US010385825B2

# (12) United States Patent
**Abu Al-Rubb**

(10) **Patent No.: US 10,385,825 B2**
(45) **Date of Patent: Aug. 20, 2019**

(54) **TURBINE BLADE WITH ADJUSTABLE TIPS**

(76) Inventor: **Khalil Abu Al-Rubb**, London (GB)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 622 days.

(21) Appl. No.: **14/235,077**

(22) PCT Filed: **Jul. 26, 2012**

(86) PCT No.: **PCT/GB2012/051812**
§ 371 (c)(1), (2), (4) Date: **Feb. 27, 2015**

(87) PCT Pub. No.: **WO2013/014463**
PCT Pub. Date: **Jan. 31, 2013**

(65) **Prior Publication Data**

US 2015/0167638 A1 Jun. 18, 2015

(30) **Foreign Application Priority Data**

Jul. 26, 2011 (GB) .................................. 1112844.4

(51) **Int. Cl.**

| | |
|---|---|
| ***F03B 3/12*** | (2006.01) |
| ***F03D 1/06*** | (2006.01) |
| ***F03D 7/02*** | (2006.01) |
| ***F03D 7/04*** | (2006.01) |

(52) **U.S. Cl.**
CPC .............. ***F03D 7/022*** (2013.01); ***F03B 3/121*** (2013.01); ***F03D 1/0675*** (2013.01); ***F03D 7/042*** (2013.01); *F05B 2210/16* (2013.01); *F05B 2240/30* (2013.01); *F05B 2240/31* (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ...... F03D 7/022; F03D 7/0228; F03D 1/0675; F03D 7/02; F03D 7/024; F03D 80/00; F03D 80/50; F05B 2240/31; F03B 3/121; F03B 3/123; Y02E 10/721
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,743,440 | A | 7/1973 | Moore |
| 3,957,232 | A | 5/1976 | Sebrell |
| 4,297,076 | A | 10/1981 | Donham et al. |

(Continued)

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| CN | 101158332 | 4/2008 |
| CN | 201666222 U | 12/2010 |

(Continued)

OTHER PUBLICATIONS

First Office Action from corresponding Chinese application CN 201280037128.4 Action dated Mar. 4, 2016.

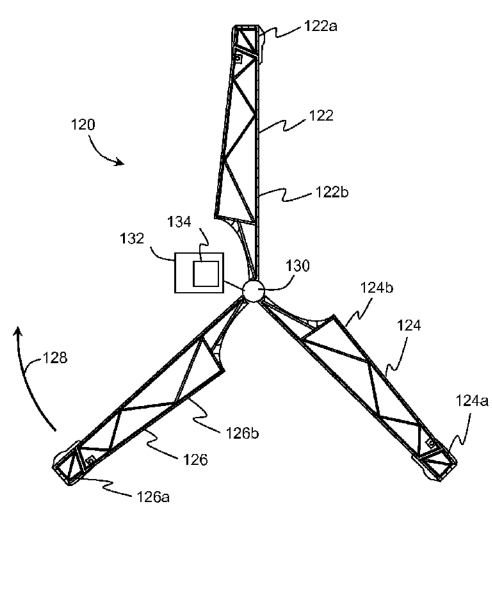
(Continued)

*Primary Examiner* — Richard A Edgar
*Assistant Examiner* — Elton K Wong
(74) *Attorney, Agent, or Firm* — John Bruckner

(57) **ABSTRACT**

Embodiments of the invention relate to blades for turbines, such as wind turbines, comprising a structural frame with a sail mounted thereon. In certain embodiments, a portion of the frame contributes to the buoyancy of the blade. In further embodiments, the frame comprises strengthening cords.
In further embodiments, the frame comprises a reinforced tip. In further embodiments, the blade has a tip arranged to articulate relative to a body portion to alter the aerodynamic profile of the blade as the blade rotates to thereby assist up-strokes of the blade.

**1 Claim, 2 Drawing Sheets**



(52) **U.S. Cl.**
CPC ....... *F05B 2270/326* (2013.01); *Y02E 10/223* (2013.01); *Y02E 10/721* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,355,955 | A | 10/1982 | Kisovec | |
| 5,448,828 | A | 9/1995 | Willems et al. | |
| 2003/0227174 | A1 | 12/2003 | Bayly | |
| 2006/0251516 | A1* | 11/2006 | Sohn | F03D 1/04 416/132 B |
| 2007/0235018 | A1* | 10/2007 | Hills | F24B 1/192 126/190 |
| 2008/0181775 | A1 | 7/2008 | Livingston et al. | |
| 2009/0104039 | A1 | 4/2009 | Vettese | |
| 2009/0148290 | A1 | 6/2009 | Garver | |
| 2010/0068058 | A1* | 3/2010 | Sorensen | F03D 1/0633 416/41 |
| 2010/0135806 | A1 | 6/2010 | Benito | |
| 2010/0158687 | A1* | 6/2010 | Dawson | F03D 7/0236 416/31 |
| 2010/0266412 | A1 | 10/2010 | Barber | |
| 2010/0329881 | A1 | 12/2010 | Mendez Hernandez et al. | |
| 2011/0142642 | A1* | 6/2011 | McGrath | F03D 1/065 416/135 |
| 2011/0215585 | A1* | 9/2011 | Caires | F03D 1/0675 290/55 |
| 2011/0255974 | A1* | 10/2011 | Nanukuttan | F03D 1/065 416/146 R |
| 2012/0242084 | A1* | 9/2012 | Agtuca | F03D 1/0675 290/44 |

