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(54) **JOINT SLEEVE FOR A ROTOR BLADE ASSEMBLY OF A WIND TURBINE**

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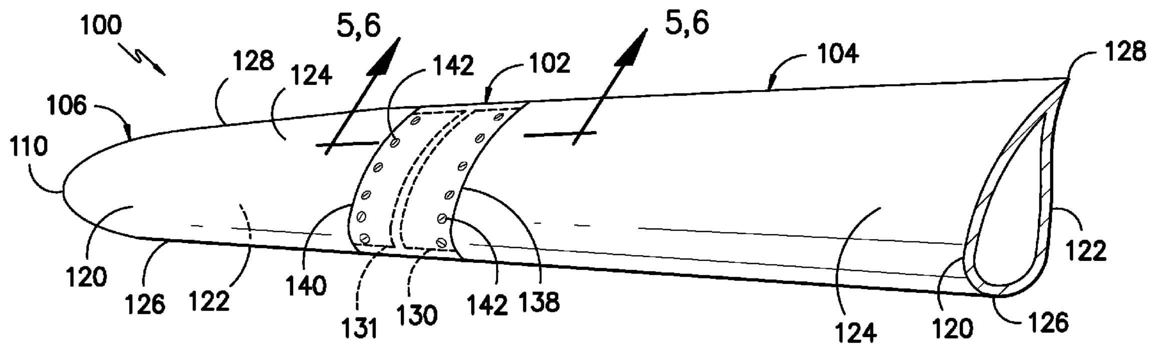
(57) **ABSTRACT**

A joint sleeve for assembling together a first blade section and a second blade section of a rotor blade assembly is disclosed. The joint sleeve may include an outer surface and an inner surface defining a cavity. The cavity may be configured to receive a joint end of the first blade section and a joint end of the second blade section. The joint sleeve may also include a plurality of openings defined between the outer and inner surfaces. The openings may be configured to receive fasteners for securing the joint ends of the first and second blade sections within the cavity. Additionally, a profile of the outer surface may be configured to generally correspond to an aerodynamic profile of the first and second blade sections such that a substantially continuous aerodynamic profile is defined between the first and second blade sections when the joint ends are inserted within the cavity.



