 A * 1/1976 Wainwright B63H 9/0607 114/102.16
3,996,877 A 12/1976 Schneekluth
4,007,407 A 2/1977 Kranert
4,057,960 A 11/1977 Werner
4,109,477 A 8/1978 Vogel
4,138,901 A 2/1979 Fortin et al.
4,141,309 A 2/1979 Halboth
4,202,762 A 5/1980 Fontein et al.
4,260,329 A 4/1981 Bjorknas
4,285,637 A 8/1981 Thompson
4,293,280 A 10/1981 Yim
4,311,472 A 1/1982 Hiersig et al.
4,365,937 A 12/1982 Hiebert et al.
4,371,350 A 2/1983 Kruppa
4,387,866 A 6/1983 Eickmann
4,427,341 A 1/1984 Eichler
4,463,555 A 8/1984 Wilcoxson
4,490,093 A 12/1984 Chertok et al.
4,503,673 A 3/1985 Schachle et al.
4,504,029 A 3/1985 Eickmann
4,540,341 A 9/1985 Wuhren
4,563,581 A 1/1986 Perten
4,563,940 A 1/1986 Wuhrer
4,565,531 A 1/1986 Kimon
4,611,774 A 9/1986 Brand
4,618,313 A 10/1986 Mosiewicz
4,626,170 A 12/1986 Dorsch
4,627,791 A 12/1986 Marshall
4,632,637 A 12/1986 Traudt
4,648,788 A 3/1987 Jochum
4,648,847 A 3/1987 Mueller
4,687,162 A 8/1987 Johnson et al.
4,743,335 A 5/1988 Krappitz et al.
4,770,371 A 9/1988 Eickmann
4,784,351 A 11/1988 Eickmann
4,792,279 A 12/1988 Bergeron
4,801,243 A 1/1989 Norton
4,856,732 A 8/1989 Eickmann
4,880,402 A 11/1989 Muller
4,891,025 A 1/1990 Brandt
4,893,989 A 1/1990 Carvalho
4,899,641 A * 2/1990 Khan B64C 27/54 416/114
4,900,226 A 2/1990 De Vries
4,919,630 A 4/1990 Erdberg
4,925,131 A 5/1990 Eickmann
4,929,201 A 5/1990 Pitt
4,964,822 A 10/1990 Mueller
4,973,225 A 11/1990 Kruppa
4,982,914 A 1/1991 Eickmann
4,988,303 A 1/1991 Thomas
4,993,919 A 2/1991 Schneider
5,017,089 A 5/1991 Schneider et al.
5,028,210 A * 7/1991 Peterson B63H 1/10 416/164
5,286,166 A 2/1994 Steward
5,449,129 A 9/1995 Carlile et al.
5,466,177 A 11/1995 Alhara et al.
5,479,869 A 1/1996 Coudon et al.
5,531,407 A 7/1996 Austin et al.
5,554,003 A 9/1996 Hall
5,557,362 A 9/1996 Ueda
5,562,413 A 10/1996 Alhara et al.
5,733,156 A 3/1998 Alhara et al.
5,791,954 A 8/1998 Johnson, Jr.
5,836,743 A 11/1998 Carvalho et al.
5,841,652 A 11/1998 Sanchez
5,859,517 A 1/1999 DePasqua
5,927,656 A 7/1999 Hinkleman
5,997,253 A 12/1999 Feehan
5,997,991 A 12/1999 Kato et al.
6,015,117 A 1/2000 Broadbent
6,019,649 A 2/2000 Freisen et al.
6,032,899 A 3/2000 Mondet et al.
6,045,096 A 4/2000 Rinn et al.
6,123,297 A 9/2000 Berry
6,196,801 B1 3/2001 Muhlbauer
6,231,005 B1 5/2001 Costes
6,260,793 B1 7/2001 Balayn et al.
6,312,223 B1 11/2001 Samuelsson
6,358,007 B1 3/2002 Castle
6,374,519 B1 4/2002 Beaumont
6,379,115 B1 * 4/2002 Hirai F03D 3/068 416/111
6,413,133 B1 7/2002 McCarthy
6,431,499 B1 8/2002 La Roche
6,441,507 B1 * 8/2002 Deering F03D 7/0208 290/44
6,443,286 B1 9/2002 Bratel et al.
6,443,701 B1 9/2002 Muhlbauer
6,454,619 B1 9/2002 Funami
6,637,202 B2 10/2003 Koch
6,665,631 B2 12/2003 Steinbrecher
6,666,312 B2 12/2003 Matranga et al.
6,666,649 B2 12/2003 Arnold
6,682,378 B1 1/2004 Day
6,688,924 B2 2/2004 Marsland et al.
6,752,595 B2 6/2004 Murakami
6,855,016 B1 2/2005 Jansen
6,875,337 B1 4/2005 Schroder et al.
6,902,370 B2 6/2005 Dawson et al.
6,902,451 B1 6/2005 Theisen
6,938,418 B2 9/2005 Koch et al.
6,940,185 B2 * 9/2005 Andersen F03D 1/0608 290/44
6,957,991 B2 10/2005 Gibbs
6,972,498 B2 12/2005 Jamieson et al.
7,021,978 B2 4/2006 Jansen
7,030,341 B2 4/2006 Maurer
7,256,509 B2 8/2007 Brandt et al.
7,393,180 B2 * 7/2008 Von Mutius .... F03D 7/0224 416/132 B
7,452,185 B2 11/2008 Ide et al.
7,513,742 B2 4/2009 Rogall et al.
7,530,785 B1 5/2009 Deering et al.
7,891,946 B2 2/2011 Mollhagen
7,942,634 B2 5/2011 Christensen
8,608,441 B2 * 12/2013 Hotto F03D 1/0608 416/42
2002/0150473 A1 10/2002 Castle
2003/0153215 A1 8/2003 Gibbs
2003/0230898 A1 12/2003 Jamieson et al.
2004/0185725 A1 9/2004 Wilkie
2004/0201220 A1 10/2004 Anderson et al.
2005/0204930 A1 9/2005 Maurer
2005/0214126 A1 9/2005 Lobrovich
2005/0287885 A1 12/2005 Mizuguchi et al.
2006/0079140 A1 4/2006 Muller
2011/0229300 A1 9/2011 Kanev et al.

OTHER PUBLICATIONS

Alan D. Wright, "National Renewable Energy Laboratory, Technical Report: Modern Control Design for Flexible Wind Turbines" NREL/TP-500-35816, Jul. 2004.

David Lawrence Lemieux, "Rotor Blade Fatigue Reduction on Wind Turbines Using Pitch Control, a Thesis submitted to the Department of General Engineering Montana Tech of the University of Montana for the degree of Master of Science in General Engineering", May 2001.

P. Caselitz, W. Kleingauf, T. Kruger, J. Petschenka, M. Reichardt, K Storzel, "Reduction of Fatigue Loads on Wind Energy Converts by Advanced Control Methods", European Wind Energy Conference, Oct. 1997.

