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(54) ROTOR BLADE

(75) Inventors: **Xiomara Irizarry-Rosado**, Greer, SC (US); **Gialdy Irizarry-Perez**, Mayaguez, PR (US)

(73) Assignee: **GENERAL ELECTRIC COMPANY**, Schenectady, NY (US)

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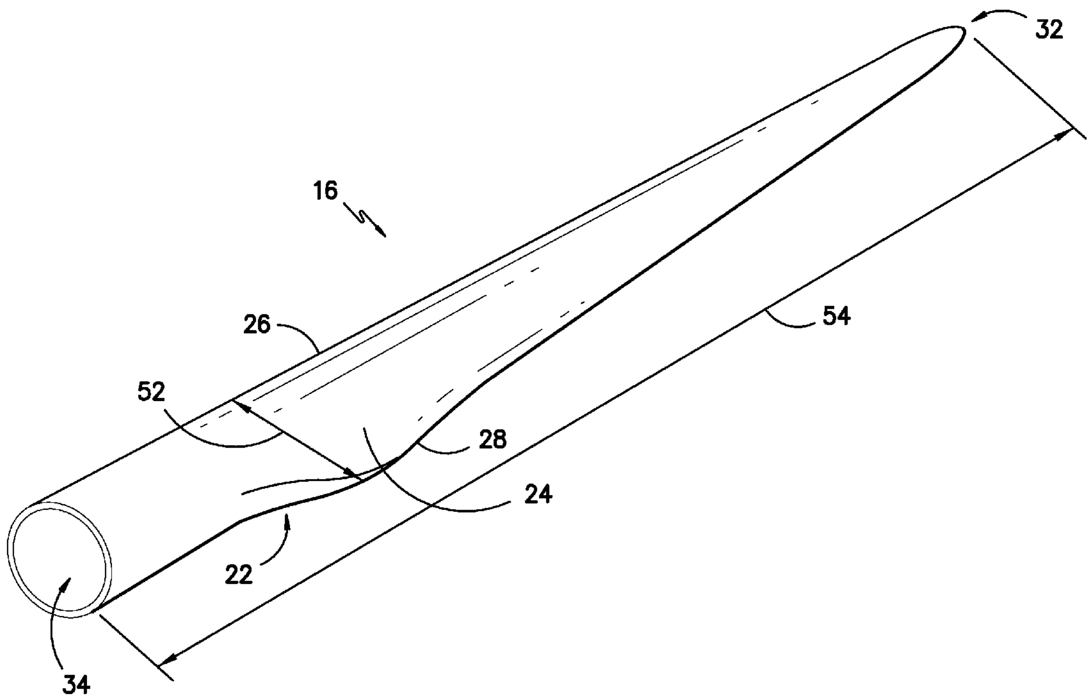
(57) **ABSTRACT**

A rotor blade for a wind turbine is disclosed. The rotor blade includes an outer shell having exterior surfaces and interior surfaces, the exterior surfaces defining a pressure side and a suction side each extending between a leading edge and a trailing edge, the interior surfaces defining a rotor blade interior. The rotor blade further includes a structural member extending through at least a portion of the interior, and a generally elastic material connecting the structural member to an interior surface. The generally elastic material allows movement of the outer shell with respect to the structural member.



