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(54) FLEXIBLE TURBINE BLADE

(76) Inventors: **Asfaw Beyene**, San Diego, CA (US); **Terrence Ireland**, San Diego, CA (US)

Correspondence Address:
DR. JAMES H. WILSON
3834 VISTA AZUL
SAN CLEMENTE, CA 92672 (US)

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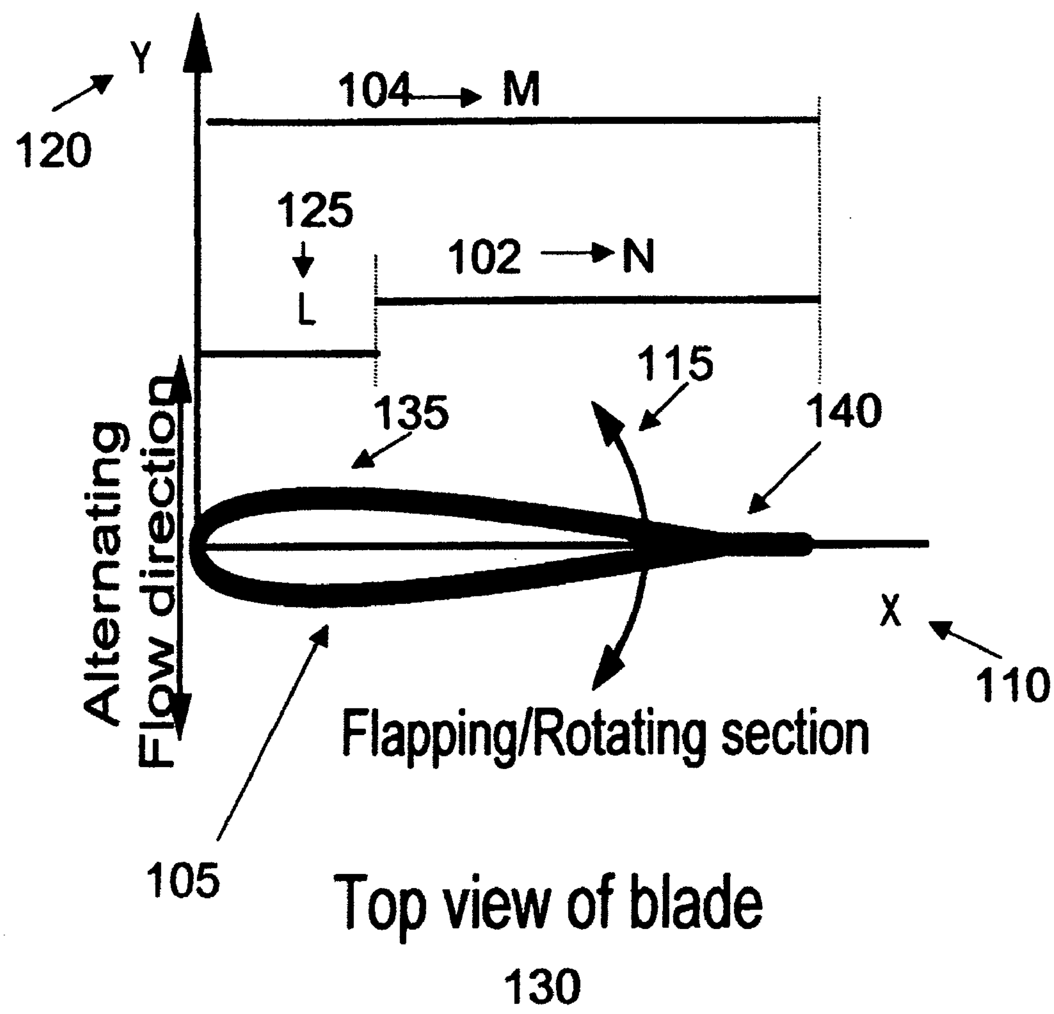
(57) **ABSTRACT**