J.L. Tangler, D.M. Somers, "NREL Airfoil Families for HAWTs", updated AWEA, Jan. 1995.

(56) **References Cited**

OTHER PUBLICATIONS

Torbjorn Thiringer, Andreas Petersson, "Control of a Variable-Speed Pitch-Regulated Wind Turbine", Division of Electric Power Engineering Department of Energy and Environment Chalmers University of Technology, 2005.

E.A. Bossanyi, "Individual Blade Pitch Control for Load Reduction", Wind Energy, 6:119-128; 2003 (published online Oct. 8, 2002).

Morten H. Hansen, Anca Hansen, Torben J. Larsen, "Riso-Report: Control Design for a Pitch-Regulated, Variable Speed Wind Turbine", Riso National Labortory, Denmark, Jan. 2005.

Ryan T. Cowgill, Jake Fouts, Byron Haley, Chris Whitham, "Wind Turbine Roto Design Final Design Report", Boise State University College of Engineering, 2006.

Torben Juul Larsen, Helge A. Madsen, Kenneth Thomsen, "Active Load Reduction Using Individual Pitch, Based on Local Blade Flow Measurements", Wind Energy, 8:67-80, 2005 (Accepted Sep. 13, 2004).

Voith Schneider® Propeller Designer Manual, Jul. 2005 3500 MSW/WA Printed in Germany, pp. 1-12.