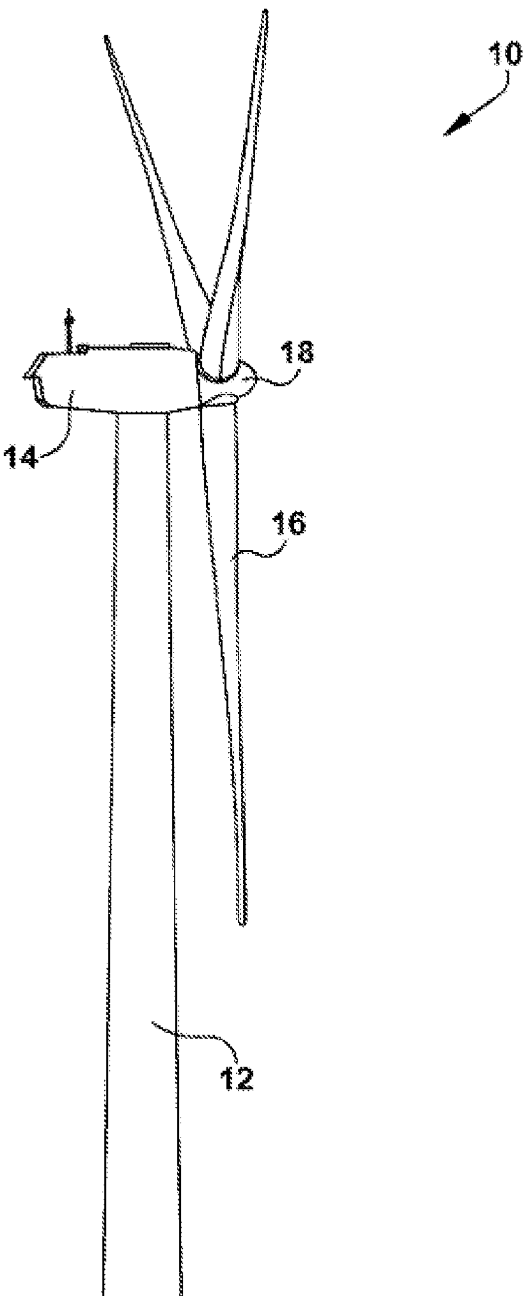


FIG. -1-

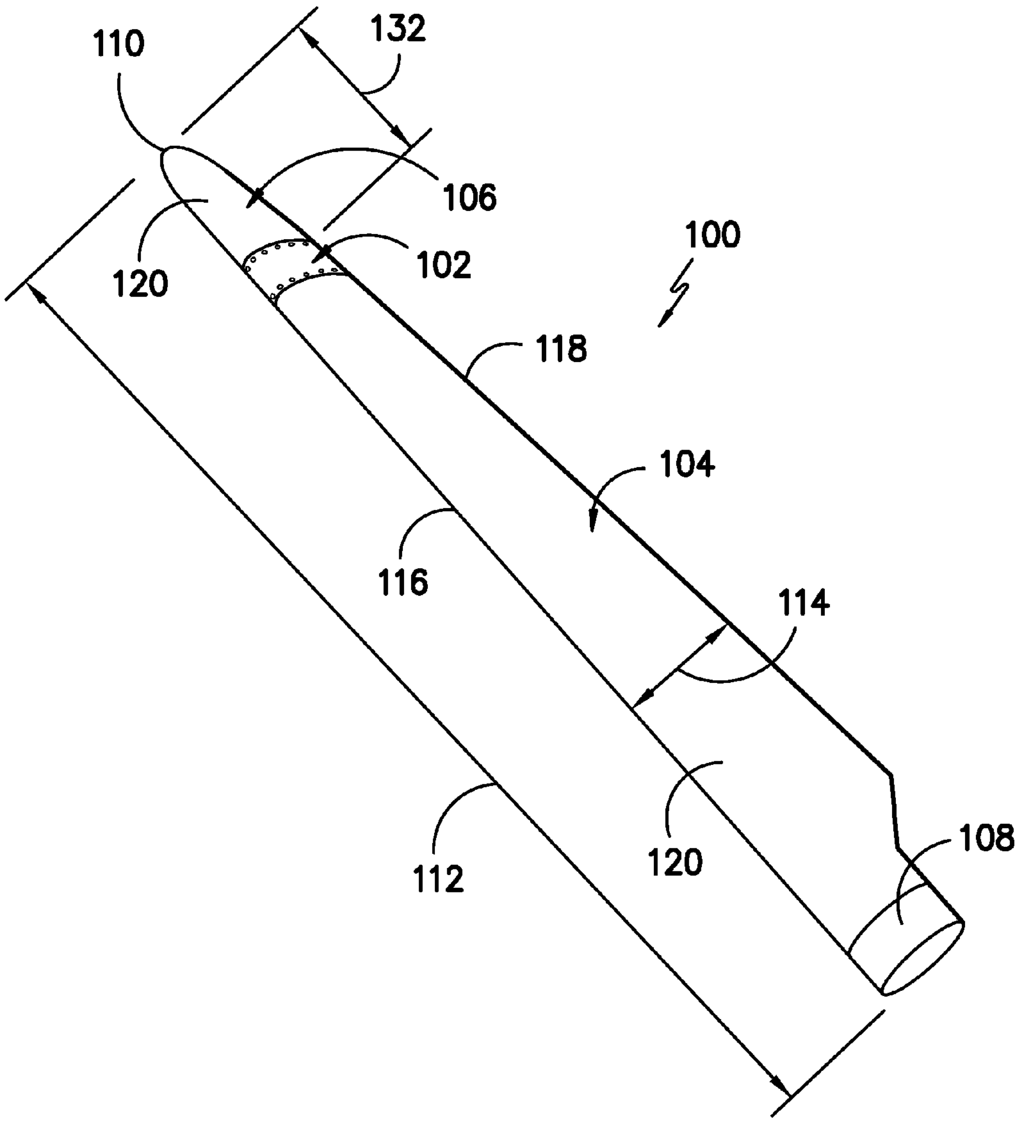
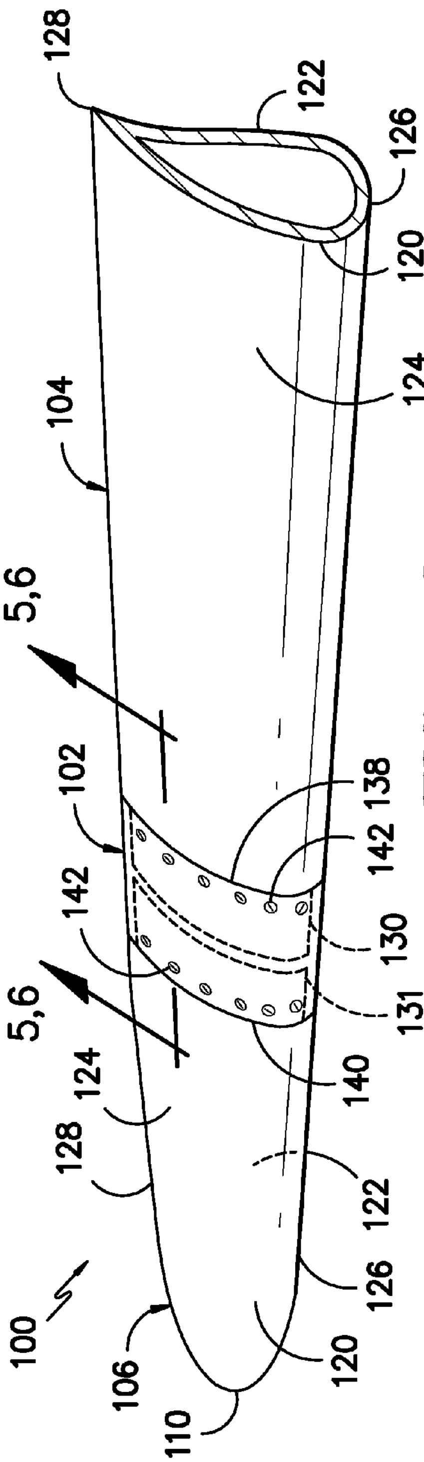


FIG. –2–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142
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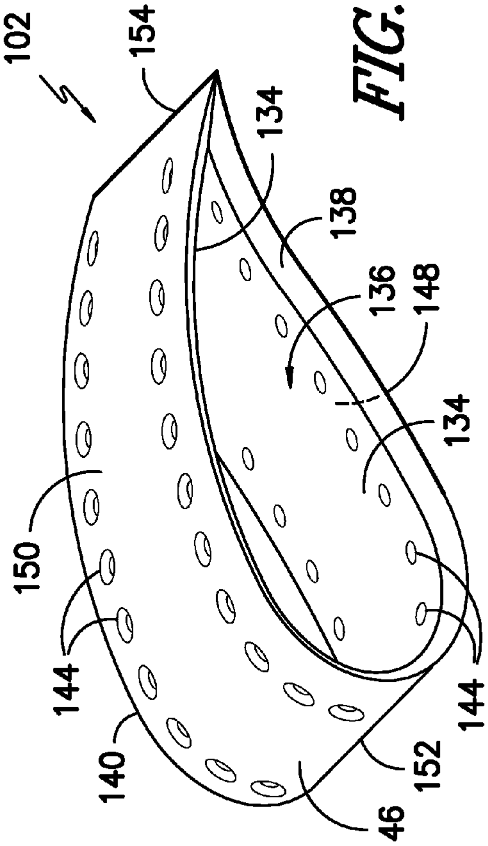
110
100