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| DE | 3715265 | | 11/1988 |
| DE | 19826086 | | 12/1999 |
| EP | 1630415 | | 12/2008 |
| EP | 2157316 | | 2/2010 |
| GB | 2227286 | | 7/1990 |
| JP | 2000064941 | | 3/2000 |
| JP | 2005113735 | | 4/2005 |
| WO | 2005050007 | | 6/2005 |
| WO | 2006/133715 | | 12/2006 |
| WO | 2009150298 | | 12/2009 |
| WO | 2010000263 | A2 | 1/2010 |
| WO | 2010000263 | A3 | 1/2010 |
| WO | 2011080177 | A1 | 7/2011 |

OTHER PUBLICATIONS

English-language translation of First Office Action from corresponding Chinese application CN 201280037128.4.
Search Report from GB1112844.4 dated Nov. 28, 2011.
Search Report from GB1112844.4 relating to claims 13-16, 28 & 40-42 dated Jun. 15, 2012.
International Search Report and Written Opinion from PCT/GB2012/051812 dated Jul. 4, 2014.
Search Report from GB1112844.4 relating to claims 26-28, 52 & 53 dated Jun. 15, 2012.
Search Report from GB1112844.4 relating to claims 17-25, 28 and 43-51 dated Jun. 15, 2012.
Search Report from GB1112844.4 relating to claims 7-12, 28 & 35-39 dated Jun. 15, 2012.
The details of the first office action from Chinese Application No. 201280037128.4 dated Mar. 22, 2016.
International search report from PCT/GB2012/051812 dated Apr. 7, 2014.
Further search report from GB1112844.4 dated Jun. 14, 2012 claims searched 26-28, 52 & 53.
Search report from GB1112844.4 dated Nov. 25, 2011 claims searched 1-6 & 29-34.
Further search report from GB1112844.4 dated Jun. 13, 2012 17-25, 28 & 43-51.
Further search report from GB1112844.4 dated Jun. 14, 2012 claims searched 7-12, 28 & 35-39.
Further search report from GB1112844.4 dated Jun. 14, 2012 claims searched 13-16, 28 & 40-42.