* cited by examiner

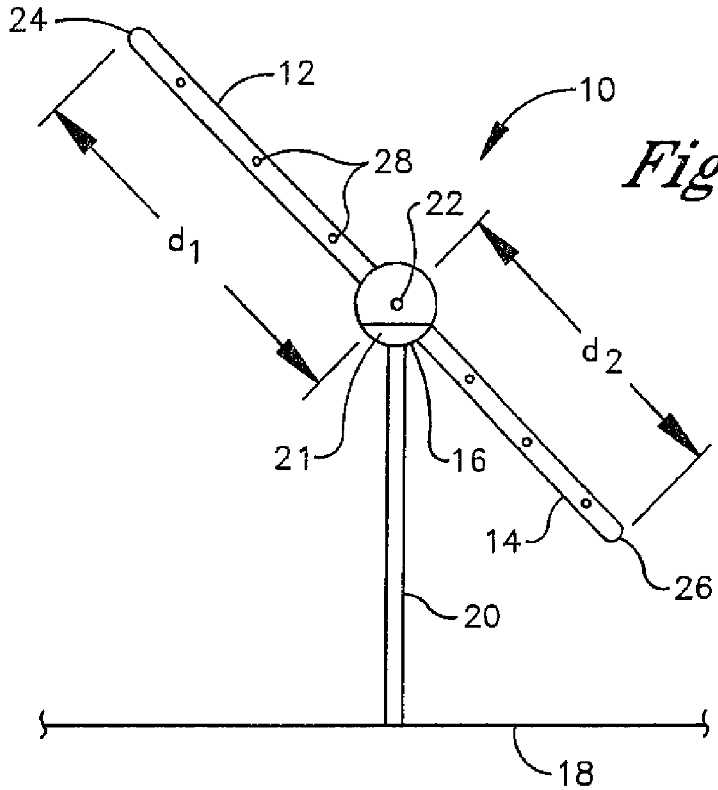


Fig. 1

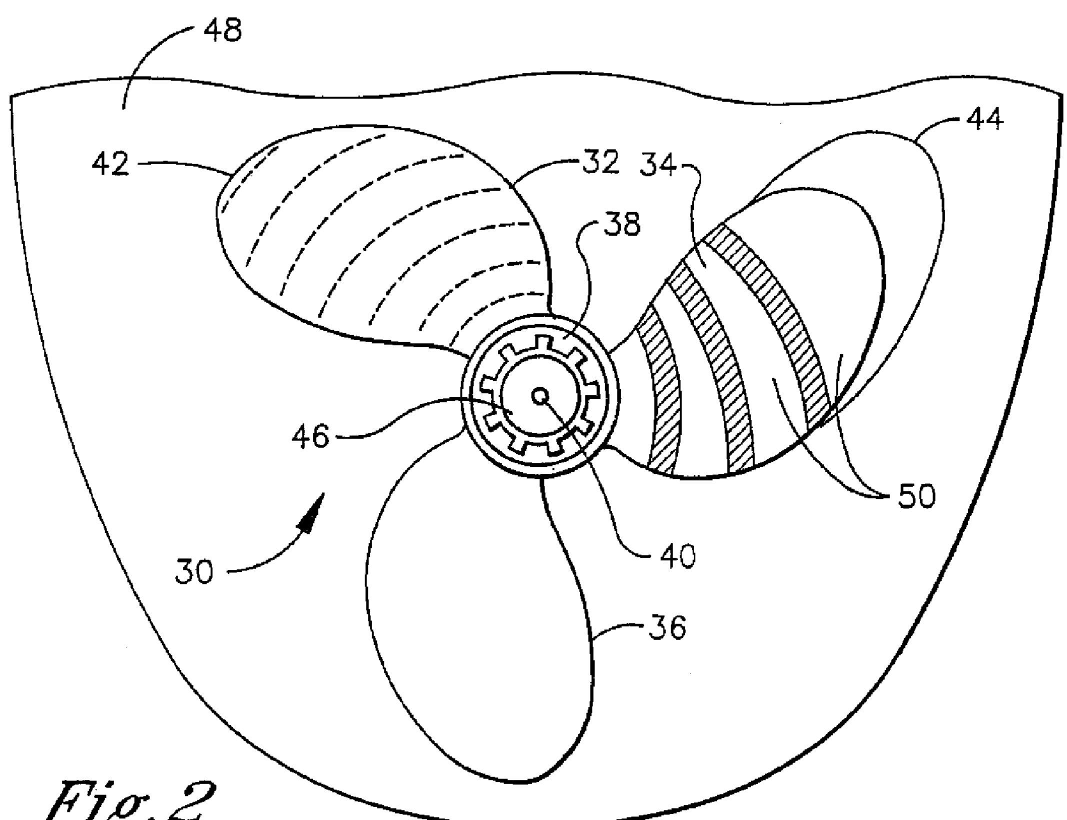


Fig. 2