FIG. —3—


102
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134
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148
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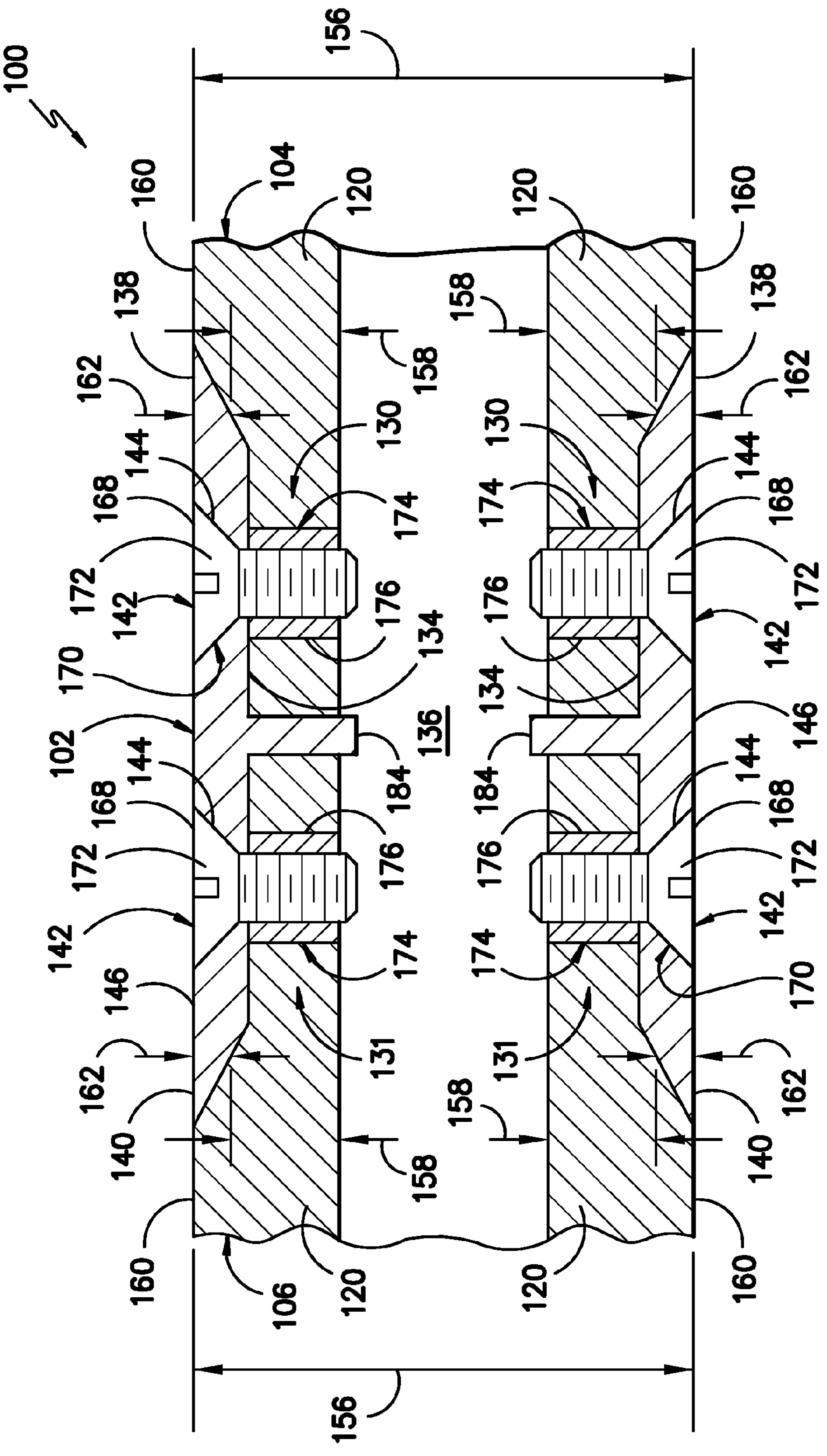
152
144

FIG. —4—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106
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102
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184

FIG. -5-

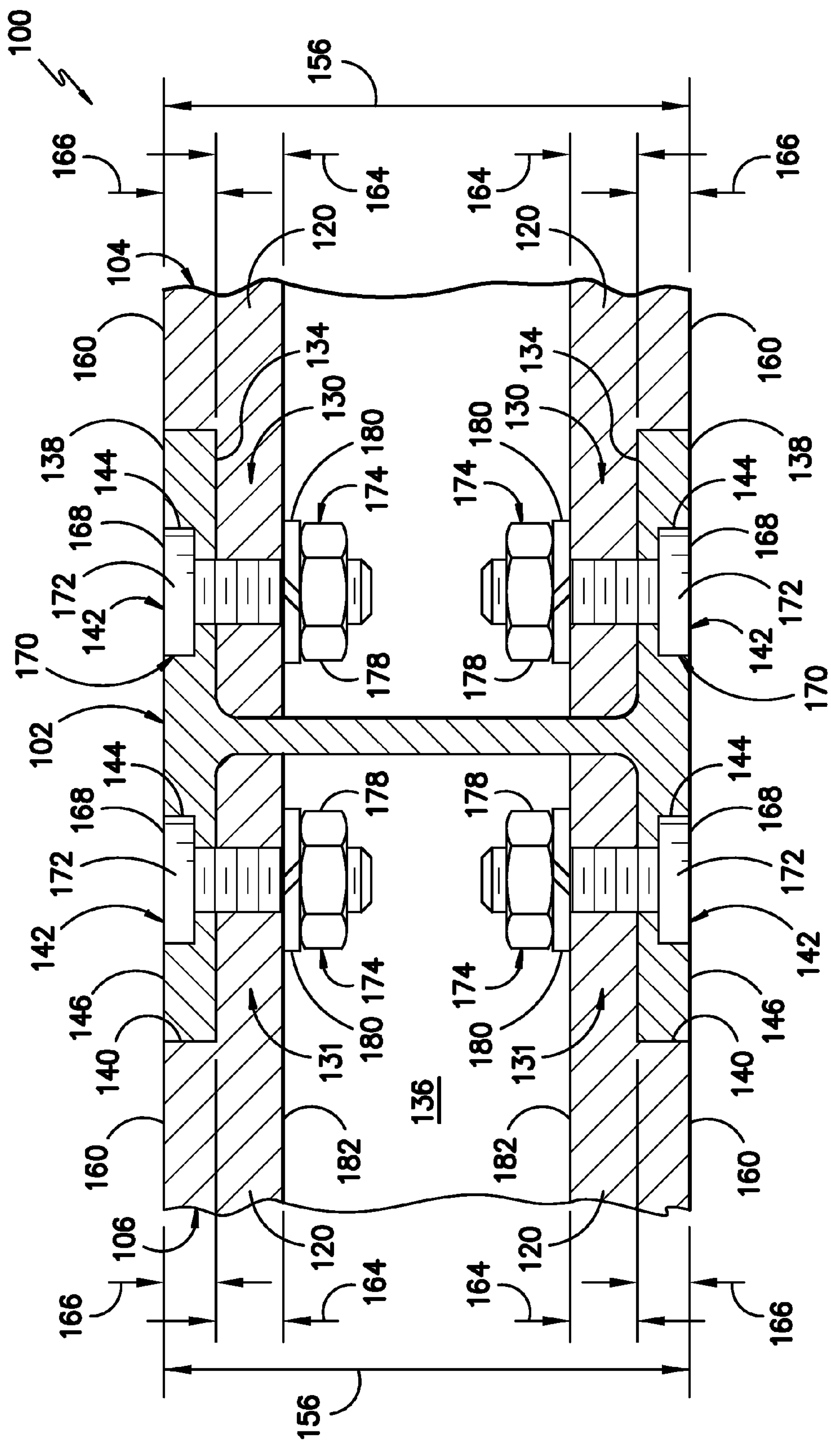
100
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FIG. -6-