* cited by examiner

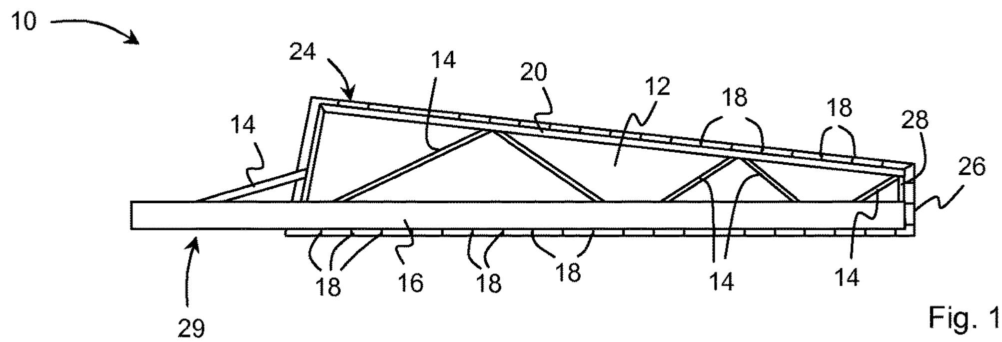



Fig. 1

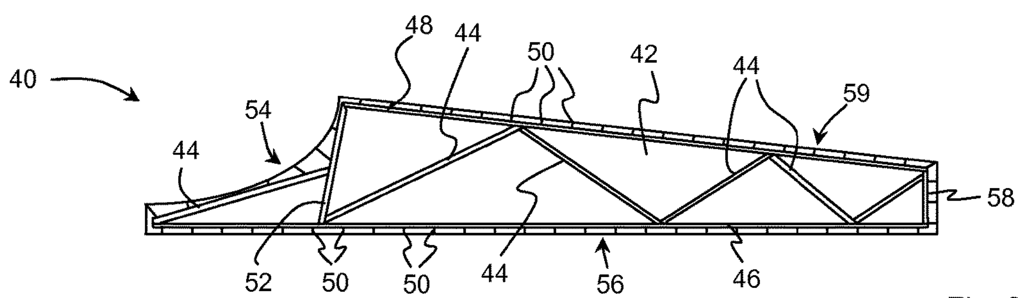



Fig. 2

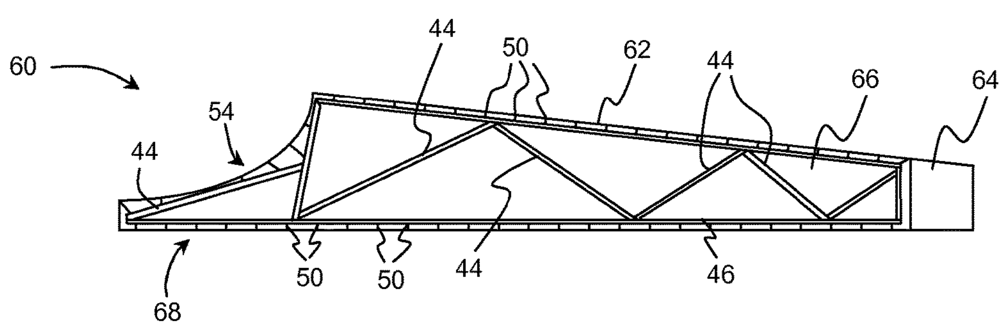



Fig. 3

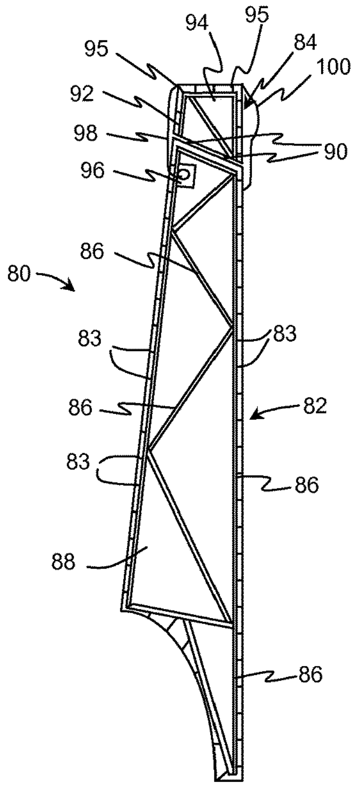



Fig. 4

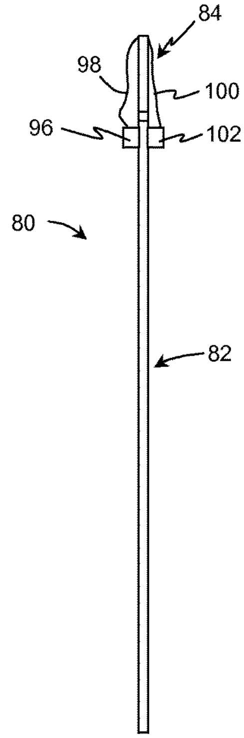



Fig. 5

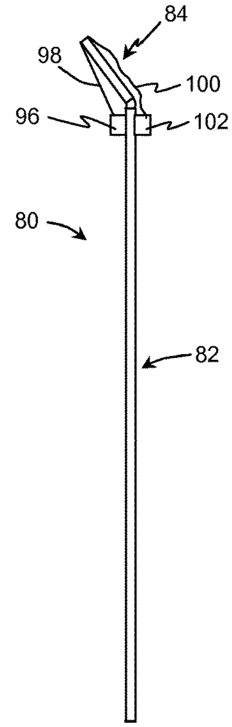



Fig. 6

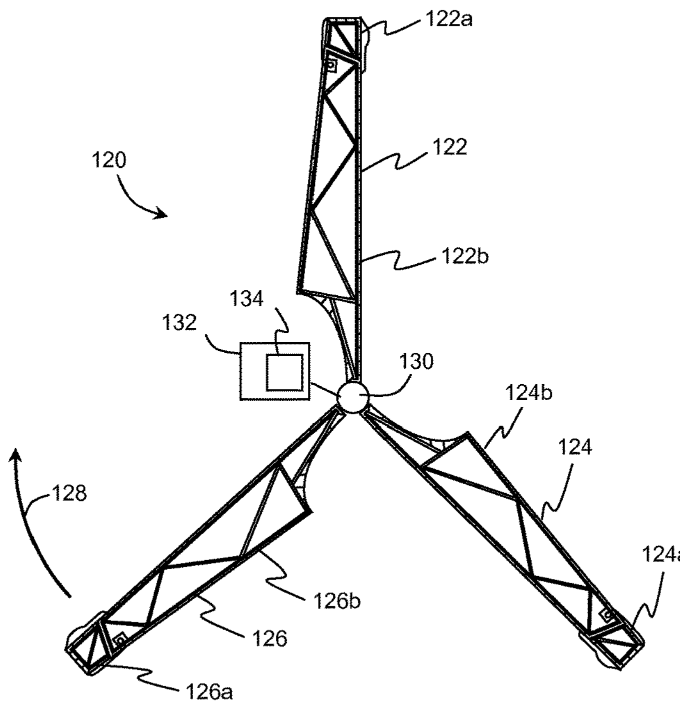



Fig. 7

# TURBINE BLADE WITH ADJUSTABLE TIPS

## CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a national stage application under 35 U.S.C. 371 of, and claims a benefit of priority under 35 U.S.C. 365(a) and/or 35 U.S.C. 365(b) from, copending international application PCT/GB2012/051812, filed Jul. 26, 2012, now WO 2013/014463, published Jan. 31, 2013, the entire contents of which are hereby expressly incorporated herein by reference for all purposes. This application is related to, and claims a benefit of priority under one or more of 35 U.S.C. 119(a)-119(d) from copending foreign patent application GB 1112844.4, filed Jul. 26, 2011.

## FIELD OF EMBODIMENTS OF THE INVENTION

Embodiments of the invention relate to a blade for use with turbines and, in particular, wind turbines.

## BACKGROUND

As the dangers and environmental impact of traditional coal, oil, gas and nuclear power generation become better understood and appreciated, there is an increasing desire for alternative forms of generating power. In recent years, one of the more successful alternative methods of generating energy has been wind power. There are many different known arrangements for generating wind power, but most rely on the principle of providing a turbine having blades arranged to turn as a result of the force of the wind and to thereby generate energy.

The efficiency with which such wind-based electricity generation occurs depends upon the efficiency with which the kinetic energy of the wind can be converted into electrical energy which, in turn, depends upon the efficiency with which the blades can rotate about their axis of rotation.

Due to the manner in which wind turbines operate, the blades which rotate under the influence of the wind are often orientated to rotate vertically with respect to the ground. Therefore, for each up-stroke it is necessary to lift the blade against the force of gravity.

Furthermore, one of the known problems experienced during wind generation is that the blade arrangement (or the portion undergoing rotation due to the wind) is subjected to significantly varying forces as the speed of the wind changes. It is therefore known to simultaneously vary the moment of inertia of all of the blades of a blade arrangement by varying a weight arrangement about an axis of rotation. Such an arrangement is, for example, disclosed in WO 2004/011801.

However, such known arrangements vary the moment of inertia symmetrically and simultaneously about the axis of rotation. Furthermore, the means proposed for varying the moment of inertia rely on relatively expensive and friction-inducing arrangements.