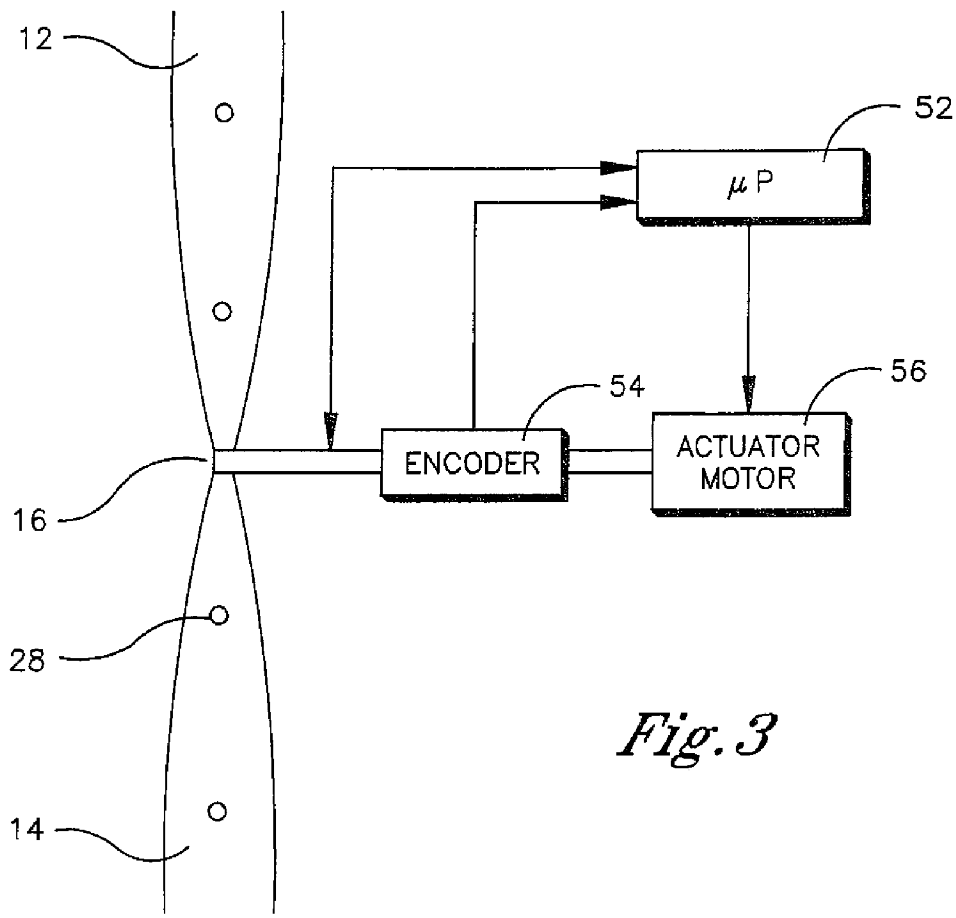


Fig. 3

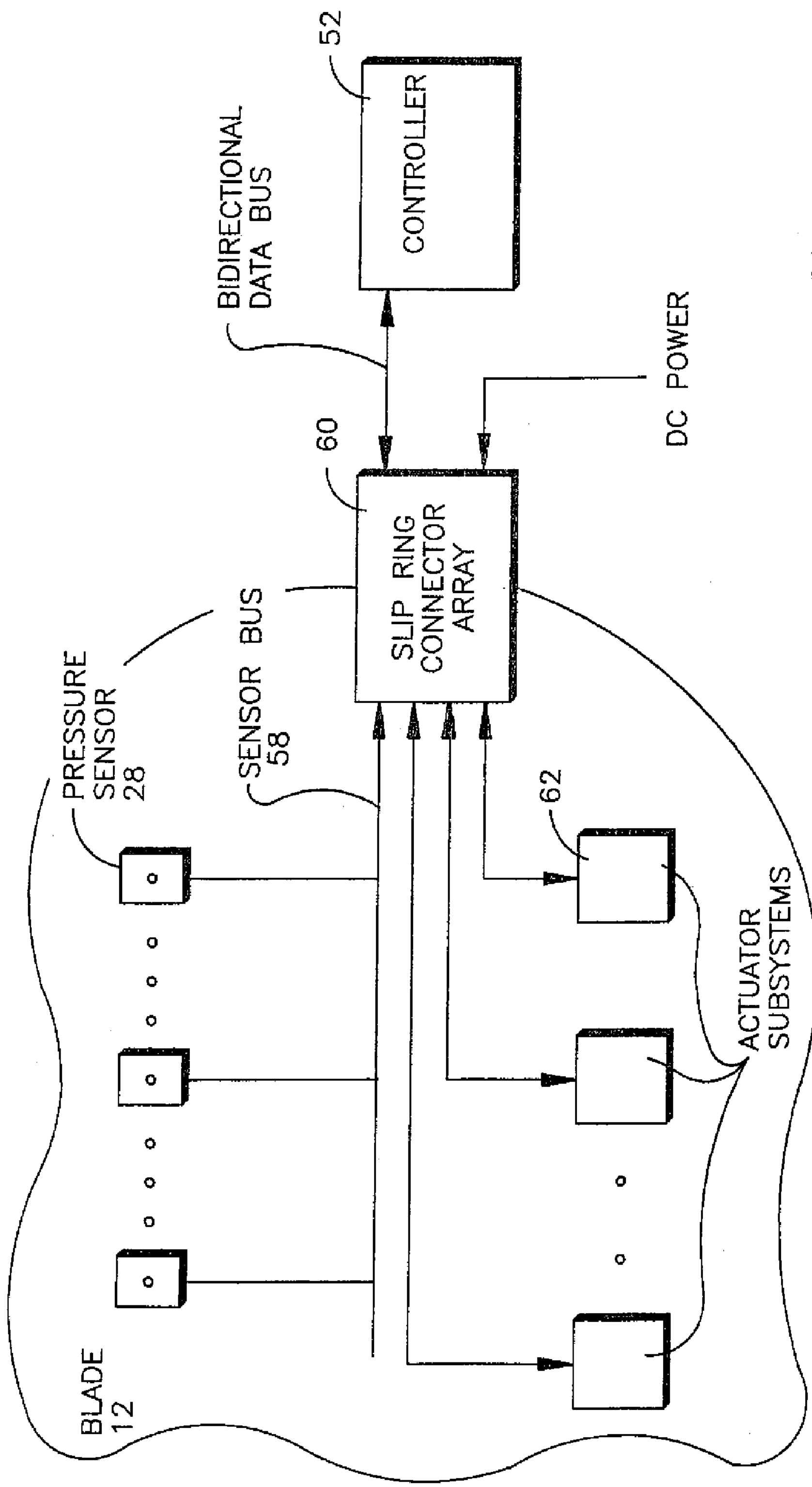
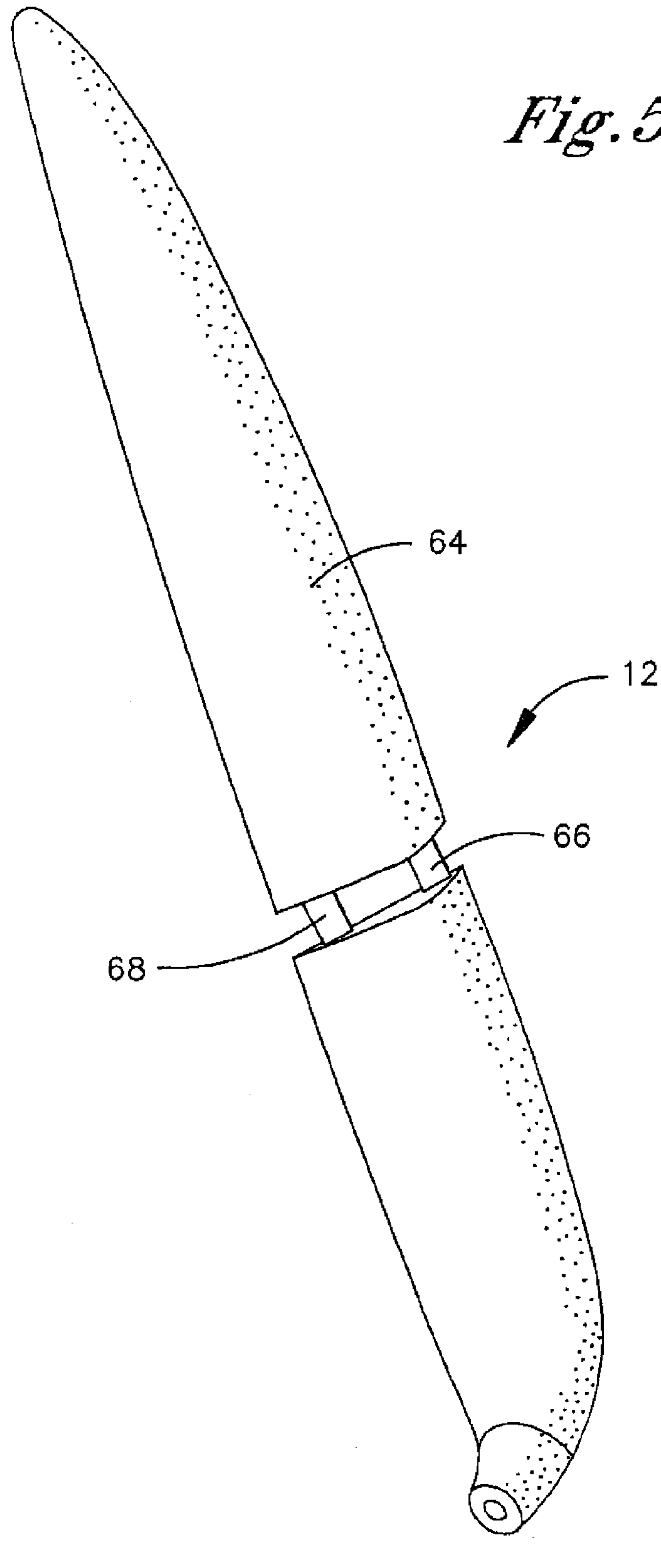