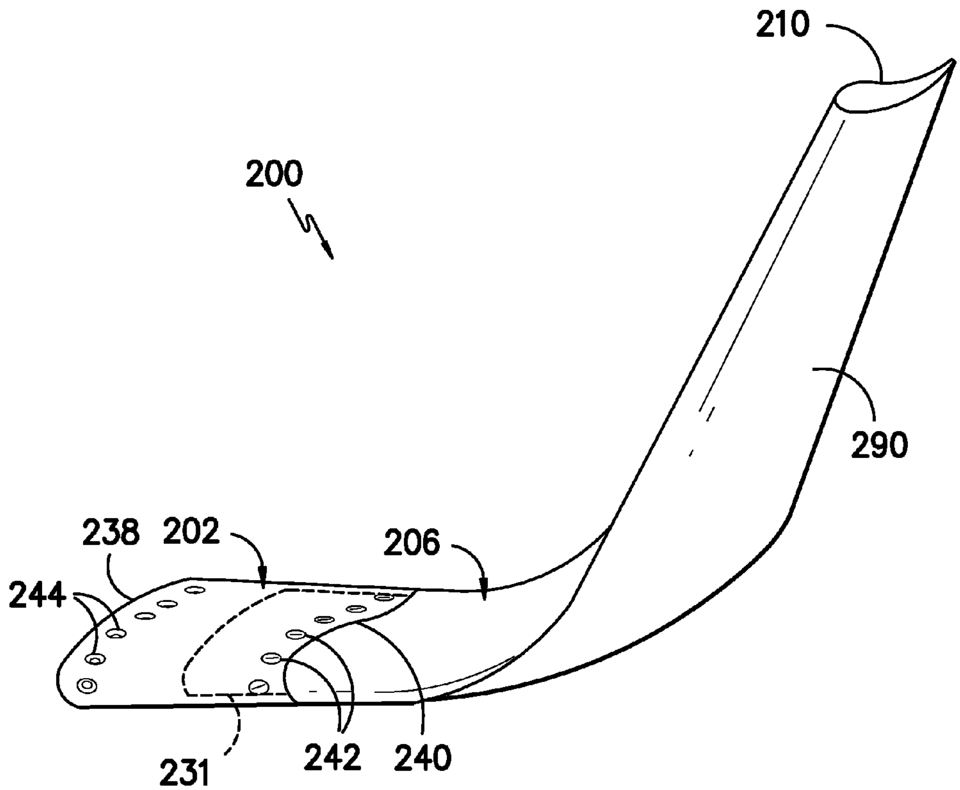

FIG. -7-

JOINT SLEEVE FOR A ROTOR BLADE ASSEMBLY OF A WIND TURBINE

FIELD OF THE INVENTION

[0001] The present subject matter relates generally to rotor blades of a wind turbine and, more particularly, to a joint sleeve for joining blade sections of a rotor blade assembly.

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 from wind using known foil principles and transmit the kinetic energy through rotational energy 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] To ensure that wind power remains a viable energy source, efforts have been made to improve the overall performance of wind turbines by modifying the size, shape and configuration of wind turbine rotor blades. One such modification has been to alter the configuration of the tip of the rotor blade. In particular, blade tips may be specifically designed to enhance or improve various aspects of a rotor blade's performance. For example, certain blade tips may be designed to operate efficiently in specific wind classes. Additionally, blade tips may be configured to enhance specific operating conditions of the wind turbine, such as by being configured to lower torque or reduce noise.

[0004] Thus, given that different operating advantages may be provided to a wind turbine depending on the configuration of the blade tip, it would be advantageous to have an attachment device that allowed for the quick and efficient assembly and disassembly of blade tips on and from a rotor blade. However, known attachment devices are typically complex and are manually intensive to install. Additionally, such attachment devices make it difficult to accurately align the blade tip with the remainder of the rotor blade.

[0005] Accordingly, there is a need for a simple and efficient attachment device for joining two blade sections of a rotor blade assembly.

BRIEF DESCRIPTION OF THE INVENTION

[0006] 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.

[0007] In one aspect, the present subject matter discloses a rotor blade assembly for a wind turbine. The rotor blade assembly generally includes a first blade section having a joint end and defining an aerodynamic profile and a second blade section having a joint end and defining an aerodynamic profile. The rotor blade assembly also includes a joint sleeve having an inner surface and an outer surface. The inner surface may generally define a cavity configured to receive the joint ends of the first and second blade sections. Additionally, the rotor blade assembly may include a plurality of fasteners configured to secure the joint ends of the first and second blade sections within the cavity. Further, a profile of the outer surface of the joint sleeve may generally correspond to the aerodynamic profiles of the first and second blade sections such that a substantially continuous aerodynamic profile is defined between the first and second blade sections when the joint ends are inserted within the cavity.