Furthermore, blades used in known arrangements can be heavy causing wear on the bearings used to support the rotation of the blades. KR 2001 0067856 A discloses a rotor blade formed by a tube of a thin bullet-proof film filled with a helium gas reinforced by a bullet-proof textile laminated onto the tube.

## SUMMARY

According to a first aspect, the invention provides a blade for a turbine comprising a body portion having a tip wherein in the tip is moveable relative to the body portion to vary the aerodynamic properties of the blade.



By moving the tip of the blade relative to a body portion, embodiments of the invention can vary the aerodynamic profile of the blade. Where blades are mounted vertically with respect to the ground they rotate against the force of gravity for half of the rotation. In such circumstances, a small change in the aerodynamic profile of the blade can counteract the force of gravity, thereby significantly reducing the force required to lift the blade against gravity. This provides for a more efficient wind turbine incorporating such blades.

The blade may further comprise a hinge connecting the tip to the body portion. In such embodiments, the tip may move by articulating about the hinge.

The blade may further comprise an actuator for moving the tip relative to the body portion. In an embodiment, the actuator may comprise a motor and pulley system or worm gear or other mechanical, electrical or hydraulic actuator.

According to a further aspect, the invention provides a blade for a turbine, the blade comprising a structural frame and a sail mounted on the frame, the sail being mounted on the frame to provide wind resistance during use of the blade and to cause rotation of the blade, wherein the blade further comprises at least one buoyant element wherein the buoyant element forms a part of said structural frame.

By providing a buoyant element which forms part of the structural frame, embodiments of the invention provide a structure which acts to both reduce the effective weight of the blade and provide structural reinforcement. By reducing the effective weight of the blade, the load on the bearing supporting rotation of the blade is decreased and the force required to rotate the blade about its axle is reduced. Furthermore, the reduction of the load on the bearing results in less friction and stress acting on the bearings, resulting in a longer service life.

The frame may comprise a plurality of structural elements, wherein the buoyant element may be at least one of the structural elements.

The buoyant element may support the sail.

The buoyant element may provide a buoyancy to the blade.

The buoyant element may be filled with a fluid which is less dense than the fluid in which the blade is to be disposed.

The buoyant element may be filled with Helium.

According to a further aspect, the invention provides a blade for a turbine, the blade comprising a structural frame and a sail mounted on the frame, the sail being mounted on the frame to provide wind resistance during use of the blade to cause rotation of the blade, wherein the frame further comprises at least one collapsible element. In an embodiment, the collapsible element is a cord element.

By providing a blade having a structural frame and a sail mounted to the frame where the frame comprises at least one cord element, embodiments of the invention provide a lightweight structure which acts to support the sail of the blade. A cord is significantly lighter than the struts or beams used for known blades and therefore provides a significantly improved structure which is lighter and easier to construct and maintain.

Furthermore, the cord provides structural reinforcement whilst contributing to a frame which can be easily dismantled and transported, as it has significantly smaller dimensions than a frame which requires a single strut, particularly where a cord is used in the longer sections of the frame.

When the blade comprises an attack edge and a trailing edge, the cord element may correspond with either the attack edge or the trailing edge, or both simultaneously.

The frame may further comprise a first cord element and a second cord element wherein the first cord element corresponds to the attack edge and the second cord element corresponds to the trailing edge.

The cord element may be braided and may comprise a wire.

A further aspect of the invention extends to a blade arrangement comprising a plurality of blades as described arranged to rotate about an axis, the blade arrangement further comprising a sensor for determining a rotational position of a selected one of the blades relative to the axis and, in dependence on the position, moving the tip of the selected blade relative to the body portion of the selected blade.

The actuator may be connected to the sensor, in which case the actuator may move the tip relative to the body portion to alter the aerodynamic profile of the selected blade to assist the rotational motion of the blade.

The actuator may move the tip to a first position while the blade undergoes a downward motion and move the tip to a second position while the blade undergoes an upward motion.

The aerodynamic profile of the blade with the tip in the first position may assist downward rotation of the blade about the axis.

The aerodynamic profile of the blade with the tip in the second position may assist upward movement of the blade about the axis.

According to a further aspect, the invention provides a method of operating a blade for a turbine having a body portion and a tip, the method comprising moving the tip relative to the body portion to vary the aerodynamic properties of the blade.

A hinge may connect the tip to the body portion.

The method may further comprise providing an actuator for moving the tip relative to the body portion.

The actuator may comprise a motor and pulley system. The actuator may comprise any mechanical, hydraulic or electrical system acting in the prescribed manner. In one embodiment, the actuator is a worm gear.

According to a further aspect, the invention provides a method of constructing a blade for a turbine comprising providing a structural frame and mounting a sail to the frame, the sail being mounted on the frame to provide wind resistance during use of the blade to cause rotation of the blade, wherein the method further comprises providing at least one buoyant element as a part of said structural frame.

The frame may comprise a plurality of structural elements, wherein said buoyant element may be at least one of said structural elements.

The buoyant element may support the sail and may provide a buoyancy to said blade.

The buoyant element may be filled with a fluid which is less dense than the fluid in which the blade is to be disposed.

The buoyant element may be filled with Helium.

According to a further aspect, the invention provides a method of manufacturing a blade for a turbine comprising providing a structural frame and mounting a sail to the frame, the sail being mounted on the frame to provide wind resistance during use of the blade to cause rotation of the blade, wherein the method further comprises providing at least one collapsible element as part of the structural frame. In an embodiment, the collapsible element is a cord element.