Systems and techniques relating to blades, in particular to symmetrical blades for turbines. In one general implementation, the present application relates to a method for increasing efficiency of a symmetrical blade comprising providing a rigid portion of the symmetrical blade and providing a flexible portion of the symmetrical blade. The rigid portion of the symmetrical blade can be connected to the flexible portion of the symmetrical blade. The flexible portion of the symmetrical blade can be adapted to bend with a flow across the symmetrical blade. The symmetrical blade can be adapted to rotate in one direction for a bi-directional flow across the symmetrical blade. The symmetrical blade can be adapted for at least one of a Wells Energy Conversion (WEC) system, a fan, an exhaust system, a blowing system, and a suction system. The rigid portion of the symmetrical blade can be fixed to an axis perpendicular to a direction of flow. The symmetrical blade can be rotated in a direction orthogonal to the direction of flow and orthogonal to the bending of the symmetrical blade. The rigid portion may comprise metal, wood, and plastic. The flexible portion may comprise plastic and rubber. The symmetrical blade may comprise a pear-shaped blade or a rectangular-shaped blade.



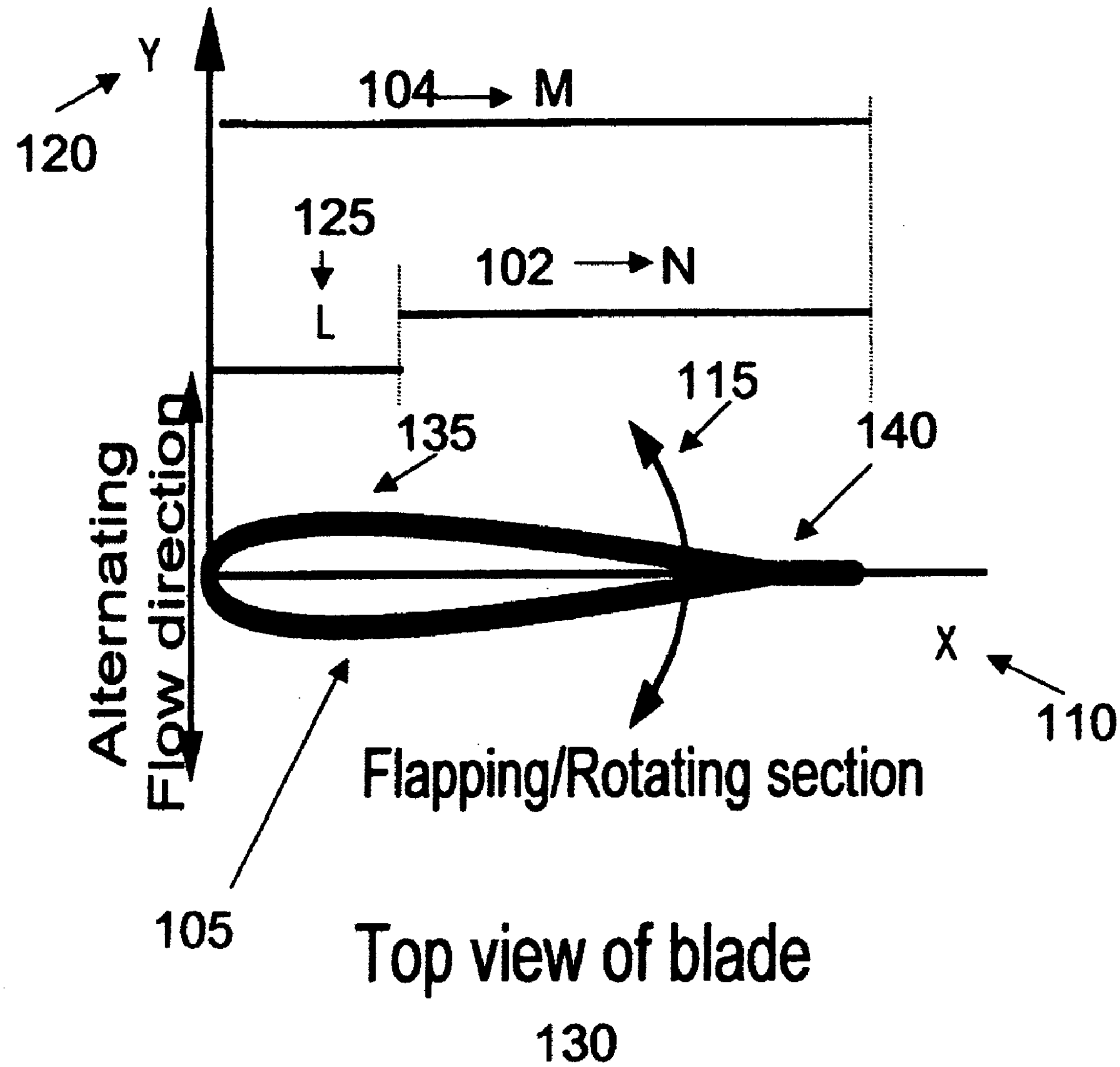
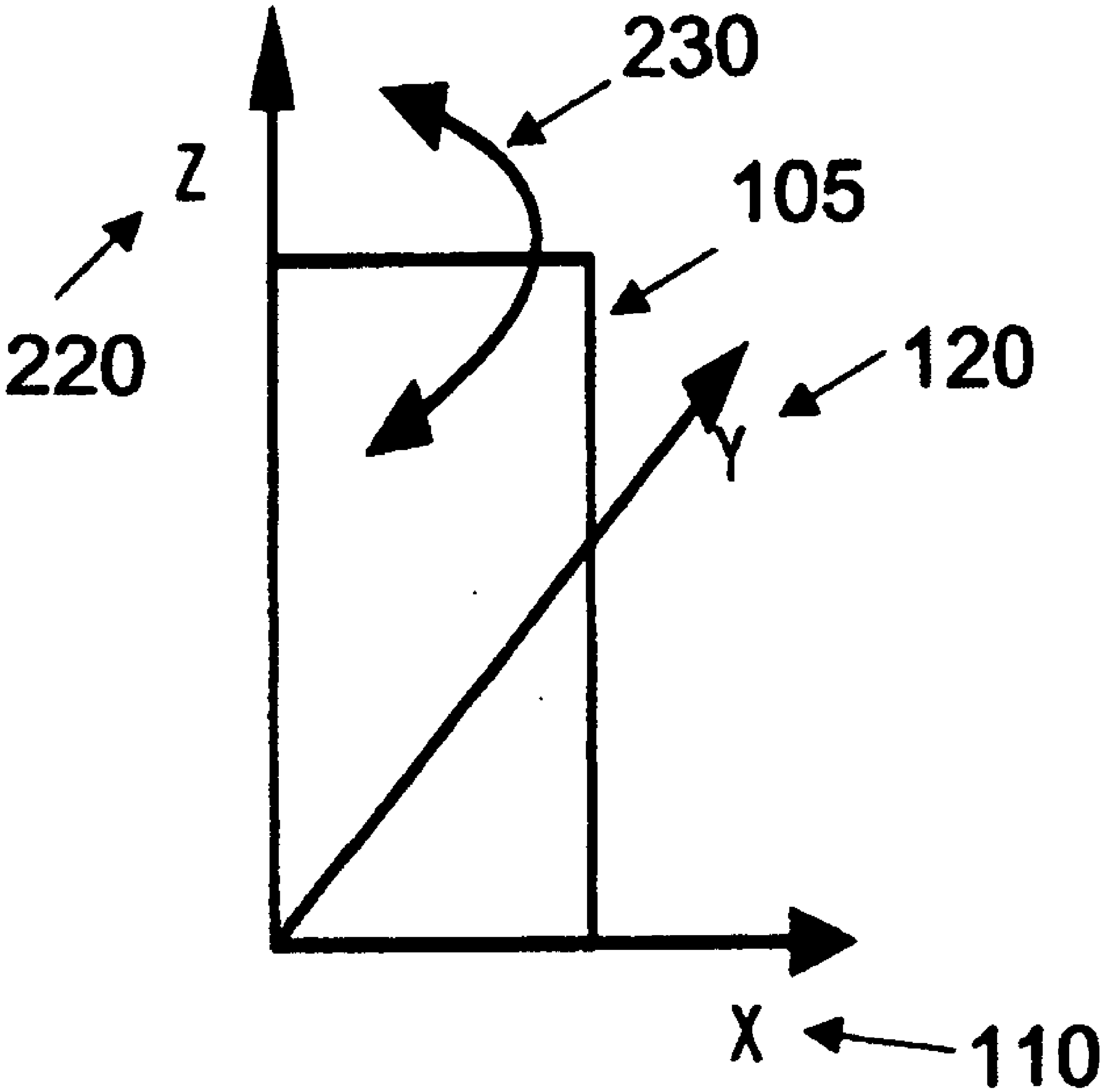