CONTROLLER
52
BIDIRECTIONAL DATA BUS
DC POWER
60
SLIP RING CONNECTOR ARRAY
SENSOR BUS
PRESSURE SENSOR 28
SENSOR 58
62
ACTUATOR SUBSYSTEMS
BLADE 12

Fig. 4

Fig. 5



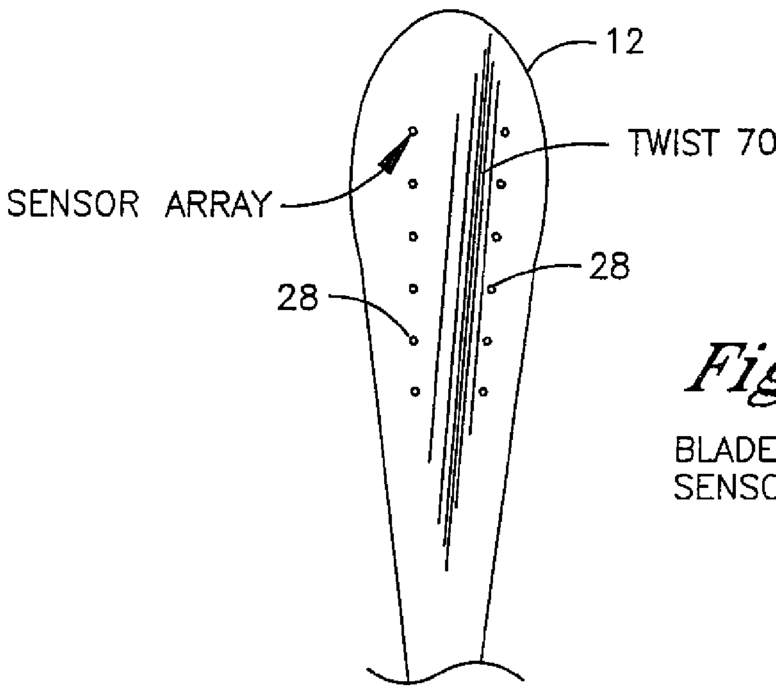


Fig. 6

BLADE WITH SENSOR ARRAY

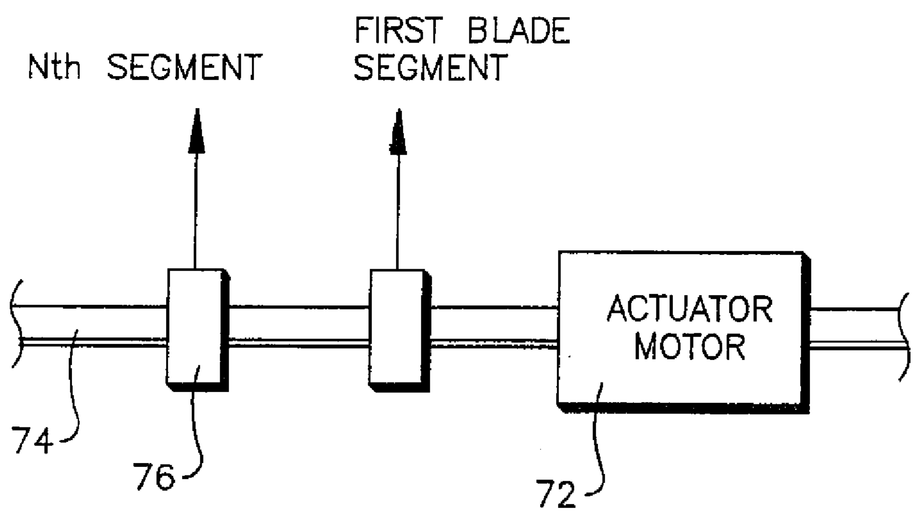


Fig. 7

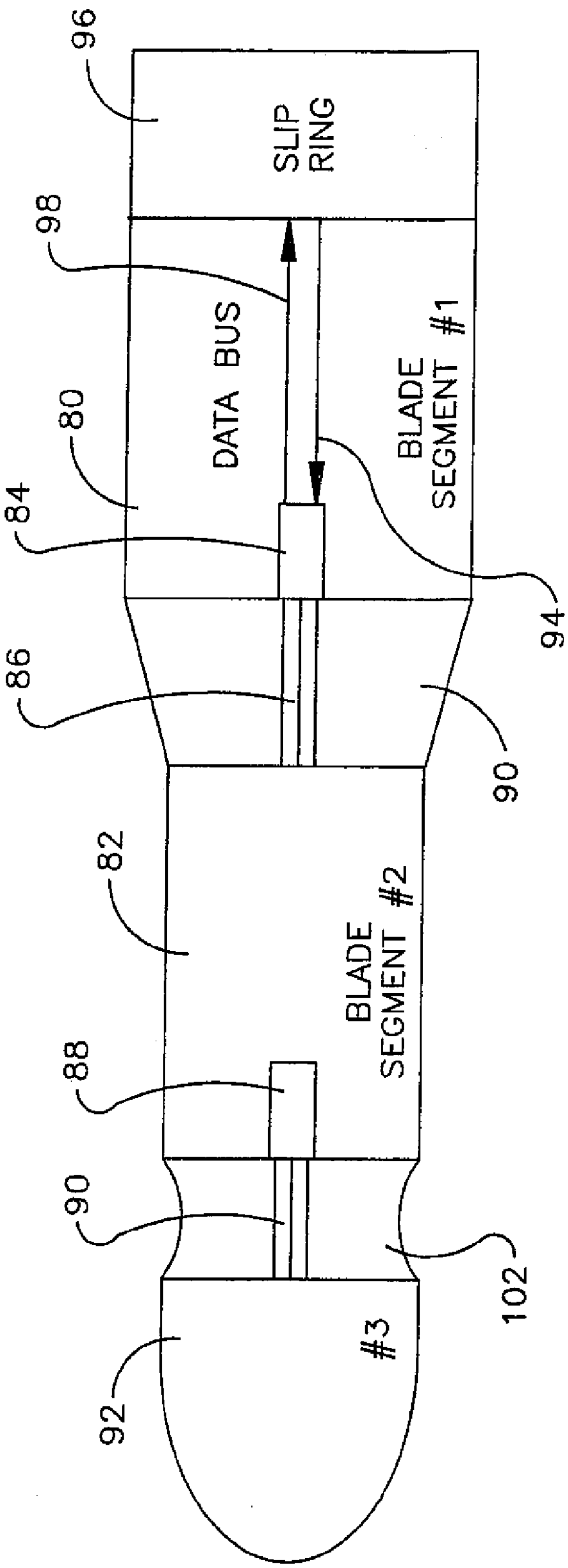

96
SLIP RING
98
DATA BUS
BLADE SEGMENT #1
80
84
94
86
90
82
BLADE SEGMENT #2
88
90
102
#3
92

Fig. 8

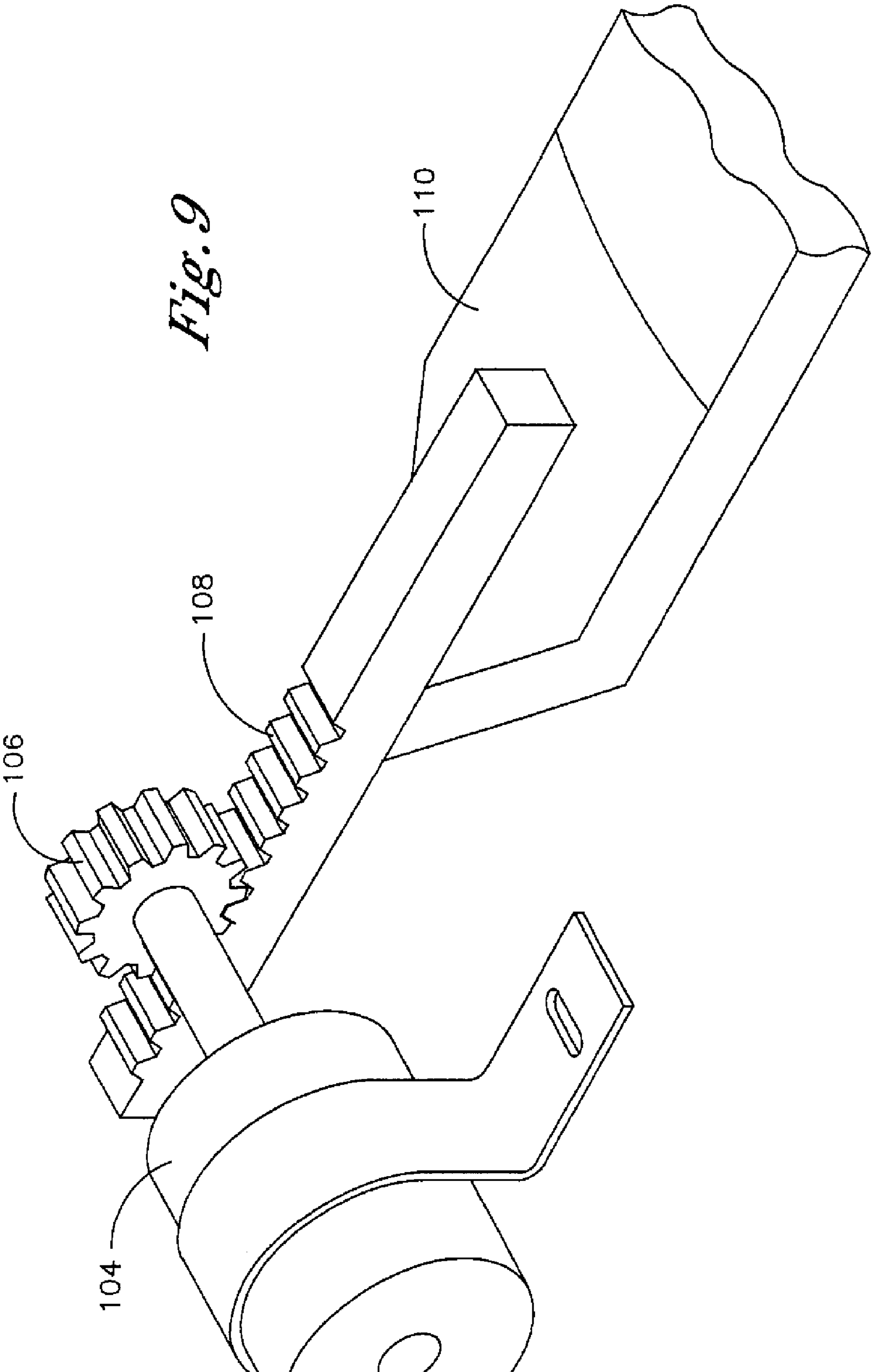


Fig. 9

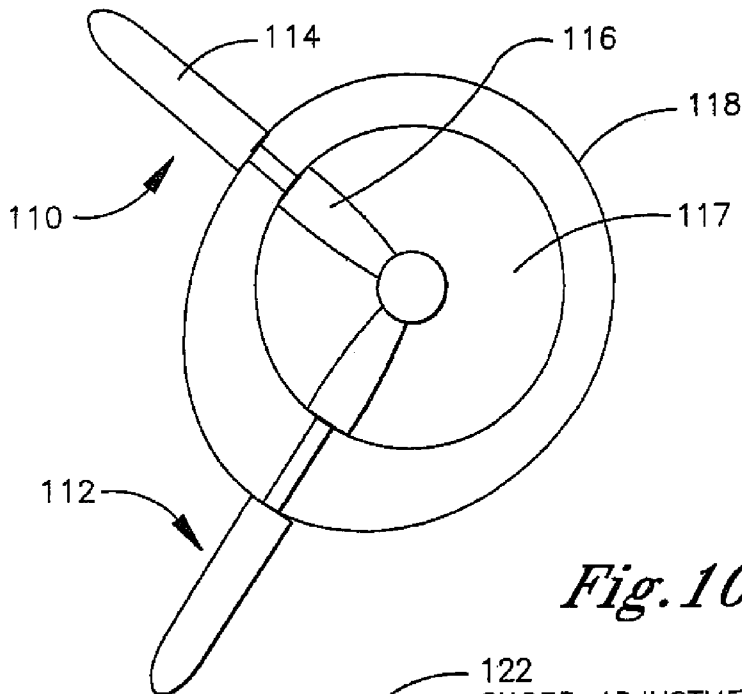


Fig. 10

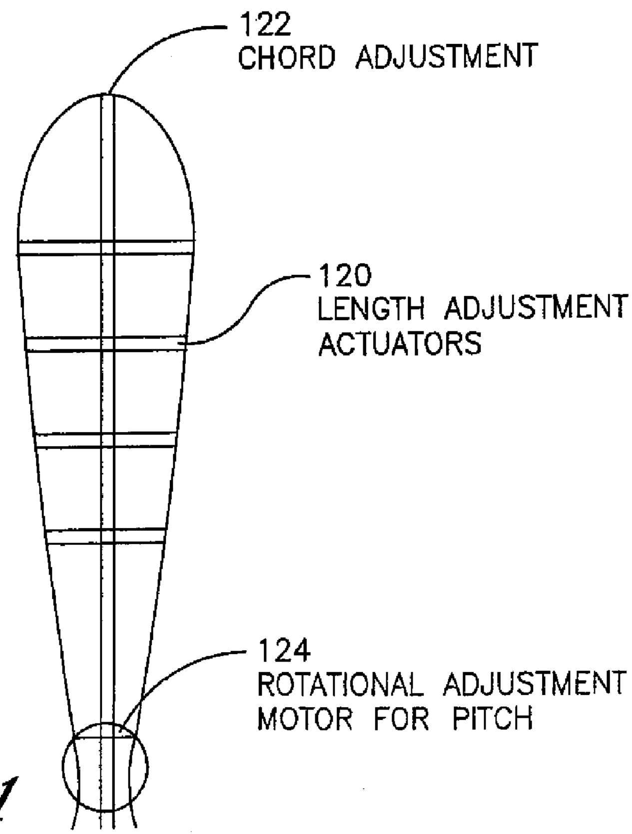


Fig. 11

BLADE ILLUSTRATING ROTATIONAL, LENGTH AND CHORD ADJUSTMENT POINTS

ROTATABLE BLADE APPARATUS WITH INDIVIDUALLY ADJUSTABLE BLADES

FIELD OF THE INVENTION

The present invention relates generally to rotatable blades for wind turbines, and more particularly to blade assemblies for wind turbines and propellers in which the parameters of chord, length, and pitch can be individually adjusted for each blade.

BACKGROUND OF THE INVENTION

Variable pitch propellers have been provided in which the pitch of all blades can be simultaneously changed as appropriate to, e.g., reduce cavitation depending on the speed of rotation of the blades. An example of such a system is disclosed in U.S. Pat. No. 5,733,156, incorporated herein by reference.

In the wind turbine art, U.S. Pat. No. 6,972,498, incorporated herein by reference, provides a wind turbine blade assembly in which the lengths of the blades may be simultaneously changed to account for changing wind speed, imbalances, and control system loads. As understood herein, it would be desirable, for each blade individually, to establish the length and/or chord and/or pitch of the blade.

SUMMARY OF THE INVENTION

A wind turbine blade assembly or a propeller blade assembly has at least first and second blades coupled to a rotor defining an axis of rotation. The tip of the first blade is positioned a first distance from the axis of rotation at a first time, while the tip of the second blade is positioned a second distance from the axis of rotation at the first time, with the first and second distances not being equal.