The blade may comprise an attack edge and a trailing edge and the cord element may correspond with either of the attack edge or the trailing edge.

The method may further comprise providing a first cord element and a second cord element as part of the frame, wherein the first cord element corresponds to the attack edge and the second cord element corresponds to the trailing edge.

The cord element may be braided and may comprise a wire.

According to a further aspect, the invention provides a method of controlling a blade arrangement comprising a plurality of blades as described arranged to rotate about an axis, the method further comprising providing a sensor for determining a rotational position of a selected one of the blades relative to the axis, the method further comprising moving the tip of the selected blade relative to the body portion of the selected blade in dependence on the position of the selected blade about the axis.

The actuator may be connected to the sensor and the method may comprise using the actuator to move the tip relative to the body portion to alter the aerodynamic profile of the selected blade and thereby assist the rotational motion of the blade.

The method may further comprise using the actuator to move the tip to a first position while the blade undergoes a downward motion and move the tip to a second position while the blade undergoes an upward motion.

The aerodynamic profile of the blade with the tip in the first position may assist downward rotation of the blade about the axis.

The aerodynamic profile of the blade with the tip in the second position may assist upward movement of the blade about the axis.

## BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments of the invention are hereinafter described with reference to the accompanying diagrams which are not to scale and where:

FIG. **1** is a schematic diagram of a blade according to an embodiment of the invention;

FIG. **2** is a schematic arrangement of a blade according to a further embodiment of the invention;

FIG. **3** is a schematic illustration of a blade according to a further embodiment of the invention;

FIG. **4** is a schematic illustration of a blade according to a further embodiment of the invention in a first configuration;

FIG. **5** is a schematic illustration of the blade of FIG. **4** in a further configuration;

FIG. **6** is a schematic illustration of the blade of FIG. **4** in a further configuration; and

FIG. **7** is a schematic illustration of a blade arrangement according to a further embodiment of the invention.

## DESCRIPTION OF EXAMPLE EMBODIMENTS

FIG. **1** illustrates a blade **10** according to an embodiment of the invention. The blade **10** comprises a frame **24** made out of struts **16** and **20** connected by crossbeams **14**. The strut **16** lies along an edge of the blade **20** corresponding to the leading edge (in other words the edge which first engages with the fluid through which the blade passes as it rotates). Strut **20** corresponds to the trailing edge of the blade **10** (in other words the edge trailing the motion of the blade **10** as it rotates). Although a particular embodiment has been illustrated and described below, it is to be realised that the invention is not limited in this respect. In particular, embodiments of the invention may be implemented with frames which do not include struts or standard wind blade construction may also be used.

The blade **10** further comprises a sail **12** attached to the frame **24** by the means of a plurality of lines **18**. In the embodiment illustrated in FIG. **1**, the sail **12** is connected to the frame **24** by the lines **18** engaged between the edges of the sail **12** and the strut **16** of the leading edge and the strut **20** of the trailing edge, as well as a number of lines **18** attached between the tip edge **26** of the sail and a tip strut **28** of the frame **24**. In an alternative embodiment, the sail **12** is connected to the frame **24** by hooks or other mechanical or chemical fitting means.

In each of the embodiments illustrated and described, where a sail is connected to a frame, the sail is illustrated as being connected to only one side of the frame (the back, with reference to the drawings). However, it is to be realised that embodiments of the invention may be provided with a sail covering both sides of the frame, in which case the frame would not be ordinarily visible. Further embodiments have two sails connected to obverse sides of the frame.

In the embodiment illustrated in FIG. **1**, the strut **16** is hollow and has been filled with helium. The blade **10** is designed to be deployed in air and to rotate through action of the wind on the sail **12**. Strut **16** corresponds to the leading edge of the blade and, in the embodiment illustrated, corresponds to the longest structural element of frame **24**. According to this embodiment of the invention, only a single structural element of the frame **24** is filled with helium. In this instance, by providing the longest structural element filled with helium, the greatest buoyancy is achieved for the least amount of engineering involved in ensuring that the particular structural element is gastight.

As stated, the blade is intended to be deployed in air and, since helium is less dense than air, the strut **16** will contribute to the buoyancy of the blade **10**. In further embodiments fluids other that Helium may be used to fill the buoyant element. The functional and cost-effectiveness of the fluid used will depend on the fluid in which the blade is to be disposed. In a further example, the blade is intended to be disposed in water, in which case the buoyant element is filled with air, which is cheaper than Helium but which, nonetheless, contributes to the buoyancy of the blade in that environment.

In the embodiment illustrated in FIG. **1**, only a single structural element of the frame **24**, strut **16**, is provided filled with helium which therefore forms a buoyant element. In a further embodiment, two or more structural elements of the frame **24** may be filled with helium or other fluid. For example, with reference to Figure, both struts **16** and **20** may be filled with Helium. Although this will provide greater buoyancy, it does require that each structural element to be filled with helium be engineered to be gastight.

In a further embodiment, the entire frame, or a substantial part of the frame, is provided as a continuous, gas-filled element.

By providing a structural element which adds stiffness (structural rigidity) and buoyancy to the blade, the support function as well as a buoyancy function are subsumed into the same element. This is substantially more cost-effective and efficient than known blades.

It is to be realised however that the provision of buoyancy is not essential, provided that the structural element is provided with an enclosed space under pressure. The pressurisation provides added stiffness which adds to the structural integrity of the element while not contributing significantly to the weight. This can apply to any of the structural elements illustrated in FIG. **1**.

The structural elements may be provided from carbon fibre, fibre glass, aluminium or any other light weight, impermeable material.

In certain embodiments, the structural elements are provided so that they are segmented. This facilitates transport and on-site construction.