Y
120
104
M
125
L
102
N
115
135
140
Alternating
Flow direction
X
110
Flapping/Rotating section
105
Top view of blade
130

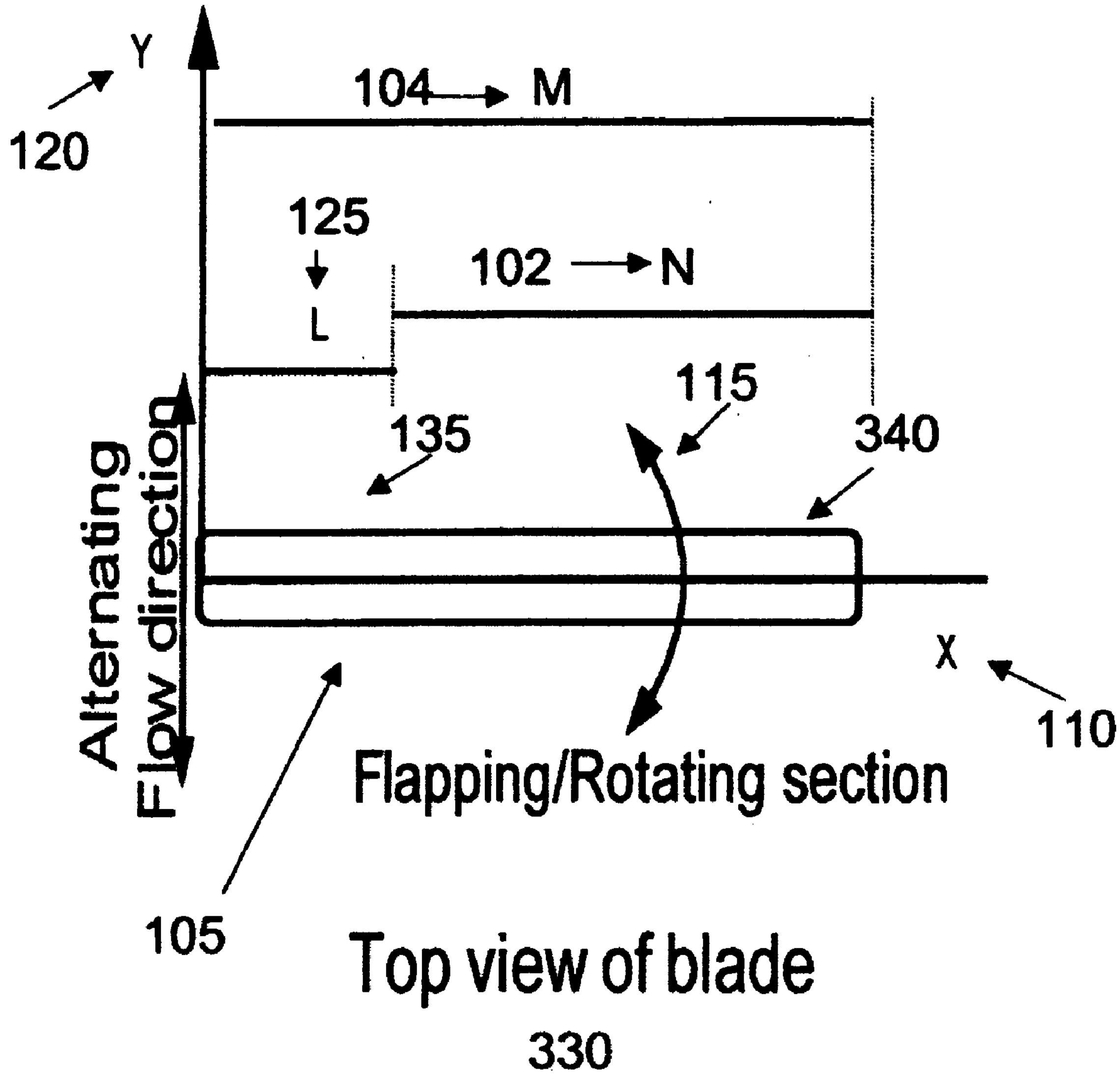
Fig. 1



Side view of blade

210

Fig. 2


Y
120
104 M
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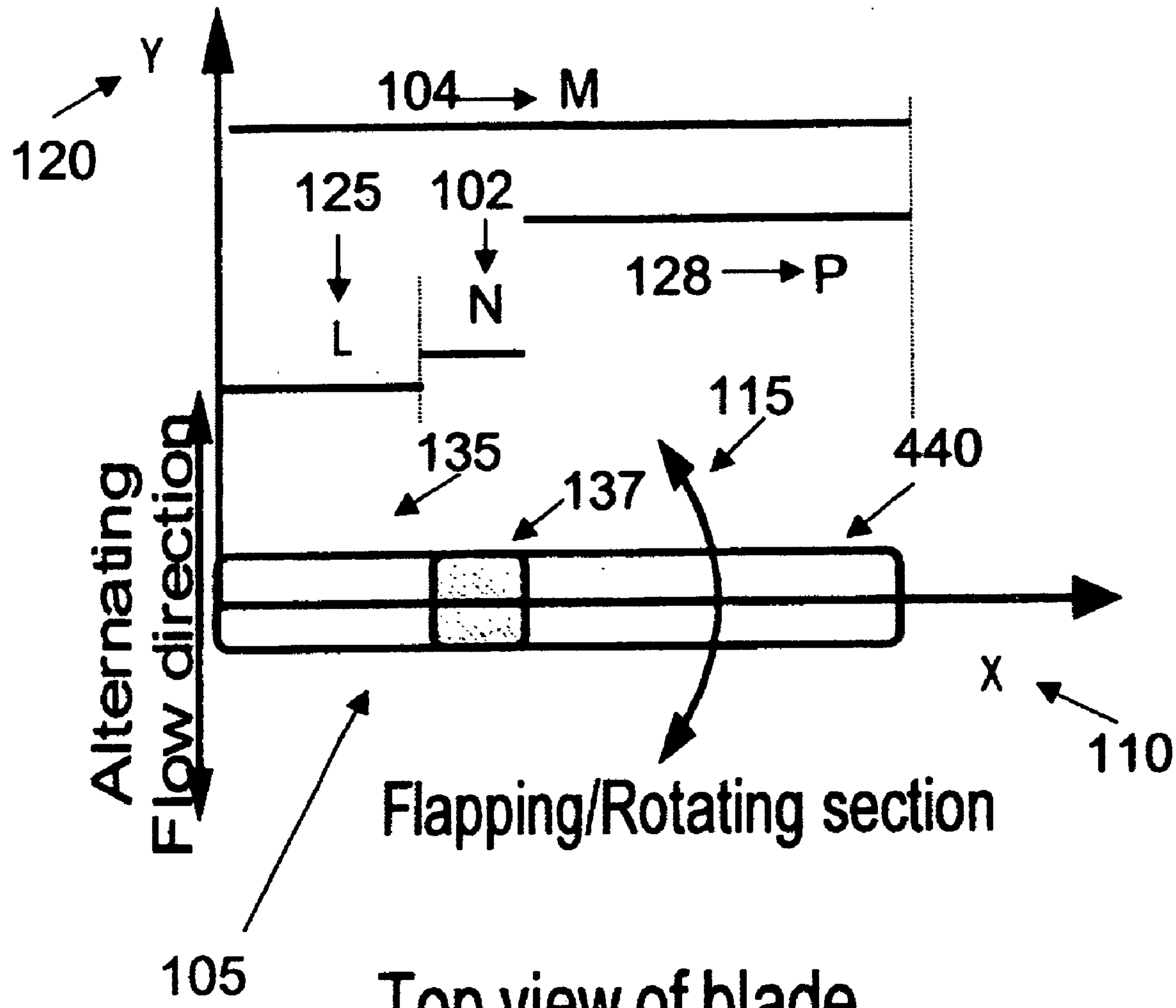
L
102 N
115
135
340
Alternating
Flow direction
X
110
Flapping/Rotating section
105
Top view of blade
330

Fig. 3



Top view of blade

430

Fig. 4

FLEXIBLE TURBINE BLADE

BACKGROUND

[0001] Conventional turbines typically have solid, rigid structures to form blades for the turbines. Such rigid blades are able to rotate at high speeds under normal conditions. However, when it is desired that the turbine blade rotates in the same direction regardless of the flow direction, symmetrical blades are often desired. For example, a Wave Energy Conversion (WEC) system can require that the turbine blade rotates in the same direction regardless of the flow direction. Such a system can use a Wells Turbine. However, the Wells Turbine has symmetrical, rigid blades and relatively low efficiency. Wells turbines with variable pitch, rigid blades to improve efficiency are being designed and tested but the variable pitch technology is very different from the flexible turbine blade described in the present application.