[0008] In another aspect, the present subject matter discloses a joint sleeve for assembling together a first blade section and a second blade section of a rotor blade assembly. The joint sleeve may include an outer surface and an inner surface defining a cavity. The cavity may have a root end configured to receive a joint end of the first blade section and a tip end configured to receive a joint end of the second blade section. The joint sleeve may also include a plurality of openings defined between the outer and inner surfaces. The openings may be configured to receive a plurality of fasteners for securing the joint ends of the first and second blade sections within the cavity. Additionally, a profile of the outer surface may be configured to generally correspond to an aerodynamic profile of the first and second blade sections such that a substantially continuous aerodynamic profile is defined between the first and second blade sections when the joint ends are inserted within the cavity.

[0009] In a further aspect, the present subject matter discloses a tip assembly for a rotor blade of a wind turbine. The tip assembly may generally include a joint sleeve having an inner surface defining a cavity and an outer surface defining an aerodynamic profile. The joint sleeve may also include a tip end and a root end. The tip assembly may also include a tip section extending between a joint end disposed within the cavity and a blade tip. The tip section may define an aerodynamic profile generally corresponding to the aerodynamic profile of the joint sleeve at the tip end. Additionally, tip assembly may include a plurality of fasteners configured to secure the joint end of the tip section within the cavity. Further, a portion of the cavity disposed at the root end of the joint sleeve may be configured to receive an end of a separate section of the rotor blade.

[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** illustrates a perspective view of a wind turbine of conventional construction;

[0013] FIG. **2** illustrates a perspective view of one embodiment of a rotor blade assembly in accordance with aspects of the present subject matter;

[0014] FIG. **3** illustrates a partial, perspective view of the rotor blade assembly shown in FIG. **2**;

[0015] FIG. **4** illustrates a perspective view of one embodiment of a joint sleeve suitable for use with the disclosed rotor blade assembly in accordance with aspects of the present subject matter;

[0016] FIG. **5** illustrates a partial, cross-sectional view of one embodiment of the attachment of several components of the disclosed rotor blade assembly in accordance with aspects of the present subject matter;

[0017] FIG. 6 illustrates a partial, cross-sectional view of another embodiment of the attachment of several components of the disclosed rotor blade assembly in accordance with aspects of the present subject matter; and,

[0018] FIG. 7 illustrates a perspective view of an embodiment of a tip assembly in accordance with aspects of the present subject matter.

DETAILED DESCRIPTION OF THE INVENTION

[0019] 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.

[0020] In general, the present subject matter is directed to a joint sleeve for joining together blades sections of a rotor blade assembly. In particular, the joint sleeve may define a cavity configured to receive an end of each blade section. For example, the cavity may generally have a shape corresponding to the shape of the ends of the blade sections, such as by having a tapered, aerodynamic profile corresponding to the tapered, aerodynamic profiles of the blade section ends. Suitable fasteners may then be inserted around the periphery of the joint sleeve to secure the ends of the blade sections within the cavity.

[0021] The disclosed joint sleeve may generally provide for the quick and efficient assembly and disassembly of a rotor blade. As such, a blade section may be easily removed from and re-assembled onto the rotor blade for purposes of maintenance, repairs and/or for upgrading the performance of the rotor blade. For example, it may be preferable to vary the tip section of the rotor blade depending on the wind turbine operating conditions and/or the desired performance of the rotor blade assembly. Thus, by using the disclosed joint sleeve, tip sections having differing dimensions, configurations and/or aerodynamic features may be efficiently assembled onto the rotor blade and/or replaced as desired. For example, a straight tip section (e.g., a tip section extending in a substantially spanwise direction) may be replaced with a winglet-type tip section or vice versa. Similarly, a winglet having a particular configuration may be replaced with a winglet having a different configuration.

[0022] Referring now to the drawings, FIG. **1** illustrates perspective view of 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**. It should be appreciated that the wind turbine **10** of FIG. **1** is provided for illustrative purposes only to place the present subject matter in an exemplary field of use. Thus, one of ordinary skill in the art should readily appreciate that the scope of the present subject matter is not limited to any particular type of wind turbine configuration.

[0023] Referring now to FIGS. **2-4**, embodiments of a rotor blade assembly **100** and a joint sleeve **102** for joining together first and second blade sections **104**, **106** of the rotor blade assembly **100** are illustrated in accordance with aspects of the present subject matter. In particular, FIG. **2** illustrates a perspective view of one embodiment of the rotor blade assembly **100**. FIG. **3** illustrates a partial, perspective view of the rotor blade assembly **100** illustrated in FIG. **2**, particularly illustrating the joint sleeve **102** disposed between the blade sections **104**, **106** of the rotor blade assembly **100**. Additionally, FIG. **4** illustrates a perspective view of one embodiment of the joint sleeve **102**.

[0024] As shown, the rotor blade assembly **100** includes a first blade section **104**, a second blade section **106** and a joint sleeve **102** configured to join the blade sections **104**, **106** together. In general, the rotor blade assembly **100** may be configured such that, when the first and second blade sections **104**, **106** are attached within the joint sleeve **102**, a complete rotor blade, defining a substantially aerodynamic profile, is formed. Thus, the complete rotor blade assembly **100** may generally include a blade root **108** (defined by the first blade section **104**) configured to be mounted to the hub **18** (FIG. **1**) of a wind turbine **10** and blade tip **110** (defined by the second blade section **106**) disposed opposite the blade root **108**. The rotor blade assembly **100** may also include a span **112** defining the total length between the blade root **108** and the blade tip **110** and a chord **114** defining the total length between the leading edge **116** and the trailing edge **118**. As is generally understood, the chord **114** may vary in length with respect to the span **112** as the rotor blade extends from the blade root **108** to the blade tip **110**.