FIG. **2** illustrates a blade **40** according to a further embodiment of the invention. The blade **40** comprises a frame **54** to which a sail **42** is attached by lines **50**. The frame **54** comprises a number of crossbars **44** attached to one another. Instead of cross bars, tensioned cables, wires or any structural element may be used. Alternatively, known fibre glass (or other material) wind blade construction may be used. At a bottom end of the blade, (measured with reference to the rotation of the blade, the side of the blade at which the numeral '**54**' is placed in FIG. **2**) a structural element **52** is provided connected one of the cross bars **44**. Similarly, at a tip portion (also measured with respect to the rotation of the blade **40** during use) a structural element **58** is connected attached to a cross bar **44**.

A leading edge of the blade **56** has a cord **46** running through its length and attached to the frame **54**. Furthermore, at a trailing edge **59**, the blade **40** comprises a cord **48** also attached to the frame **54**.

In the embodiment of FIG. **2**, the cords **46** and **48** each provide a collapsible structure. Furthermore, the cords **46** and **48** each provide a lightweight reinforcement for the frame **54**, significantly reducing the weight of the frame **54** over similar frames using rigid structures at the leading and trailing edges. Furthermore, collapsible structures such as cords are easy to pack and transport compared to more lengthy structural elements. Therefore, embodiments of the invention are suited to transport to regions which are accessible only over narrow mountain roads, rough terrain, or areas where no roads at all are provided.

Although the embodiment of FIG. **2** includes two cords, cords **46** and **48**, further embodiments of the invention comprise a single collapsible element, which may be a cord.

FIG. **3** illustrates a blade **60** according to a further embodiment of the invention. The embodiment illustrated in FIG. **3** is similar to the blade **40** illustrated in FIG. **2** and, where appropriate, similar reference numerals have been used to refer to similar elements. The frame **54** of blade **60** has a sail **66** mounted thereon by lines **50**. The sail **66**, unlike the sail **42** of blade **40** illustrated in FIG. **2**, is not attached to a tip portion of the blade. Instead, the blade **60** comprises a cap **64** over the blade tip. The cap **64** provides additional reinforcing to the frame **54** and protects the tip of the blade **60** against the effect of the air passing the blade **60** which, it would appreciated, is at a greater speed at the tip of the blade than elsewhere along the length of the blade. Therefore the cap **64** serves to protect the portion of the blade **60** most vulnerable to wear during use. The cap **64** may be constructed from steel or fibreglass. Alternatively, the cap **64** may be a filled region of the blade **60**.

Although the steel cap is illustrated in conjunction with cords **46** and **48**, it is to be realised that such caps may be used in conjunction with any blades prone to wear and tear.

A further aspect of the invention is illustrated by comparison between the blade **60** of FIG. **3** and the blade **10** of FIG. **1**. The blade **60** comprises a base portion **68** where the sail **66** is attached by lines **50** to the frame **54**. In comparison, the blade **10** of FIG. **1** includes a base portion **29** where the corresponding sail **12** is not connected to the supporting frame. In addition, element **44** in this embodiment may be provided as a tensioned cord. This provides extra stability to the blade by tensioning an additional portion of the blade.

It will be appreciated that the base portions **29** and **68** of corresponding blades **10** and **60** provide relatively little contribution to the function of the corresponding blade. The majority of the action of the blade is performed in the upper portions. Therefore, it has been realised that savings in both weight and materials can be made by providing a blade such as blade **10** of FIG. **1** where a base portion of the frame does not support the sail, and the sail is substantially restricted to the functional portion of the blade **10**. It is to be realised that a separate flexible sail is not essential. The blade may be provided as a unibody, or with a blade portion mounted on a structural frame, having a pressurised or tensioned portion or member and the advantages discussed herein still apply.

FIGS. **4**, **5** and **6** illustrate a blade **80** according to a further embodiment of the invention. As illustrated in FIG. **4**, blade **80** comprises a body portion **82** and a tip **84**. The body portion **82** comprises a support frame made up of supporting struts **86** and a sail **88** connected to the struts **86** by lines **83**.

Similarly, the tip **84** comprises a support frame made up of support struts **92** and a sail **94** connected to the support struts **92** by lines **94**.

The tip **84** is connected to the body portion **82** by means of a hinge **90**. In the embodiment shown the hinge **90** comprises two hinge members attached to the supporting struts **92** of the body portion **82** and the tip **84** (the means of attachment is not illustrated in FIG. **4**).

The blade **80** further comprises a motorised pulley **96** connected by means of a cord **98** to the tip **84**. The motorised pulley **96** is mounted on body portion **82**. The arrangement of the motorised pulley **96** and the cord **98** is better illustrated in FIG. **5** which is a side view of the blade **80**. As illustrated in FIG. **5**, the blade **80** further comprises a second motorised pulley **102** mounted on an obverse side of body portion **82** to motorised pulley **96**. Motorised pulley **102** is connected to tip **84** by cord **100**.

The motorised pulleys **96** and **102** control the tension of corresponding cords **98** and **100**. By tensioning the cord in the appropriate manner, the motorised pulleys **96** and **102** can cause the tip **84** to articulate relative to body portion **82** about hinge **90**.

FIG. **6** illustrates the blade **80** when the motorised pulley **96** has been activated to tension cord **98** to cause tip portion **84** to articulate about hinge **90** relative to body portion **82**. It will be realised that articulation of the tip **84** relative to body portion **82** in the other direction may be achieved through causing motorised pulley **102** to tension cord **100** while, at the same time, releasing the tension in cord **98** through appropriate activation of motorised pulley **96**.