SUMMARY

[0002] The present application describes systems, methods and techniques for a flexible blade turbine system.

[0003] One aspect of the present application relates to a method for increasing efficiency of a symmetrical blade comprising providing a rigid portion of the symmetrical blade and providing a flexible portion of the symmetrical blade. The rigid portion of the symmetrical blade can be connected to the flexible portion of the symmetrical blade. The flexible portion of the symmetrical blade can be adapted to bend with a flow across the symmetrical blade. The symmetrical blade can be adapted to rotate in one direction for a bi-directional flow across the symmetrical blade. The symmetrical blade can be adapted for at least one of a Wave Energy Conversion (WEC) system, a fan, an exhaust system, a blowing system, and a suction system. The rigid portion of the symmetrical blade can be fixed to an axis perpendicular to a direction of flow. The symmetrical blade can be rotated in a direction orthogonal to the direction of flow and orthogonal to the bending of the symmetrical blade. The rigid portion may comprise metal, wood, and plastic, wherein the flexible portion may comprise plastic and rubber. The symmetrical blade may comprise a pear-shaped blade or a rectangular-shaped blade.

[0004] In another aspect, the present application may describe a system for increasing the efficiency of a turbine with a symmetrical blade. The system may comprise a rigid portion of the symmetrical blade and a flexible portion of the symmetrical blade. The flexible portion of the symmetrical blade may connect to the rigid portion of the symmetrical blade, wherein the flexible portion is adapted to bend in a direction of flow across the symmetrical blade. The geometry of the symmetrical blade can vary to reduce an amount of loss from an entirely rigid, symmetrical blade. The geometry of the symmetrical blade can also vary to increase the efficiency of the symmetrical blade over an entirely rigid symmetrical blade. The symmetrical blade can be adapted to rotate in a single direction for a bi-directional flow across the symmetrical blade. The symmetrical blade may comprise plastic and metal.

[0005] Details of one or more implementations are set forth in the accompanying drawings and the description below. Other features and advantages may be apparent from the description, drawings, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] These and other aspects will now be described in detail with reference to the following drawings.

[0007] **FIG. 1** illustrates a top view of an exemplary blade.

[0008] **FIG. 2** illustrates a side view of an exemplary blade.

[0009] **FIG. 3** illustrates a top view of a flat exemplary blade.

[0010] **FIG. 4** illustrates a top view of an exemplary blade comprising one flexible portion between two rigid portions.

[0011] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0012] The systems and techniques described here relate to a blade for turbine or fan systems. In particular, the system described herein relates to a blade that rotates in the same direction regardless of a flow direction (e.g., bi-directional flow). The disclosed system may provide higher efficiencies than conventional symmetric blades responding to bi-directional flows.

[0013] A symmetrical blade can allow the blade to rotate in one direction regardless of the direction of a flow across the blade. Such a flow may be referred to as a bi-directional flow. In conventional systems, such as a Wave Energy Conversion (WEC) system, the symmetry of the blade can lead to lower efficiencies than a conventional non-symmetrical turbine blade. A typical turbine that can be used for a WEC system may be a Wells Turbine. A Wells Turbine has rigid, symmetrical blades. The system described herein can provide a higher efficiency than the efficiency of a Wells Turbine.