[0025] In general, the first and second blade sections **104**, **106** of the rotor blade assembly **100** may be configured similarly to any suitable blade section and/or blade segment known in the art. For example, each blade section **104**, **106** may include a body shell **120** serving as the outer casing/covering of the blade section **104**, **106** and one or more structural components (not shown) for providing stiffness and/or strength to the blade section **104**, **106** (e.g., a shear web/spar cap assembly). Additionally, each blade section **104**, **106** may generally define an aerodynamic profile. For instance, the body shells **120** of each blade section **104**, **106** may be configured to define an airfoil shaped cross-section, such as a symmetrical or cambered airfoil shaped cross-section. Thus, as shown in FIG. **3**, each body shell **120** may generally define a pressure side **122**, and a suction side **124** extending between a leading edge **126** and trailing edge **128**.

[0026] It should be appreciated that the body shells **120** may generally be formed from any suitable material. For instance, in one embodiment, each body shell **120** may be formed entirely from a laminate composite material, such as a carbon fiber-reinforced composite or a glass fiber-reinforced composite. Alternatively, one or more portions of each body shell **120** may be configured as a layered construction and may include a core material, formed from a lightweight material such as wood (e.g., balsa), foam (extruded polystyrene foam) or a combination of such materials, disposed between layers of laminate composite material.

[0027] Additionally, the first and second blade sections **104**, **106** may each include a joint end **130**, **131** terminating within the joint sleeve **102**. Thus, in the illustrated embodiment, the first blade section **104** may generally extend from the blade root **108** of the rotor blade assembly **100** to its joint end **130** within the joint sleeve **102**. Similarly, the second blade section **102** may generally extend from its joint end **131** within joint sleeve **102** to the blade tip **110** of the rotor blade assembly **100**. Further, as will be described in greater detail below with reference to FIGS. **5** and **6**, the joint ends **130**, **131** of the blade sections **104**, **106** may define a particular profile in order to facilitate insertion of the joint ends **130**, **131** within the joint sleeve **102**. For instance, in several embodiments, the joint ends **130**, **131** of each blade section **104**, **106** may define a tapered or stepped profile corresponding to a tapered or stepped profile defined in the joint sleeve **102**.

[0028] Moreover, as shown in FIGS. **2** and **3**, the first blade section **104** may generally extend lengthwise along a substantial portion of the span **112** of the rotor blade assembly **100** such that the joint sleeve **102** is disposed at an outboard position on the rotor blade generally proximate to the blade tip **110**. As such, the second blade section **106** may generally be configured as an outboard or tip section of the rotor blade assembly **100**. Thus, in the illustrated embodiment, the second blade section **106** may be configured similarly to the outboard portion of a conventional rotor blade **16** (FIG. **1**), such as by extending in a substantially spanwise direction between the joint end **131** of the blade section **106** and the blade tip **110**. Alternatively, as will described below with reference to FIG. **7**, the second blade section **106** may be configured as a winglet-type tip section or may otherwise have any other suitable tip configuration know in the art.

[0029] It should be appreciated that, in embodiments in which the second blade section **106** is configured as an outboard or tip section of the rotor blade assembly **100**, the second blade section **106** may generally define a relatively short length **132**. For example, in several embodiments, the second blade section **106** may define a length **132** which is less than 10 meters (m) long, such as less than 5 m long or less than 3 m long and all other subranges therebetween. However, in alternative embodiments, the second blade section **106** need not be configured as a tip section of the rotor blade assembly **100** and, thus, may generally define any suitable length **132**, such as a length greater than or equal to 10 m. In such embodiments, it should be appreciated that the joint sleeve **102** may generally be disposed at any suitable location along the span **112** of the rotor blade assembly **100**, such as by being located at a more inboard position closer to the blade root **108**.

[0030] Still referring to FIGS. **2-4**, the joint sleeve **102** of the disclosed rotor blade assembly **100** may generally be configured as an attachment device for joining the first and second blade sections **104**, **106**. Thus, it should be appreciated that the joint sleeve **102** may generally have any suitable configuration that permits the joint ends **130**, **131** of the blade sections **104**, **106** to be received within the joint sleeve **102**. For example, in several embodiment, the joint sleeve **102** may have a hollow or a substantially hollow configuration for receiving the joint ends **130**, **131** of the blade sections **104**, **106**. In particular, as shown in FIG. **4**, the joint sleeve **102** may generally include an inner perimeter or inner surface **134** defining a cavity **136** extending between a root end **138** and a tip end **140** of the joint sleeve **102**. As such, the joint end **130** of the first blade section **104** may be configured to be received within the portion of the cavity **136** defined at the root end **138** of the joint sleeve **102** and the joint end **131** of the second blade section **106** may be configured to be received within the portion of the cavity **136** defined at the tip end **140** of the joint sleeve **102**.

[0031] It should be appreciated that the joint ends **130**, **131** of the blade sections **104**, **106** may generally be attached within the cavity **136** of the joint sleeve **102** using any suitable means. For example, in one embodiment, the joint ends **130**, **131** may be bonded within the joint sleeve **102** using any suitable adhesive. In another embodiment, a plurality of fasteners **142** may be utilized to secure the joint ends **130**, **131** within the joint sleeve **102**. For example, as shown in FIGS. **3** and **4**, the joint sleeve **102** may define a plurality of openings **144** extending between its inner and outer surfaces **134**, **146**, with each opening **144** being configured to receive a fastener **142**. Specifically, a plurality of openings **144** may be defined proximate to the root end **138** of the joint sleeve **102** to permit a like number of fasteners **142** to be inserted through the openings **144** and attached to the joint end **130** of the first blade section **104**. Similarly, a plurality of openings **144** may be defined proximate the tip end **140** of the joint sleeve **102** to permit a like number of fasteners **142** to be inserted through the openings **144** and attached to the joint end **131** of the second blade section **106**. It should be readily appreciated that the openings **144** may be defined in the joint sleeve **102** so as to form any suitable bolt hole pattern. For example, in one embodiment, the openings **144** may form a single row along the root and tips ends **138**, **140** of the joint sleeve **102**. In another embodiments, multiple rows (e.g., two or more rows) of openings **144**, being aligned or offset from one another, may be defined in the root and tip ends **138**, **140** of the joint sleeve **102**.