The pulleys **96** and **102** are controlled centrally by a controller, which is not illustrated in FIGS. **4**, **5** and **6**, but the operation of which is described below with reference to FIG. **7**.

FIG. **7** illustrates a blade arrangement **120** comprising three blades **122**, **124** and **126**. Each of the blades **122**, **124** and **126** is similar to the blade **80** illustrated in FIGS. **4**, **5** and **6**. Therefore blade **122** comprises body portion **122***b* and tip **122***a*; blade **124** comprises body portion **124***b* and tip **124***a*; and blade **126** comprises body portion **126***b* and tip **126***a*. The blades **122**, **124** and **126** are mounted to an axle **130** and are arranged to rotate about the axle **130** in the direction of arrow **128** under the influence of a prevailing wind. It is to be realised that although the preferred embodiments refer to wind turbines, the principles herein described are equally applicable to blades for use in other turbines, such as flood turbines which operate in the sea.

Referring back to FIG. **7**, the blade arrangement **120** further comprises a controller **132** having a sensor **134** connected to axis **130**. The sensor **134** detects the angular position of the blades **122**, **124** and **126** about the axis **130**. The controller **132** controls the articulation of the tips **122***a*, **124***a* and **126***a* through the use of corresponding motorised pulleys and cords in the manner described above with reference to FIGS. **4**, **5** and **6**.

As the blade arrangement **120** rotates, the sensor **134** detects the angular position of the blades and the controller controls the articulation of the tips. As the tips articulate, the aerodynamic profile of the corresponding blade is altered. By controlling the articulation of the tips in dependence upon the rotational position of the blades, the controller **132** is able to use the strength of the prevailing wind to lift the blade during the up-stroke. The tip is returned to its original position during the down-stroke to ensure that the blade maintains its maximum efficiency.

In this manner, the blade arrangement **120** provides an arrangement whereby rotation of the blades **122**, **124** and **126** about axis **130** is more efficient when compared to a similar arrangement, also mounted vertically with respect to the ground, which does not alter the aerodynamic profiles of the blades' independence upon their rotational position.

For each of the blades **122**, **124** and **126**, changing the position of the tip relative to the body portion will alter the aerodynamic profile of that blade. It is to be realised that to do so the tip need not be very large in comparison to the body portion. In a particular embodiment, the surface area of the tip is less than 5% of the surface are of the entire blade. In yet a further embodiment, the surface are of the tip is less than 1% of the surface area of the entire blade. In yet a further embodiment, the surface are of the tip is less than 1% of the surface area of the entire blade.

It will be appreciated that the particular design of the tip and the lift created by articulation of this relative to the blade will depend on a number of factors such as the speed at which the blade arrangement is designed to operate, and the viscosity of the fluid in which the blade arrangement is disposed. In any event, the required shape and size of the tip relative to the body portion can be determined through trial and error.

There follows a list of numbered features which relate to embodiments of the invention. Where a numbered feature refers to one or more other numbered features then those features should be considered in combination.

1. A blade for a turbine comprising a body portion having a tip wherein in the tip is moveable relative to the body portion to vary the aerodynamic properties of the blade.

2. The blade according to feature 1 further comprising a hinge connecting said tip to the body portion.

3. The blade according to feature 1 or feature 2 further comprising an actuator for moving the tip relative to the body portion.

4. The blade according to feature 3 wherein the actuator comprises a motor and pulley system.

5. A blade arrangement comprising a plurality of blades according to any of features 1 to 4 arranged to rotate about an axis, said blade arrangement further comprising a sensor for determining a rotational position of a selected one of said blades relative to the axis and, in dependence on said position, moving the tip of the selected blade relative to the body portion of the selected blade.

6. The blade arrangement according to feature 5, when dependent on feature 3, wherein the actuator is connected to

the sensor, and wherein the actuator moves the tip relative to the body portion to alter the aerodynamic profile of the selected blade to assist the rotational motion of the blade.

7. The blade arrangement according to feature 6 wherein the actuator moves the tip to a first position while the blade undergoes a downward motion and moves the tip to a second position while the blade undergoes an upward motion.

8. The blade arrangement according to feature 7 wherein the aerodynamic profile of the blade with the tip in the first position assists downward rotation of the blade about the axis.

9. The blade arrangement according to feature 8 wherein the aerodynamic profile of the blade with the tip in the second position assists upward movement of the blade about the axis.

10. A blade for a turbine, the blade comprising a structural frame and a sail mounted on the frame, the sail being mounted on the frame to provide wind resistance during use of the blade and to cause rotation of the blade, wherein the blade further comprises at least one buoyant element wherein the buoyant element forms a part of said structural frame.

11. The blade according to feature 10 wherein said frame comprises a plurality of structural elements, and wherein said buoyant element is at least one of said structural elements.

12. The blade according to feature 10 or feature 11 wherein said buoyant element supports said sail.

13. The blade according to any preceding feature wherein said buoyant element provides a buoyancy to said blade.

14. The blade according to feature 13 wherein said buoyant element is filled with a fluid which is less dense than the fluid in which the blade is to be disposed.

15. The blade according to feature 14 wherein said buoyant element is filled with Helium.

16. A blade for a turbine, the blade comprising a structural frame and a sail mounted on the frame, the sail being mounted on the frame to provide wind resistance during use of the blade to cause rotation of the blade, wherein the frame further comprises at least one collapsible element.

17. The blade according to feature 16 wherein in the collapsible element is a cord.

18. The blade according to feature 16 or feature 17 comprising an attack edge and a trailing edge and wherein said cord element corresponds with either of the attack edge or the trailing edge.

19. The blade according to feature 18 wherein the frame further comprises a first cord element and a second cord element wherein the first cord element corresponds to the attack edge and the second cord element corresponds to the trailing edge.