[0014] **FIG. 1** shows an exemplary schematic diagram of a top view **130** of a blade **105**. **FIG. 2** shows an exemplary schematic diagram of a side view **210** of the blade **105**. The blade **105** may be a symmetrical blade **105**. When looking at the top view **130** of the blade **105**, the blade may have a total length M **104**. The blade **105** can have a firmly mounted portion **135** of length L **125** on the X axis **110**. The blade **105** can have a portion **140** of length N **102** that is not firmly mounted on the X axis **110**. The total blade length M **104** is the sum of lengths L **125** and N **102**. The blade **105** can wobble around the Z axis **220** and have the freedom to also move in the X-Y plane **110**, **120**. The flow direction in this exemplary embodiment is shown in the y direction **120**. The flow direction may be in a positive y direction, a negative y direction, or the positive y direction for one time period and the negative y direction in another time period. The blade **105** may be (1) partially rigid and partially flexible, (2) entirely rigid, or (3) entirely flexible.

[0015] In one aspect, the blade **105** may be partially rigid and partially flexible. The blade **105** can have firmly mounted part **135** of length L **125** on the X axis. The blade **105** may also have a length N **102** on the X axis towards the trailing edge **140** (e.g., tail part) that allows a flapping movement **115**. The bending/flapping movement **115** can be in response to a force and a direction of flow. The flexible portion **140** of the blade **105** can bend with the flow direction and give the turbine blade more impulse. The bending of the blade **115** allows the blade **105** to rotate faster than a conventional, rigid Wells turbine blade. The bending of the blade **115** can allow the geometry of the symmetrical blade **105** to vary from a conventional rigid, symmetrical blade. The varying geometry of the symmetrical blade **105** can reduce an amount of loss and increase the efficiency of the symmetrical blade **105** over a conventional rigid, symmetrical blade.

[**0016**] In another aspect, the blade **105** can be entirely rigid. For this aspect, length L **125** is equal to length M **104** and length N **102** is zero. The rigid blade **105** may rotate in a direction of the Z axis **220** without the bending of the blade **115**.

[**0017**] In another aspect, the blade **105** can be entirely flexible. For this aspect, length L **125** is zero and length N **102** is equal to length M **104**. The blade **105** can bend in response to the flow direction. The entire blade **105** can also rotate around the Z axis **220**. In one embodiment, the blade **105** may bend in a y direction **120** and not rotate around the Z axis **220**. In another embodiment, the blade may not bend in a Y direction **120** and rotate around the Z axis **220**. Under typical operation, the blade **105** can both bend **115** in the y direction **120** and rotate around the Z axis **220**. The amount of bending **115** may depend on an intensity of the flow, the flexibility of the blade **105**, and the amount of rotation around the Z axis **220**.

[**0018**] The entirely flexible blade **105** can bend with the flow direction and give a turbine blade more impulse. The entirely flexible blade **105** has the freedom to move in the X direction and/or the y direction. The entirely flexible blade **105** may rotate faster than a rigid Wells Turbine blade. The flexibility of the symmetrical blade **105** may (1) vary the geometry of the blade **105**, (2) reduce the losses of the blade **105** and (3) increase the efficiency of the blade **105** over a rigid, symmetrical blade.

[**0019**] The blade **105** may be constructed out of a material that can allow the blade **105** to have a flexible portion and/or a rigid portion. For example, the blade **105** may have a rigid portion made from materials such as hard plastic, wood, or metal. The blade **105** may have a flexible portion made out of materials such as plastic or rubber. The blade **105** may be constructed with a hard plastic material for a rigid portion **135** and a flexible plastic material for the flexible portion **140**. The rigid portion **135** and flexible portion **140** may be one piece of material or two or more attached pieces of material.

[**0020**] The blade **105** may operate in other systems other than WEC systems. For example, the blade **105** may operate in suction systems and blowing systems. The blade **105** may also operate in exhaust systems and fans.

[**0021**] In another aspect, the blade **105** may be have a different shape other than what is shown in **FIGS. 1-2**. For example, the blade **105** may have a rectangular or flat shape as shown in **FIG. 3**.

[**0022**] In another aspect, the blade **105** may have a flexible portion **137** of length N **102** positioned between a rigid portion **135** of length L **125** fixed to the X axis **110** and a rigid portion **440** of length p **128** that is not fixed to the X axis **110** as shown in **FIG. 4**. The bending of the blade **105** at **115** may occur along the flexible portion **137** that is positioned between the two rigid portions **135**,**440**. The blade **105** may also rotate around the Z axis **220**.