In some implementations, at least one blade has respective plural parts telescoping relative to each other along the length of the blade. Each blade defines a respective length, and the lengths are different from each other at least at the first time. An actuator can telescope one part of a blade relative to another part of the blade. In some aspects plural actuators can be provided to telescope plural parts. The actuator may be supported on the blade and may receive power through a slip ring. Or, the blades can move longitudinally as they ride against a cam surface. The lengths of the blades may be established based on respective pressure signals representative of fluid pressure on the blades, and/or based on respective angular positions of the blades.

In another aspect, a wind turbine blade assembly or a propeller blade assembly has at least first and second blades coupled to a rotor defining an axis of rotation. The first blade defines a first chord at a first time, the second blade defines a second chord at the first time, and the first and second chords are not equal.

In still another aspect, a wind turbine blade assembly or a propeller blade assembly has at least first and second blades coupled to a rotor defining an axis of rotation. The first blade defines a first pitch at a first time, the second blade defines a second pitch at the first time, and the first and second pitches are not equal.

In another aspect, a method for operating a wind turbine includes establishing a first value for a first parameter of a first blade at a first time, and establishing a second value for the first parameter of a second blade at the first time. According to this aspect, when the blades are disposed in wind, they rotate to cause the wind turbine to produce electrical power.

In another aspect, a wind turbine has an upright support, a rotor coupled to the support, and at least first and second blades coupled to the rotor to cause it to rotate when wind passes the blades. Each blade has first and second configurations. The first configuration of the first blade is identical to the first configuration of the second blade and the second configuration of the first blade is identical to the second configuration of the second blade. As set forth further below, the first blade assumes the first configuration at a first time and the second blade assumes the second configuration at the first time.