20. The blade according to any of features 16 to 19 wherein said cord element is braided or filament winded.

21. The blade according to any of features 16 to 20 wherein said cord element comprises a wire.

22. A blade for a turbine comprising a body portion and a tip and a protective member covering the tip.

23. The blade according to feature 22 wherein the protective member is made of steel or composite.

24. The blade according to feature 22 or feature 23 wherein the protective member covers a portion of the blade and protects the covered portion from wear and tear.

25. The blade according to feature 22 wherein the blade further comprises a frame and a sail mounted to the frame wherein the protective member acts to protect a portion of the sail.

26. A blade for a turbine, the blade comprising a structural frame and a sail mounted on the frame, the blade having a functional portion which allows the blade to move under the influence of a moving fluid in which the blade is immersed, wherein the sail is only mounted to a portion of the frame corresponding to the functional portion of the blade.

27. The blade according to feature 26 wherein the blade further comprises a blade structure having a portion of said frame without the sail mounted thereto.

28. The blade according to any of features 9 to 24 or 26 further comprising a reinforcing cap.

29. A method of operating a blade for a turbine having a body portion and a tip, the method comprising moving the tip relative to the body portion to vary the aerodynamic properties of the blade.

30. The method according to feature 43 wherein a hinge connects said tip to the body portion.

31. The method according to feature 43 or feature 44 further comprising providing an actuator for moving the tip relative to the body portion.

32. The method according to feature 45 wherein the actuator comprises a motor and pulley system.

33. A method of controlling a blade arrangement comprising a plurality of blades according to any of features 1 to 3, 24 or 25 arranged to rotate about an axis, said method further comprising providing a sensor for determining a rotational position of a selected one of said blades relative to the axis, the method further comprising moving the tip of the selected blade relative to the body portion of the selected blade in dependence on the position of the selected blade about the axis.

34. The method according to feature 33, when dependent on feature 31, wherein the actuator is connected to the sensor, the method comprising using the actuator to move the tip relative to the body portion to alter the aerodynamic profile of the selected blade and thereby to assist the rotational motion of the blade.

35. The method according to feature 34 further comprising using the actuator to move the tip to a first position while the blade undergoes a downward motion and move the tip to a second position while the blade undergoes an upward motion.

36. The method according to feature 35 wherein the aerodynamic profile of the blade with the tip in the first position assists downward rotation of the blade about the axis.

37. The method according to feature 36 wherein the aerodynamic profile of the blade with the tip in the second position assists upward movement of the blade about the axis.

38. A method of constructing a blade for a turbine comprising providing a structural frame and a sail mounted on the frame, the sail being mounted on the frame to provide wind resistance during use of the blade to cause rotation of the blade, wherein the method further comprises providing at least one buoyant element as a part of said structural frame.

39. The method according to feature 38 wherein said frame comprises a plurality of structural elements, and wherein said buoyant element is at least one of said structural elements.

40. The method according to feature 38 or feature 39 wherein said buoyant element supports said sail.

41. The method according to any of features 38 to 40 wherein said buoyant element provides a buoyancy to said blade.

42. The method according to feature 41 wherein said buoyant element is filled with a fluid which is less dense than the fluid in which the blade is to be disposed.

43. The method according to feature 42 wherein said buoyant element is filled with Helium.

44. A method of manufacturing a blade for a turbine comprising providing a structural frame and a sail mounted on the frame, the sail being mounted on the frame to provide wind resistance during use of the blade to cause rotation of the blade, wherein the method further comprises providing at least one collapsible member such as a cord element as part of the structural frame.

45. The method according to feature 44 wherein the blade comprises an attack edge and a trailing edge and wherein said cord element corresponds with either of the attack edge or the trailing edge.

46. The method according to feature 45 comprising providing a first cord element and a second cord element as part of the frame, wherein the first cord element corresponds to the attack edge and the second cord element corresponds to the trailing edge.

47. The method according to any of features 44 to 45 wherein said cord element is braided.

48. The method according to any of features 44 to 47 wherein said cord element comprises a wire.

49. A method of manufacturing a blade for a turbine comprising providing a body portion and a tip and a protective member covering the tip.

50. The method according to feature 49 wherein the tip is made of steel.

51. The method according to feature 49 or feature 50 wherein the tip covers a portion of the blade and protects the covered portion from wear and tear.

52. A method of constructing a blade having a functional portion and a non-functional portion, the functional portion contributing to the motion of the blade due to motion of a fluid in which the blade is immersed, the method comprising attaching a sail only to the functional portion.

53. The method according to feature 52 further comprising providing a frame having a base structure, said base structure being provided without a sail.

The invention claimed is:

**1**. A method of operating a blade arrangement including a plurality of blades for a turbine, the blades each having a structural frame and a sail mounted on the structural frame, the structural frame including a body portion, a tip and a hinge connecting the tip to the body portion, the method comprising:

rotating the tip relative to the body portion at the hinge to vary the aerodynamic properties of the blade, the hinge defining a hinge axis in a plane of the blade and inclined with respect to a longitudinal axis of the blade, wherein the blades are arranged to rotate about an axis, wherein rotating the tip relative to the body portion at the hinge includes rotating a cord element that acts to support the sail of the blade;

providing an actuator for moving the tip relative to the body portion, wherein the actuator comprises a motor and pulley system, configured to control the tension of corresponding cords, by which the motor and pulley system cause the tip to articulate relative to the body portion;

providing a sensor for determining a rotational position of a selected one of said blades relative to the axis; and

rotating the tip of the selected blade relative to the body portion of the selected blade in dependence on the position of the selected blade about the axis.

* * * * *