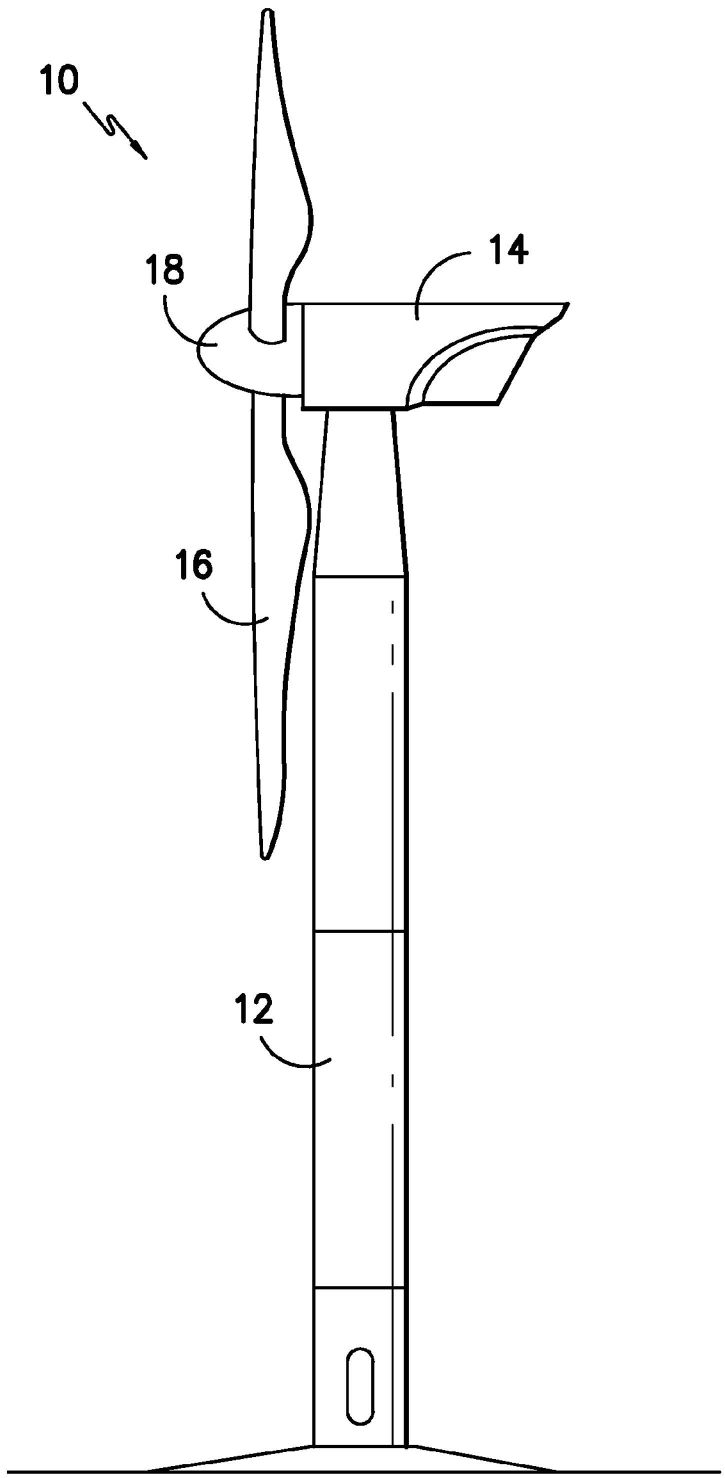


FIG. –1–

PRIOR ART

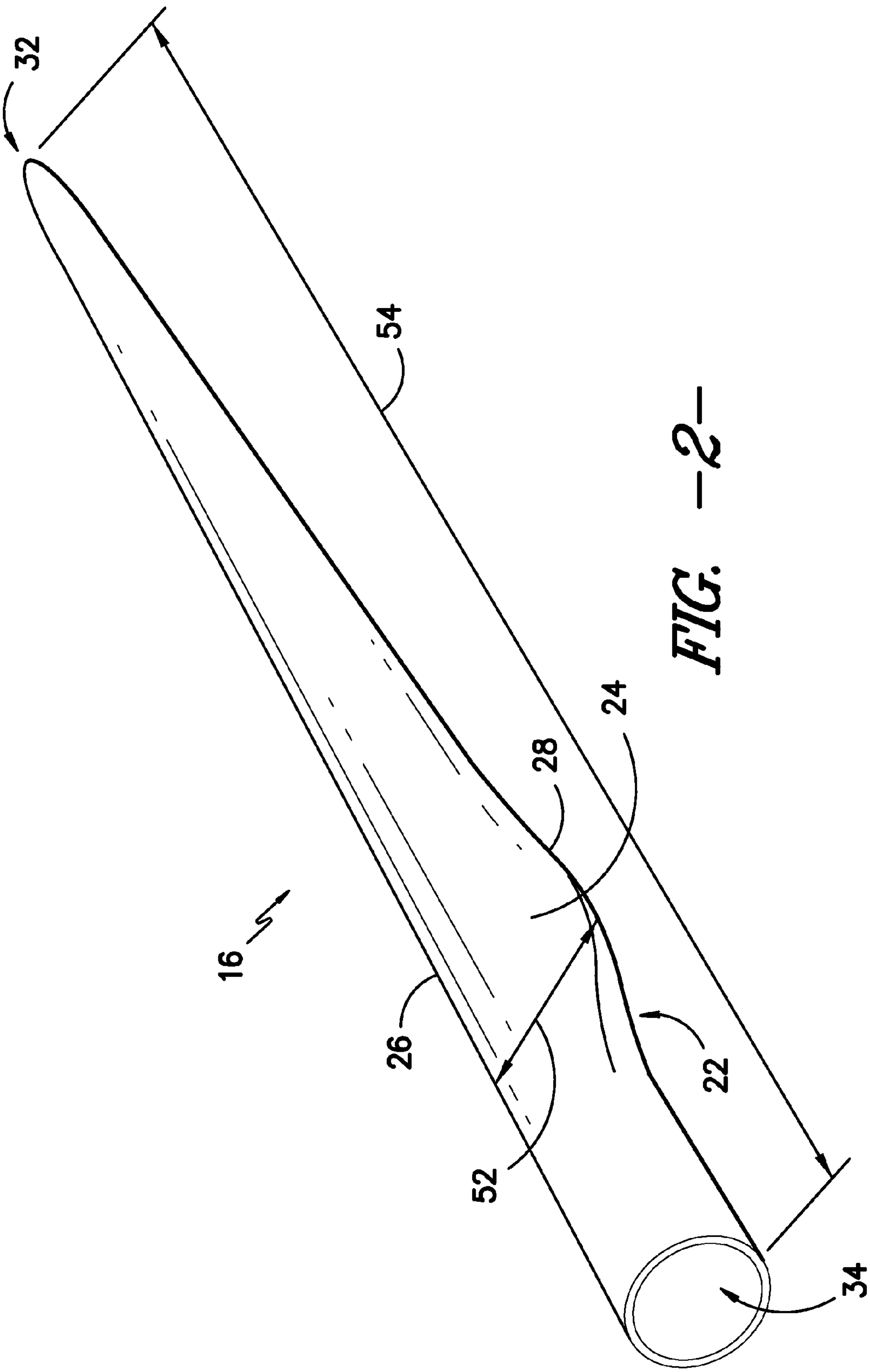


FIG. -2-

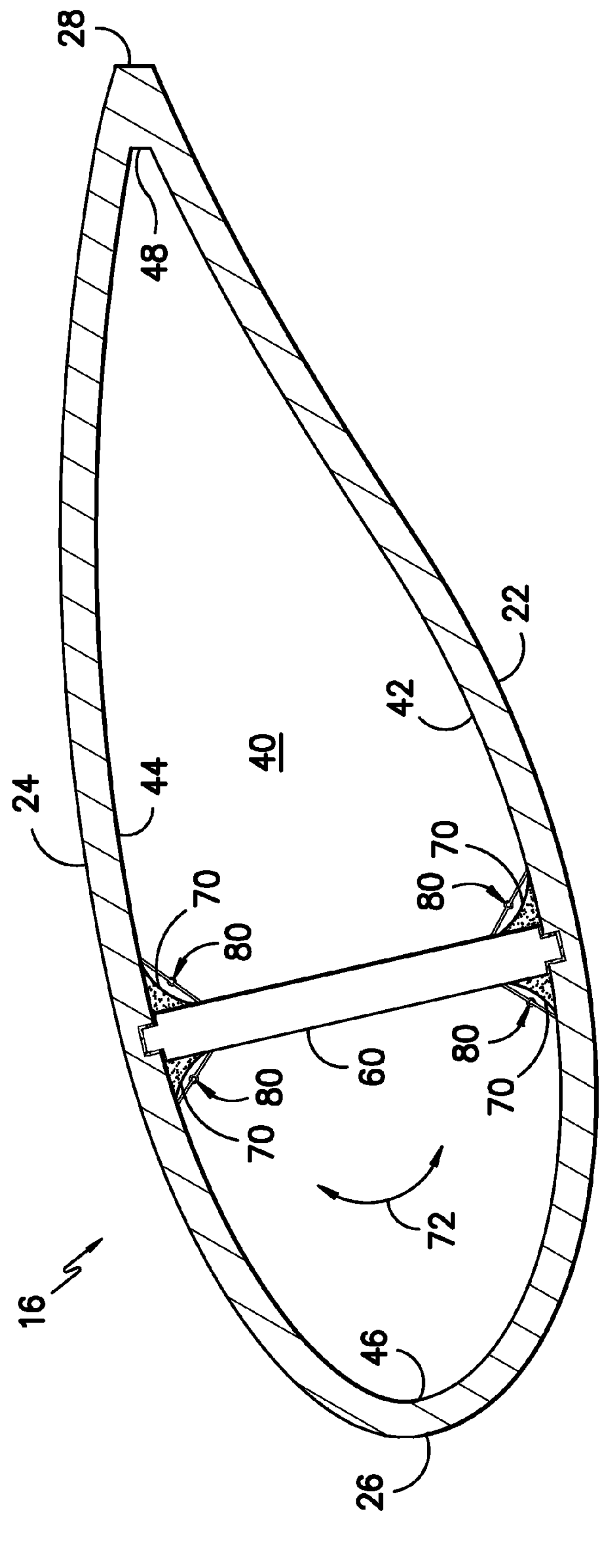


FIG. —3—