[**0023**] In another aspect, the rigid portion **135** (**FIG. 4**) may have a length L **125** of zero. The total length M **104** of the blade **105** may comprise the flexible portion **137** of length N **102** and a rigid portion **440** of length p **128**. The flexible portion **137** and the rigid portion **440** may not be fixed to the X axis **110**. The blade **105** may also rotate around the Z axis **220** and bend along the flexible portion **137** of the blade **105**.

[**0024**] The direction of flow, the bending of the blade, and the rotation of the blade may be in other directions, axes, or combinations of axes other than what is shown in **FIGS. 1-4**. Furthermore, the construction of the blade may use other flexible and non-flexible materials than the materials disclosed herein.

[**0025**] Other embodiments may be within the scope of the following claims.

What is claimed is:

1. A method for increasing efficiency of a symmetrical blade, the method comprising:

providing a rigid portion of the symmetrical blade; and

providing a flexible portion of the symmetrical blade, wherein the rigid portion of the symmetrical blade is connected to the flexible portion of the symmetrical blade, wherein the flexible portion of the symmetrical blade is adapted to bend with a flow across the symmetrical blade.

2. The method of claim 1, wherein the symmetrical blade is adapted to rotate in one direction for a bi-directional flow across the symmetrical blade.

3. The method of claim 2, wherein the symmetrical blade is adapted for at least one of a Wave Energy Conversion (WEC) system, a fan, an exhaust system, a blowing system, and a suction system.

4. The method of claim 3, further comprising:

fixing the rigid portion of the symmetrical blade to an axis perpendicular to a direction of flow.

5. The method of claim 4, further comprising:

rotating the symmetrical blade in a direction orthogonal to the direction of flow and orthogonal to the bending of the symmetrical blade.

6. The method of claim 5, wherein the rigid portion comprises metal, wood, and plastic, wherein the flexible portion comprises plastic and rubber.

7. The method of claim 6, wherein the symmetrical blade comprises a pear-shaped blade.

8. The method of claim 6, wherein the symmetrical blade comprises a rectangular-shaped blade.

9. A system for increasing the efficiency of a turbine with a symmetrical blade, the system comprising:

a rigid portion of the symmetrical blade; and

a flexible portion of the symmetrical blade, the flexible portion of the symmetrical blade connecting to the rigid portion of the symmetrical blade, wherein the flexible portion is adapted to bend in a direction of flow across the symmetrical blade.

10. The system of claim 9, wherein a geometry of the symmetrical blade varies to reduce an amount of loss from an entirely rigid, symmetrical blade.

11. The system of claim 9, wherein a geometry of the symmetrical blade varies to increase the efficiency of the symmetrical blade over an entirely rigid symmetrical blade.

12. The system of claim 9, wherein the geometry of the symmetrical blade varies with the direction of flow.

13. The system of claim 9, wherein the symmetrical blade is adapted to rotate in a single direction for a bi-directional flow across the symmetrical blade.

14. The system of claim 13, wherein the symmetrical blade comprises plastic and metal.

15. An apparatus comprising a flexible symmetric blade adapted to increase an efficiency of a Wave Energy Conversion (WEC) system, wherein the geometry of the symmetrical blade is adapted to vary to reduce the loss of the symmetrical blade over an entirely rigid symmetrical blade.

16. The apparatus of claim 15, wherein the flexible symmetric blade remains unfixed to an axis perpendicular to a direction of flow, the flexible symmetric blade comprising an entirely flexible symmetric blade.

17. The apparatus of claim 15, wherein the flexible symmetric blade is adapted to provide additional impulse to the apparatus.

18. A turbine system, the turbine system comprising a rigid symmetrical blade adapted to rotate in a direction orthogonal to a direction of flow across the symmetrical blade.

19. A turbine system, the turbine system comprising:

a first rigid portion of a symmetrical blade;

a second rigid portion of the symmetrical blade and

a flexible portion of the symmetrical blade, the flexible portion of the symmetrical blade connected between the first and the second rigid portions of the symmetrical blade, wherein the flexible portion is adapted to bend in a direction of flow across the symmetrical blade.

20. The turbine system of claim 19, wherein the symmetrical blade may rotate around an axis perpendicular to the direction of flow, wherein the symmetrical blade is adapted to rotate in a single direction regardless of the direction of flow.

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