The details of the present invention, both as to its structure and operation, can best be understood in reference to the accompanying drawings, in which like reference numerals refer to like parts, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a wind turbine in accordance with present principles;

FIG. **2** is a schematic view of a vessel propeller in accordance with present principles;

FIG. **3** is a block diagram showing control elements in accordance with one embodiment;

FIG. **4** is a block diagram showing control elements in accordance with another embodiment;

FIG. **5** is a perspective view of a blade in the extended configuration;

FIG. **6** is a plan view of a blade, showing one preferred non-limiting pressure sensor disposition on the blade;

FIG. **7** is a block diagram of one actuator embodiment, in which a single motor moves plural blade segments;

FIG. **8** is a block diagram of one actuator embodiment, in which respective motors move respective blade segments;

FIG. **9** is a perspective view of a non-limiting actuator;

FIG. **10** is an elevational view of an alternative cam-based system; and

FIG. **11** is a plan view showing that the present principles, in addition to being applied to change the length of a blade, may also be applied in changing the chord and/or pitch of the blade.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring initially to FIG. **1**, a wind turbine blade assembly is shown, generally designated **10**, which includes first and second blades **12**, **14** that are coupled to a rotor **16**, it being understood that present principles apply to two, three, or more blades. The rotor **16** is rotatably supported above the surface **18** of the earth by an upright support **20**, which holds the blades **12**, **14** in a vertical plane above the earth's surface as shown. In accordance with principles known in the art, wind flowing past the blades causes them to turn to thereby cause an associated generator, shown schematically at **21**, to generate electric power.

The rotor **16** defines an axis **22** of rotation, and in accordance with disclosure below at least the first blade **12** and preferably both blades **12**, **14** can be moved between a long configuration and a short configuration, as well as to intermediate configurations therebetween, and the blade **12** is not constrained to be in the same configuration as the second blade **14**. Thus, to illustrate, FIG. **1** shows that the blade **12** has a blade tip **24** that can be configured to be a relatively long distance d_1 from the axis **22** of rotation. Simultaneously, the tip **26** of the second blade **14** can be configured to be a second distance d_2 from the axis **22** of rotation, with the distances d_1,

d_2 being unequal when present principles are applied. For purposes that will shortly become clear, one or more pressure sensors **28** can be disposed on one or both blades **12**, **14**. Alternatively, wind speed sensors on the blades **12**, **14** or elsewhere can be used.

As set forth further below, the principles outlined herein in terms of variable length also apply to variable pitches and chords, so that in addition to or in lieu of different lengths, the pitches and/or chords of the respective blades **12**, **14** may be different from each other at the same point in time. It is to be further understood that the assembly **10** may also, at other times, embody conventional operating principles wherein the blades **12**, **14** are identically configured in length, chord, and pitch.

FIG. **2** shows that the present principles can also be applied to a propeller blade assembly **30** that has at least first and second blades **32**, **34**, and potentially additional blades **36**, coupled to a rotatable rotor **38** that defines an axis **40** of rotation. The tip **42** of the first blade **32** can be configured to be a first distance from the axis **40** of rotation and simultaneously the tip **44** of the second blade **34** can be configured to be a further distance from the axis **40** of rotation than is the tip **42** of the first blade **32**. A shaft **46** of a waterborne vessel **48** can hold the blades **32**, **34**, **36** in a vertical plane (at neutral vessel pitch) as shown.

As set forth further below, the principles outlined herein in terms of variable length also apply to variable pitches and chords, so that in addition to or in lieu of different lengths, the pitches and/or chords of the respective blades **32**, **34**, **36** may be different from each other at the same point in time. It is to be further understood that the assembly **30** may also, at other times, embody conventional operating principles wherein the blades are identically configured in length, chord, and pitch.

For illustration purposes the disclosure below focuses on a wind turbine application, it being understood that the principles embodied therein may be applied to the propeller assembly **30**, in which, e.g., the blade **34** has plural portions **50** that can telescope or otherwise move in the axial dimension of the blade **34** relative to each other (and, as stated above, potentially can also move relative to each other in the chord dimension).

FIGS. **3** and **4** show various system configurations for controlling the lengths (and/or chords and/or pitches) of the blade **12**, and preferably also of the blade **14**. A controller or processor **52** can receive input from the pressure sensors **28** on the blades and/or from an encoder **54** that outputs a signal representing the angular position of the rotor **16**. The controller or processor **52** controls an actuator with motor **56** to establish the length (and/or chord and/or pitch) of the blades. The motor may be a stepper motor or other appropriate motor, and as set forth further below may be located within the blade **12** or outside the blade **12**. From time to time herein, "actuator" may be used to refer to both a motor and the linkages that couple the motor to the movable blade portions, and to just the linkages themselves.

In some implementations, the length of each blade **12**, **14** is established based on its angular position. Thus, in non-limiting embodiments a blade can assume the long configuration when at the top dead center position (pointing straight up vertically from the rotor) and the short configuration in the opposite position, and can have intermediate lengths when moving therebetween. In terms of the two blade application of FIG. **1**, the first blade **12** is in the long configuration at the same time the second blade **14** is in the short configuration.

In addition to or in lieu of using angular position to establish the lengths of the blades, the lengths of the blades can depend on respective pressure signals from the sensors **28**, which are representative of fluid pressure on the blades. In this embodiment, the controller or processor **52** establishes blade length both to optimize performance while minimizing load imbalances on the rotor by, e.g., establishing blade lengths that result in equal pressures on both blades **12**, **14** while providing optimum length based on wind speed, to ensure that the blades rotate as fast as feasible while remaining below angular velocity limits.

FIG. **4** shows further details of the controls of one illustrative non-limiting embodiment. As shown, the pressure sensors **28** on the blade **12** are electrically connected to a sensor bus **58** within the blade. The bus **58** is connected to the controller or processor **52** through a slip ring connector array **60**, which, in accordance with slip ring principles known in the art, permits relative rotational movement between the blade **12** and the controller **52** while maintaining electrical connectivity between them. A bidirectional data bus **59** can be provided between the slip ring connector array **60** and the controller **52** to permit the controller **52** to receive pressure signals and to output control signals to the actuators discussed below.

More particularly, electrical power, as well as control signals from the controller **52**, is also provided through the slip ring to one or more actuator subsystems **62**, each of which can include a respective motor and a respective linkage that connects the actuator to a respective blade portion to move the blade portion. Alternatively, a single motor may be provided within the blade **12** and linked through gears or other linkages as set forth further below to move each of plural individual actuator subsystems that, in such a circumstance, would include only linkages to respective blade portions.

FIGS. **5-8** show further details of non-limiting implementations of the present blade. As shown in FIG. **5** and using the first blade **12** as an example, the blade can have plural portions **64** that move relative to each other in the length dimension of the blade, it being understood that similar principles apply to expand and contract the blade in the chord dimension. As shown at **66**, an actuator linkage can be coupled to two adjacent substantially rigid hollow blade portions **64** to move the blade portions relative to each other. In the embodiment shown in FIG. **5**, the blade portions abut each other along their transverse edges in the short configuration, with facing transverse edges of adjacent blade portions being distanced from each other in the long configuration and, if desired, a flexible membrane **68** (portions of which are removed in FIG. **5** to show the linkage **66**) can enclose the space between the portions.

FIG. **6** shows that the pressure sensors **28** can be arranged in two lines along the length of the blade **12**, with one line of sensors being disposed on a first side of the "twist" **70**, or blade surface aspect change line, and with a second line of sensors being disposed on the opposite side of the twist as shown.