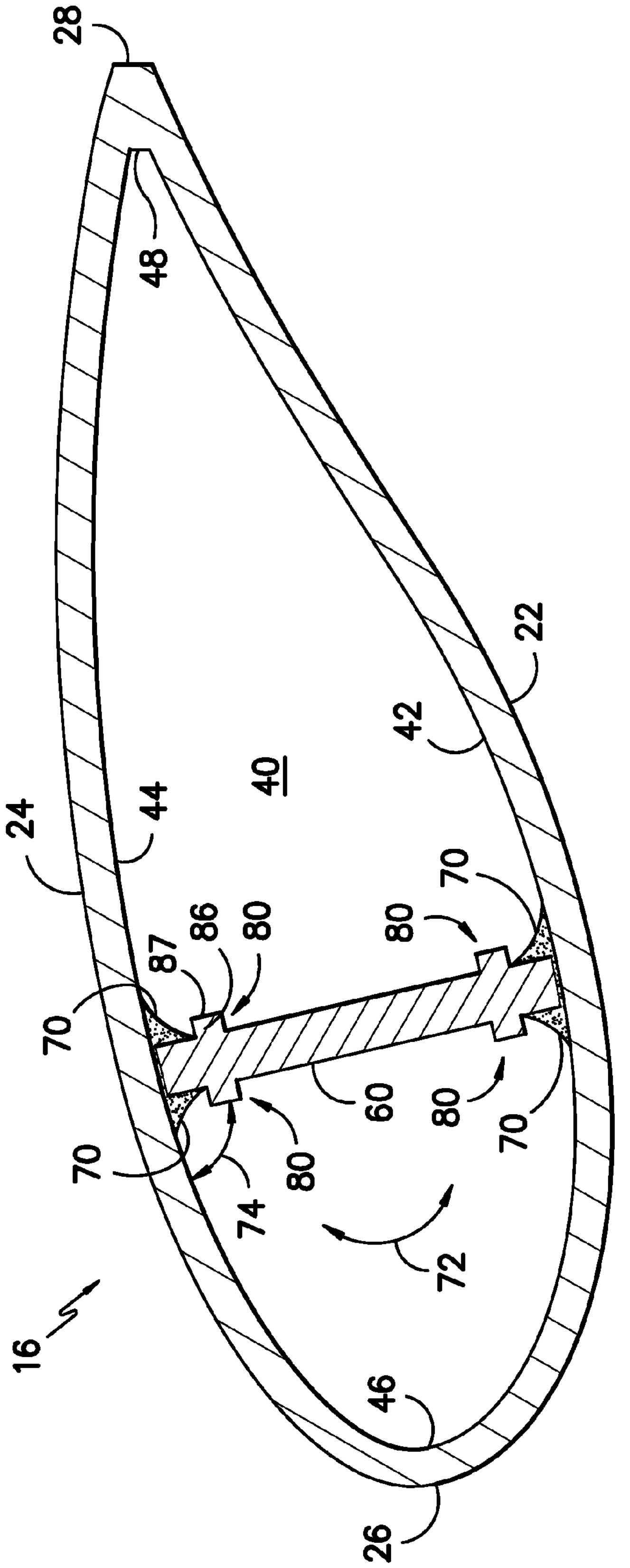


FIG. -4-

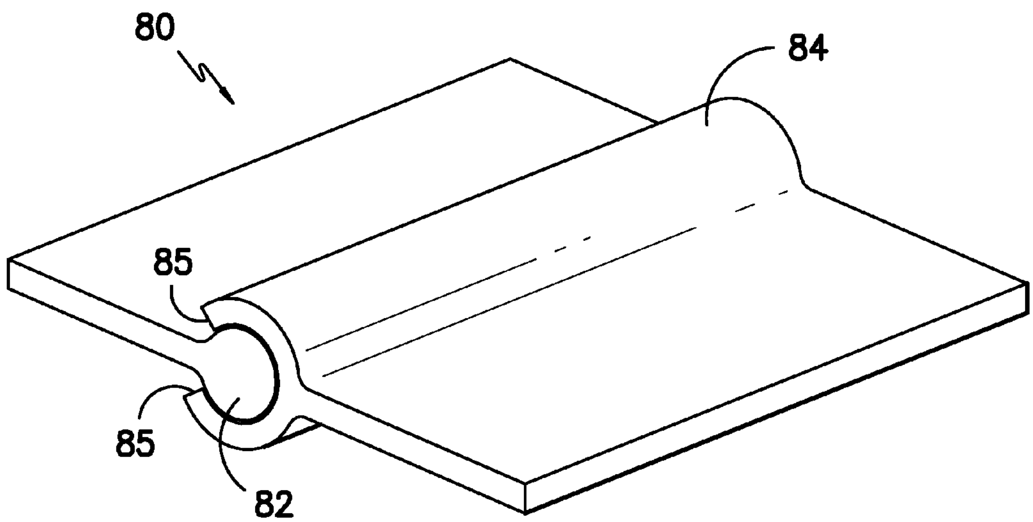


FIG. –5–

ROTOR BLADE

FIELD OF THE INVENTION

[0001] The present disclosure is directed in general to rotor blades, and more particularly to apparatus for allowing movement, such as twist, of the rotor blade with respect to inner structural members of the rotor blade.