[0032] It should also be appreciated that the fasteners **142** described herein may generally comprise any suitable fasteners known in the art. For example, in several embodiments, the fasteners **142** may be configured as threaded fasteners, such as threaded bolts, screws and other suitable threaded fastening devices. In other embodiments, the fasteners may comprise other suitable fastening and/or attachment devices, such as pins, clips, brackets, rods, rivets, bonded fasteners and the like.

[0033] The disclosed joint sleeve **102** may also define a substantially aerodynamic profile. For example, as shown in FIG. **4**, the joint sleeve **102** may define an airfoil-shaped cross-section. Thus, similar to the first and second blade sections **104**, **106**, the outer surface **146** of the joint sleeve **102** may generally define a pressure side **148** and a suction side **150** extending between a leading edge **152** and a trailing edge **152**. Additionally, in several embodiments of the present subject matter, the aerodynamic profile defined by the joint sleeve **102** may generally correspond to or otherwise match the aerodynamic profiles of the first and second blade sections **104**, **106**. In particular, the aerodynamic profile of the joint sleeve **102** at the root end **138** may generally correspond to the aerodynamic profile of the first blade section **102** in an area adjacent to its joint end **130**. Similarly, the aerodynamic profile of the joint sleeve **102** at the tip end **140** may generally correspond to the aerodynamic profile of the second blade section **106** in an area adjacent to its joint end **131**. As such, when the blade sections **104**, **106** are assembled together within joint sleeve **102**, the rotor blade assembly **100** may generally define a substantially continuous aerodynamic profile along its entire span **112**. For instance, as shown in FIG. **3**, the joint sleeve **102** may be configured such that a substantially flush, aerodynamic surface is defined at the interface of the first blade section **104** and the root end **138** of the joint sleeve **102** and at the interface of the second blade section **106** and the tip end **140** of the joint sleeve **102**. Thus, the rotor blade assembly **100** may generally define a continuous aerodynamic surface between the first and second blade sections **104**, **106**.

[0034] It should be appreciated that, in several embodiments, an additional surface feature may be applied to or positioned over the seams formed at the interfaces of the blade sections **104**, **106** and the ends **138**, **140** of the joint sleeve **102** to ensure that a substantially smooth aerodynamic surface is achieved. For example, in a particular embodiment, several plies of a laminate composite material may be applied around the outer perimeter of the rotor blade assembly **100** at the joint seams, such as by using a wet lay-up process, to provide a substantially flush aerodynamic surface between the blade sections **104**, **106** and the joint sleeve **102**.

[0035] It should also be appreciated that the joint sleeve **102** may generally be formed from any suitable material. For example, in one embodiment, the joint sleeve **102** may be formed from a metal, such as aluminum, steel and the like. In other embodiments, the joint sleeve **102** may be formed from a laminate composite material, such as various fiber-reinforced composites, or any other suitable non-metallic material.

[0036] Referring now to FIGS. **5** and **6**, there is illustrated partial, cross-sectional views of two embodiments of the disclosed rotor blade assembly **100**, particularly illustrating the attachment of the first and second blade sections **104**, **106** within the joint sleeve **102**. As indicated above, the joint ends **130**, **131** of the blade sections **104**, **106** may generally be configured to be attached within the cavity **136** defined by the joint sleeve **102** such that a substantially continuous aerodynamic profile is defined along the span **112** (FIG. **2**) of the rotor blade assembly **100** and, particularly, at the interfaces between the root and tip ends **138**, **140** of the joint sleeve **102** and the blade shells **120** of the blade sections **104**, **106**. Thus, in several embodiments, a cross-sectional height **156** of each blade section **104**, **106** may generally be reduced at the joint ends **130**, **131** to permit the joint ends **130**, **131** to be inserted within the joint sleeve **102** and to ensure that a substantially continuous or flush surface is defined between the blade sections **104**, **106** and the joint sleeve **102**.

[0037] For example, as shown in FIG. **5**, in one embodiment, at least a portion of the joint ends **130**, **131** of the blade sections **104**, **106** may define a tapered profile, such as by configuring the blade shells **120** to have a tapered thickness **158**, in order to permit the joint ends **130**, **131** to be positioned with the joint sleeve **102**. Additionally, the joint sleeve **102** may define a corresponding tapered profile so that the outer surface **146** of the joint sleeve **102** is positioned substantially flush with the outer surfaces **160** of the blade shells **120**. Thus, as shown, the joint sleeve **102** may generally define tapered widths **162** at its root and tip ends **138**, **140** corresponding to the tapered thicknesses **158** of the blade shells **120**. It should be appreciated that, although the tapered widths **162** of the joint sleeve **102** are shown as defining a substantially sharp or knife edge at the root and tip ends **138**, **140**, the tapered widths **162** need not define such sharp or knife edges. For example, in one embodiment, the tapered profile of the joint sleeve **102** may be configured to extend only partially along the tapered profiles of the blade sections **104**, **106** such that relatively thin, blunt edges may be defined at the root and tip ends **138**, **140** of the joint sleeve **102**. In such an embodiment, an additional surface feature, such as the laminate plies described above, may be applied at the root and tip ends **138**, **140** to ensure that a substantially continuous aerodynamic surface is defined between the blade sections **104**, **106** and the joint sleeve **102**.

[0038] Alternatively, as shown in FIG. **6**, the joint ends **130**, **131** of the blade sections **104**, **106** may define a stepped profile, such as by configuring the blade shells **120** to have a stepped reduction in thickness **164** at the root and tip ends **138**, **140** of the joint sleeve **102**. In such an embodiment, the joint sleeve **102** may generally define a width **166** substantially equal to the reduction in thickness defined in the blade shells **120** so that the outer surface **146** of the joint sleeve **102** is positioned substantially flush with the outer surfaces **160** of the blade shells **120**. In further embodiments, it should be appreciated that the joint sleeve **102** and/or the joint ends **130**, **131** of the blade sections **104**, **106** may generally have any other suitable configuration that permits the joint ends **130**, **131** to be inserted within the joint sleeve **102**.