FIG. **7** shows that in some implementations, a single motor **72** can be provided in the blade **12** to turn a lead screw **74** or equivalent structure, with plural nuts **76** or equivalent linking structure riding on the lead screw **74** and connected to respective blade portions to move the blade portions.

In contrast, FIG. **8** shows that each of plural movable blade portions **80**, **82** can house its own respective motor and linkage that connects the blade portion to the distally successive blade portion. Thus, the blade portion **80** has a motor **84** with linkage **86** that extends between the blade portions **80**, **82** to move the medial blade portion **82** outward from the proximal blade portion **80**. Likewise, the medial blade portion **82** supports a motor **88** with associated linkage **90** extending to a distal blade portion **92**, to move the distal blade portion **92** outward from the medial blade portion **82**. Additional blade portions with motors and linkages may be provided. As mentioned earlier, power can be supplied to the motors through a power line **94** and slip ring assembly **96**, and data and control signals can be exchanged through the slip ring assembly **96** and data bus **98** within the blade **12**.

As also shown in FIG. **8**, instead of using a flexible membrane **68** (FIG. **5**) between adjacent blade portions, each adjacent blade portion can, in the short configuration, be partially nested within the immediately proximal portion. Accordingly, in the short configuration the sub-portion **100** (with parts broken away in FIG. **8** to expose the linkage **86**) of the medial blade portion **82** is nested within the proximal blade portion **80**, whereas in the long configuration shown the sub-portion **100** is telescoped distally beyond the proximal portion **80**. All portions of the blade in this embodiment can be substantially rigid. Similarly, a sub-portion **102** (part of which is removed in FIG. **8** to expose the linkage **90**) of the distal blade portion **92** is nested within the medial portion **82** in the short configuration and is telescoped distally beyond the medial portion **82** in the long configuration.

FIG. **9** shows an illustrative non-limiting example of one of the motor actuators shown in FIG. **8**. A motor **104** such as DC motor is affixed to one blade portion (not shown) to turn a pinion gear **106**, which translates rotational motion to longitudinal (with respect to the blade) translational movement of a rack **108**. The rack **108** is affixed to the successive blade portion **110**, to move it toward and away the blade portion that supports the motor **104**.

When the length of the blade is sought to be changed only based on angular position, FIG. **10** shows that instead of using motor actuators, each blade **110**, **112** of a wind turbine or propeller can have proximal and distal portions **114**, **116** that telescope relative to each other as the blade, which is attached to a rotor **117**, rotates past a cam **118** on which a part of the blade between the portions **114**, **116** ride. The contour of the surface of the cam is established to establish the desired length-to-angular position relationship. Other mechanisms, including gearing, can be employed.

Other mechanisms for moving a blade are disclosed in U.S. Pat. No. 6,972,498, modified as appropriate to permit the individual establishment of the length of each blade, independently of other blades, as described above.

FIG. **11** schematically illustrates that individual blade configuration may be independently established not just in the length dimension by length adjustment actuators **120** but alternatively or additionally in the chord dimension by chord adjustment actuators **122** and/or in the pitch dimension by a pitch adjustment actuator **124**, which rotates the blade about its hub using, as non-limiting examples, the mechanisms described in U.S. Pat. No. 5,733,156. In any case, it is to be appreciated that the length and/or chord and/or pitch of each blade of the present wind turbine or propeller can be established independently of the length and/or chord and/or pitch of one or more other blades as necessary to equalize fluid pressure on the blades, to optimize performance by, e.g., attaining an optimum speed of rotation, and in the case of propellers to lower the rudder profile as necessary to avoid cavitation or even to assist in turning the vessel.

While the particular ROTATABLE BLADE APPARATUS WITH INDIVIDUALLY ADJUSTABLE BLADES is herein shown and described in detail, it is to be understood that the subject matter which is encompassed by the present invention is limited only by the claims. For instance, the principles described herein could be applied to airplane propellers and to helicopter rotor blades.

What is claimed is:

1. A wind turbine blade assembly comprising:

at least first and second blades coupled to a rotor defining an axis of rotation, the first blade defining a first pitch at a first time, the second blade defining a second pitch at the first time, the first and second pitches not being equal and at least one of the pitches being established by a pressure signal from at least one pressure sensor.

2. The assembly of claim **1**, wherein the pitches are based on respective positions of the blades.

3. The assembly of claim **1**, comprising an actuator coupled to at least one blade to establish the pitch of the blade.

4. The assembly of claim **1**, wherein the at least one pressure sensor is disposed on at least one blade to provide the pressure signal.

5. The assembly of claim **1**, wherein the pitches of the blades are established at least in part in response to at least one pressure sensor.

6. The assembly of claim **1**, wherein the blades define respective chords and the chords are adjusted as the blades turn.

7. A wind turbine blade assembly comprising:

at least first and second blades coupled to a rotor, the first blade defining a first pitch at a first time, the second blade defining a second pitch at the first time, the first and second pitches not being equal and at least one pitch being established by a pressure signal from at least one pressure sensor.

8. The assembly of claim **7**, wherein the pitches are established at least in part in response to at least one signal from at least one sensor disposed on at least one airfoil surface of at least one of the blades.

9. The assembly of claim **7**, wherein the blades define respective chords and the chords are adjusted.

10. A turbine blade assembly comprising:

at least first and second blades coupled to a rotor defining an axis of rotation, the first blade defining a first pitch at a first time, the second blade defining a second pitch at the first time, the first and second pitches not being equal, wherein the pitches are established based on respective pressure signals from at least one pressure sensor on at least one of the blades.

11. The assembly of claim **10**, comprising an actuator coupled to at least one blade to establish the pitch of the at least one blade.

12. A propeller blade assembly comprising:

at least first and second blades coupled to a rotor defining an axis of rotation, the first blade defining a first pitch at a first time, the second blade defining a second pitch at the first time, the first and second pitches not being equal, the assembly being configured for being engaged with a waterborne vessel shaft for holding the blades in a vertical plane, at least one of the pitches being established according to at least one pressure signal from at least one pressure sensor.

13. The assembly of claim **12**, comprising an actuator coupled to at least one blade to establish the pitch of the blade.

14. The assembly of claim **12**, wherein the blades move as they ride against a cam surface.

15. The assembly of claim **12**, wherein the blades define respective chords and the chords are adjusted.

16. A propeller blade assembly comprising:

at least first and second blades coupled to a rotor defining an axis of rotation, the first blade defining a first pitch at a first time, the second blade defining a second pitch at the first time, the first and second pitches not being equal, wherein the pitches are established based on respective pressure signals from at least one of the blades.

17. The assembly of claim **16**, wherein the pitches are based on respective angular positions of the blades with respect to the rotor.

18. The assembly of claim **16**, wherein the blades define respective chords and the chords are adjusted.

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