BACKGROUND OF THE INVENTION

[0002] Wind power is considered one of the cleanest, most environmentally friendly energy sources presently available, and wind turbines have gained increased attention in this regard. A modern wind turbine typically includes a tower, generator, gearbox, nacelle, and one or more rotor blades. The rotor blades capture kinetic energy of wind using known airfoil principles. The rotor blades transmit the kinetic energy in the form of rotational energy so as to turn a shaft coupling the rotor blades to a gearbox, or if a gearbox is not used, directly to the generator. The generator then converts the mechanical energy to electrical energy that may be deployed to a utility grid.

[0003] The construction of a modern rotor blade generally includes shell components, spar caps, and one or more shear webs. The shell components, typically manufactured from layers of fiber composite and a lightweight core material, forms the exterior aerodynamic foil shape of the rotor blade. The spar caps provide increased rotor blade strength by integrating one or more structural elements running along the span of the rotor blade on both interior sides of the rotor blade. Shear webs are structural beam-like components running essentially perpendicular between the top and bottom spar caps and extending across the interior portion of the rotor blade between the shell components.

[0004] The size, shape, and weight of rotor blades are factors that contribute to energy efficiencies of wind turbines. An increase in rotor blade size increases the energy production of a wind turbine, while a decrease in weight furthers the efficiency of a wind turbine. Furthermore, as rotor blade sizes grow, extra attention needs to be given to the structural integrity of the rotor blades. Presently, large commercial wind turbines in existence and in development are capable of generating from about 1.5 to about 12.5 megawatts of power. These larger wind turbines may have rotor blade assemblies larger than 90 meters in diameter. Additionally, advances in rotor blade shape encourage the manufacture of a forward swept-shaped rotor blade having a general arcuate contour from the base to the tip of the blade, providing improved aerodynamics. Accordingly, efforts to increase rotor blade size, decrease rotor blade weight, and increase rotor blade strength, while also improving rotor blade aerodynamics, aid in the continuing growth of wind turbine technology and the adoption of wind energy as an alternative energy source.

[0005] Rotor blades with such increases and improvements in size, shape, and weight may, however, have various disadvantages. For example, these rotor blades must be relatively flexible in order to prevent damage when experiencing high loading. Thus, for example, many such rotor blades may be formed from materials that allow bending towards the tower when experiencing high loading from, for example, high wind speeds. However, too much bending may cause a rotor blade to strike the tower, potentially causing damage to both the rotor blade and tower. Some blades are thus curved, as discussed above, to allow twisting of the rotor blade. Twisting of the rotor blade may allow for shedding of loads when high loads are experienced, which may help prevent a rotor blade from striking the tower. However, curving in many cases does not allow for sufficient twisting.

[0006] Thus, a rotor blade that can twist sufficiently to allow desirable levels of load shedding would be desired in the art.

BRIEF DESCRIPTION OF THE INVENTION

[0007] Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

[0008] In one embodiment, a rotor blade for a wind turbine is disclosed. The rotor blade includes an outer shell having exterior surfaces and interior surfaces, the exterior surfaces defining a pressure side and a suction side each extending between a leading edge and a trailing edge, the interior surfaces defining a rotor blade interior. The rotor blade further includes a structural member extending through at least a portion of the interior, and a generally elastic material connecting the structural member to an interior surface. The generally elastic material allows movement of the outer shell with respect to the structural member.

[0009] In another embodiment, a rotor blade for a wind turbine is disclosed. The rotor blade includes an outer shell having exterior surfaces and interior surfaces, the exterior surfaces defining a pressure side and a suction side each extending between a leading edge and a trailing edge, the interior surfaces defining a rotor blade interior. The rotor blade further includes a structural member extending through at least a portion of the interior, the structural member movably connected to an interior surface such that passive movement of the outer shell is allowed with respect to the structural member.

[0010] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

[0012] FIG. **1** is a side view of a wind turbine according to one embodiment of the present disclosure;

[0013] FIG. **2** is a perspective view of a rotor blade according to one embodiment of the present disclosure;

[0014] FIG. **3** is a cross-sectional view of a rotor blade according to one embodiment of the present disclosure;

[0015] FIG. **4** is a cross-sectional view of a rotor blade according to another embodiment of the present disclosure; and,

[0016] FIG. **5** is a perspective view of a stop according to one embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0018] FIG. **1** illustrates a wind turbine **10** of conventional construction. The wind turbine **10** includes a tower **12** with a nacelle **14** mounted thereon. A plurality of rotor blades **16** are mounted to a rotor hub **18**, which is in turn connected to a main flange that turns a main rotor shaft. The wind turbine power generation and control components are housed within the nacelle **14**. The view of FIG. **1** is provided for illustrative purposes only to place the present invention in an exemplary field of use. It should be appreciated that the invention is not limited to any particular type of wind turbine configuration.

[0019] Referring to FIG. **2**, a rotor blade **16** according to the present disclosure may include a shell **20**. The shell **20** may have exterior surfaces defining a pressure side **22** and a suction side **24** extending between a leading edge **26** and a trailing edge **28**, and may extend from a blade tip **32** to a blade root **34**. The exterior surfaces may be generally aerodynamic surfaces having generally aerodynamic contours, as is generally known in the art.

[0020] The shell **20** may further have interior surfaces. The interior surfaces may define an interior **40** of the rotor blade **16**. Further, the interior surfaces may include a pressure side interior surface **42**, suction side interior surface **44**, leading edge interior surface **46**, and trailing edge interior surface **48**.

[0021] The rotor blade **16** according to the present disclosure may include a plurality of individual rotor blade sections aligned in a generally span-wise, end-to-end, order between the blade tip **32** and the blade root **34**. Each of the individual rotor blade sections may be uniquely configured so that the plurality of rotor blade sections define a complete rotor blade **16** having a designed aerodynamic profile, length, and other desired characteristics. For example, each of the rotor blade sections may have an aerodynamic profile that corresponds to the aerodynamic profile of adjacent rotor blade sections. Thus, the aerodynamic profiles of the rotor blade sections may form a continuous aerodynamic profile of the rotor blade **16**.

[0022] The rotor blade **16** may, in exemplary embodiments, be curved. Curving of the rotor blade **16** may entail bending the rotor blade **16** in a generally flapwise direction and/or in a generally edgewise direction. The flapwise direction may generally be construed as the direction (or the opposite direction) in which the aerodynamic lift acts on the rotor blade **16**. The edgewise direction is generally perpendicular to the flapwise direction. Flapwise curvature of the rotor blade **16** is also known as pre-bend, while edgewise curvature is also known as sweep. Thus, a curved rotor blade **16** may be pre-bent and/or swept. Curving may enable the rotor blade **16** to better withstand flapwise and edgewise loads during operation of the wind turbine **10**, and may further provide clearance for the rotor blade **16** from the tower **12** during operation of the wind turbine **10**.

[0023] The rotor blade **16** may further define a chord **52** and a span **54** extending in chord-wise and span-wise directions, respectively. As shown, the chord **52** may vary throughout the span **54** of the rotor blade **16**.

[0024] In some embodiments, the outer shell **20** may additionally include a spar cap or spar caps (not shown). The spar caps may extend through at least a portion of the rotor blade **16**, such as in the generally span-wise direction along at least a portion of the span **54**. For example, in some embodiments, the outer shell **20** may include a pressure side spar cap and a suction side spar cap.

[0025] As shown in FIGS. **3** and **4**, the rotor blade **16** may further include a structural member **60** or a plurality of structural members **60**. Each structural member **60** may extend though at least a portion of the interior **40**. A structural member **60** may have any suitable cross-sectional shape. For example, a structural member may be generally rectangular, or may be generally I-shaped, or may have any other suitable cross-sectional shape. As discussed below, the structural member **60** may be connected to the outer shell **20**. Thus, the structural member **60** may provide structural integrity to the rotor blade **16**. In some embodiments, for example, the structural member **60** may be a shear web, as shown. However, it should be understood that the structural member **60** is not limited to shear webs, and rather that any suitable structural member **60** is within the scope and spirit of the present disclosure.

[0026] In some embodiments, the structural member **60** may extend in a generally span-wise direction through at least a portion of the interior **40**, and thus through at least a portion of the span **54**. In other embodiments, however, the structural member **60** may extend in a generally chord-wise direction through at least a portion of the interior **40**, or may extend in at any suitable angle or in any suitable direction through at least a portion of the interior.

[0027] A structural member **60** may be connected to the outer shell **20**, such as to one or more interior surfaces of the outer shell **20**. For example, a structural member **60** may be connected to any one or more interior surfaces adjacent to the pressure side **22**, suction side **24**, leading edge **26**, and/or trailing edge **28**, such as to any one or more of the pressure side interior surface **42**, suction side interior surface **44**, leading edge interior surface **46**, and/or trailing edge interior surface **48**. In some embodiments as shown, for example, a structural member **60** is connected to the interior surfaces adjacent to the pressure side **22** and the suction side **24**, such as connected to the pressure side interior surface **42** and suction side interior surface **44**. Further, the shear web may in some embodiments be connected to the spar caps of the outer shell **20**.

[0028] The structural members **60** according to the present disclosure may allow passive movement of the outer shell **20** with respect to the structural members **60**. Passive movement according to the present disclosure means movement due to external forces, such as high speed winds, rather than active movement, such as mechanical movement, of a structural member **60** to move the outer shell **20**. Thus, the outer shell **20** may passively move linearly or rotate with respect to the structural member **60**. This movement may generally occur due to loading of the rotor blade **16**, such as from high speed winds or other forces. Further, after such loading has decreased or discontinued, the outer shell **20** to return to its approximate original position with respect to the structural member **60**.

[0029] In some embodiments, for example, passive twisting of the outer shell **20** with respect to the structural member may occur. Twist is generally defined as rotation in twist direction **72**, such as about an axis generally defined as extending in the direction of the span **54**. However, it should be understood that the present disclosure is not limited to twist, and rather that any suitable movement, linearly and/or rotationally, is within the scope and spirit of the present disclosure.

[0030] For example, the rotor blade **16** according to the present disclosure may further include a generally elastic material **70**. The material **70** connects a structural member **60** to an interior surface of the outer shell **20**, as discussed above. The material **70** thus adheres the structural member **60** to the outer shell **20**, allowing the structural member **60** to provide structural rigidity to the rotor blade **16**.

[0031] The generally elastic material **70** may be, for example, an elastomer, such as a rubber. For example, the material **70** may be a saturated rubber, an unsaturated rubber, a thermoplastic elastomer, a resilin, an elastin, a polysulfide rubber, or any other suitable elastomer. Alternatively, the generally elastic material **70** may be any suitable material that allows movement of the outer shell **20** with respect to the structural member **60**, as discussed below.

[0032] As mentioned, the generally elastic material **70** advantageously allows movement of the outer shell **20**, such as any portion thereof, with respect to the structural member **60**. Thus, the outer shell **20** may move linearly or may rotate with respect to the structural member **60** due to the generally elastic material **70**. This movement may generally occur due to loading of the rotor blade **16**, such as from high speed winds or other forces. Further, after such loading has decreased or discontinued, the generally elastic material **70** may allow the outer shell **20** to return to its approximate original position with respect to the structural member **60**.

[0033] In some embodiments, for example, the material **70** may allow twist of the outer shell **20** with respect to the structural member. Twist is generally defined as rotation in twist direction **72**, such as about an axis generally defined as extending in the direction of the span **54**. However, it should be understood that the present disclosure is not limited to twist, and rather that any suitable movement, linearly and/or rotationally, is within the scope and spirit of the present disclosure.

[0034] In some embodiments, the material **70** may only allow the outer shell **20** to move within a certain specified range, and up to a certain maximum movement. For example, in some embodiments, the material **70** may only allow a specified twist of the outer shell **20** with respect to the structural member **60**. For example, the material **70** may allow a maximum twist **74** of approximately 30 degrees, approximately 20 degrees, approximately 15 degrees, approximately 10 degrees, or any other suitable maximum twist range. It should be understood that the specified range, such as maximum twist, is a range in any direction from an original position. Thus, for example, with a maximum twist of approximately 30 degrees, for example, the outer shell **20** may be allowed to twist approximately 30 degrees in one twist direction as well as 30 degrees in the opposite twist direction.

[0035] As shown in FIGS. **3** through **5**, a rotor blade **16** according to the present disclosure may further comprise a stop **80** or a plurality of stops **80**. Each stop **80** may be positioned to prevent movement of the outer shell **20** with respect to the structural member **60** beyond a maximum movement, such as a maximum twist. For example, the stop **80** may be mounted to an interior surface and/or to a structural member **60**, and may limit the movement of the outer shell **20** with respect to the structural member **60** to within the maximum allowed movement, such as the maximum twist.

[0036] In some embodiments, as shown in FIGS. **3** and **5**, for example, a stop **80** may include a ball portion **82** and a socket portion **84**. The socket portion **84** may have one or more stop surfaces **85**. The ball portion **82** may be mounted to one of the interior surface or the structural member **60**, and the socket portion **84** may be mounted to the other of the interior surface or the structural member **60**. The ball portion **82** may be movably mounted within the socket portion **84**, such that the ball portion **82** may move with respect to the socket portion **84** when the outer shell **20** moves with respect to the structural member **60**. However, stop surfaces **85** may contact the ball portion **82** to prevent movement of the ball portion **82** past a certain point, which may define the maximum movement of the outer shell **20** with respect to the structural member **60**.

[0037] In other embodiments, as shown in FIG. **4**, for example, a stop **80** may comprise a protrusion **86**. The protrusion **86** may extend from an inner surface or from a structural member **60**, and may be integral with or a separate component from the inner surface or structural member **60**. The protrusion **86** may have one or more stop surfaces **87**. The protrusion **86** may be sized such that, when movement of the outer shell **20** with respect to the structural member **60** reaches a maximum movement, a stop surface **87** contacts the other of the inner surface or structural member **60**, thus preventing movement past this maximum movement.

[0038] A stop **80** according to the present disclosure may extend throughout at least a portion of the structural member **60** in the direction that the structural member **60** extends with respect to the rotor blade **16**. For example, in embodiments wherein the structural member **60** extends in a generally span-wise direction, the stop **80** may extend throughout at least a portion of the structural member in the span-wise direction.

[0039] It should be understood that the present disclosure is not limited to stops **80** as disclosed above, and rather that any suitable stop device that may prevent movement of the outer shell **20** with respect to the structural member **60** past a maximum movement is within the scope and spirit of the present disclosure.

[0040] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A rotor blade for a wind turbine, the rotor blade comprising:

an outer shell having exterior surfaces and interior surfaces, the exterior surfaces defining a pressure side and a suction side each extending between a leading edge and a trailing edge, the interior surfaces defining a rotor blade interior;

a structural member extending through at least a portion of the interior; and,

a generally elastic material connecting the structural member to an interior surface, the generally elastic material allowing movement of the outer shell with respect to the structural member.

2. The rotor blade of claim **1**, wherein the generally elastic material is an elastomer.

3. The rotor blade of claim **1**, wherein the generally elastic material is a rubber.

4. The rotor blade of claim **1**, wherein the structural member extends in a generally span-wise direction through at least a portion of the interior.

5. The rotor blade of claim **1**, wherein the structural member is a shear web.

6. The rotor blade of claim **1**, wherein the structural member is connected to interior surfaces adjacent to the pressure side and the suction side.

7. The rotor blade of claim **1**, wherein the generally elastic material allows twist of the outer shell with respect to the structural member.

8. The rotor blade of claim **7**, wherein the generally elastic material allows a maximum twist of the outer shell with respect to the structural member of approximately 15 degrees.

9. The rotor blade of claim **1**, further comprising a stop, the stop positioned to prevent movement of the outer shell with respect to the structural member beyond a maximum movement.

10. The rotor blade of claim **9**, wherein the generally elastic material allows twist of the outer shell with respect to the structural member, and wherein the stop prevents movement of the outer shell with respect to the structural member beyond a maximum twist.

11. The rotor blade of claim **10**, wherein the maximum twist is approximately 15 degrees.

12. The rotor blade of claim **9**, wherein the stop comprises a ball portion and a socket portion.

13. The rotor blade of claim **9**, wherein the stop comprises a protrusion extending from the structural member.

14. A wind turbine comprising:

a plurality of rotor blades, at least one of the plurality of rotor blades comprising:

an outer shell having exterior surfaces and interior surfaces, the exterior surfaces defining a pressure side and a suction side each extending between a leading edge and a trailing edge, the interior surfaces defining a rotor blade interior;

a structural member extending through at least a portion of the interior; and,

a generally elastic material connecting the structural member to an interior surface, the generally elastic material allowing movement of the outer shell with respect to the structural member.

15. The wind turbine of claim **14**, wherein the generally elastic material is an elastomer.

16. The wind turbine of claim **14**, wherein the structural member extends in a generally span-wise direction through at least a portion of the interior.

17. The wind turbine of claim **14**, wherein the structural member is connected to interior surfaces adjacent to the pressure side and the suction side.

18. The wind turbine of claim **14**, wherein the generally elastic material allows twist of the outer shell with respect to the structural member.

19. The wind turbine of claim **14**, further comprising a stop, the stop positioned to prevent movement of the outer shell with respect to the structural member beyond a maximum movement.

20. A rotor blade for a wind turbine, the rotor blade comprising:

an outer shell having exterior surfaces and interior surfaces, the exterior surfaces defining a pressure side and a suction side each extending between a leading edge and a trailing edge, the interior surfaces defining a rotor blade interior; and,

a structural member extending through at least a portion of the interior, the structural member movably connected to an interior surface such that passive movement of the outer shell is allowed with respect to the structural member.

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