[0039] In general, the tapered or stepped profiles defined at the joint ends **130**, **131** of the blade sections **104**, **106** may be formed using any suitable means. For example, in one embodiment, the tapered or stepped profiles may be a molded feature of the blade shells **120**, such as by creating a mold having a tapered/stepped profile defined therein or by placing a mold insert defining the tapered/stepped profile within the mold as the blade shells **120** are being formed. In another embodiment, the tapered or stepped profile may be machined into the blade shells **120** after the shells **120** have been formed, such as by using any suitable machining process and/or any suitable machining equipment. Additionally, it should be appreciated that the corresponding profile of the joint sleeve **102** may generally be formed using any suitable means. For example, in one embodiment, the joint sleeve **102** may be molded or otherwise formed to include the corresponding profile. In another embodiment, the corresponding profile may be machined into the joint sleeve **102** using any suitable machining process and/or any suitable machining equipment.

[0040] In a further embodiment of the present subject matter, one of the tapered or stepped profiles of the blade shells **120** or the corresponding profile of the joint sleeve **102** may be initially formed and/or machined and then scanned to permit the exact geometry of such profile(s) to be known. For example, in one embodiment, a metrology or other 3-D scan may be performed on the tapered profiles of the joint ends **130**, **131** of each blade section **104**, **106**. In such an embodiment, the tapered width **162** of the joint sleeve **102** may then be formed and/or machined based on the scan to ensure that the tapered width **162** corresponds the tapered profiles of the blade sections **104**, **106**.

[0041] Referring still to FIGS. **5** and **6**, in several embodiments, the openings **144** defined in the joint sleeve **102** may include recessed features **170** for recessing the fasteners **142** between the inner and outer surfaces **134**, **146** of the joint sleeve **102**. In particular, the openings **144** may be configured such that the fasteners **142** are recessed partially or fully within the joint sleeve **102**. For example, as shown in FIGS. **5** and **6**, the recessed openings **144** may be configured such that the top surface **168** of each fastener **142** is positioned substantially flush with the outer surface **146** of the joint sleeve **102**. As such, the joint sleeve **102** may generally define a substantially continuous aerodynamic profile between its root and tip ends **138**, **140**.

[0042] It should be appreciated that the size, shape and/or configuration of the recessed features **170** of the openings **144** may generally vary depending on the size, shape and/or configuration of the fasteners **142** being used to attach the joint ends **130**, **131** of the blade sections **104**, **106** within the joint sleeve **102**. For example, as shown in FIG. **5**, the fasteners **142** may generally comprise threaded fasteners having a fastener head **172** defining a tapered diameter. In such an embodiment, the openings **144** formed in the joint sleeve **102** may generally define a corresponding tapered diameter such that the fastener head **172** may be fully recessed within the joint sleeve **102**. In another embodiment, shown in FIG. **6**, the openings **144** may be configured as counterbored holes having a shape and/or configuration corresponding to the shape and/or configuration of the fastener head **172**.

[0043] Referring still to FIGS. **5** and **6**, to ensure proper attachment of the blade sections **104**, **106** within the joint sleeve **102**, the disclosed rotor blade assembly **100** may also include features for retaining the disclosed fasteners **142** within the joint ends **130**, **131** of the blade sections **104**, **106**. For example, in embodiments in which the fasteners **142** are configured as a threaded fasteners (e.g., threaded bolts), the rotor blade assembly **100** may include a plurality of female threaded members **174** configured to receive the threaded fasteners **142** such that a clamped interface is provided between the inner surface **134** of the joint sleeve **102** and the joint ends **130**, **131** of the blade sections **104**, **106**. Thus, as shown in FIGS. **5** and **6**, a plurality of female threaded members **174** may be configured to be aligned with the openings **144** defined in the joint sleeve **102** such that the fasteners **142** may be inserted through the openings **144** and screwed into the threaded members **174**. For instance, in the embodiment shown in FIG. **5**, the threaded members **174** may comprise a plurality threaded channels or plugs **176** configured to be mounted or otherwise disposed within the joint ends **130**, **131** of the blade sections **104**, **106**. In another embodiment, the threaded members **174** may comprise a plurality of nuts **178** mounted directly or indirectly to an inner surface **182** of the blade shells **120**. For example, as shown in FIG. **6**, the nuts **178** may be mounted onto a ganged channel or nut plate **180** extending around the inner perimeter of each blade shell **120**. It should be appreciated that the nuts **178** may generally comprise any suitable nut known in the art, including conventional, threaded nuts and floating nuts. Additionally, in alternative embodiments, it should be appreciated that the threaded members **174** may have any other suitable configuration that permits the fasteners **142** to be securely attached to the joint ends **130**, **131** of the first and second blade sections **104**, **106**.

[0044] In several embodiments of the present subject matter, the disclosed rotor blade assembly **100** may also include a divider **184** configured to separate the joint end **130** of the first blade section **104** from the joint end **131** of the second blade section **106** within the joint sleeve **102**. The divider **131** may also serve as a stop for locating or positioning the joint ends **130**, **131** of the blade sections **104**, **106** within the joint sleeve **102**. For example, in one embodiment, the divider **184** may be positioned within the joint sleeve **102** such that, when the joint ends **130**, **131** of the blade sections **104**, **106** are inserted fully within the joint sleeve **102** and contact the divider **184**, the threaded members **174** disposed within or mounted to the blade shells **120** may generally be aligned with the openings **144** defined in the joint sleeve **102**.

[0045] It should be appreciated that the divider **184** may generally have any suitable configuration that permits the divider **184** to function as described herein. For instance, as shown in FIGS. **5** and **6**, the divider **184** may be configured as a relatively thin member extending around the inner perimeter of the joint sleeve **102** substantially perpendicularly to the inner surface **134**. Additionally, as shown in FIG. **5**, in one embodiment, the divider **184** may extend inwardly from the inner surface **134** only partially into the cavity **136** defined by the joint sleeve **102**. Alternatively, as shown in FIG. **6**, the divider **184** may be configured to extend from the inner surface **134** throughout the entire cavity **136** so as to divide the cavity **136** into two separate cavities.

[0046] Referring now to FIG. **7**, there is illustrated a perspective view of a tip assembly **200** in accordance with aspects of the present subject matter. In general, the tip assembly **200** may include a joint sleeve **202** and a tip section **206**. The joint sleeve **202** may generally be configured similarly to the joint sleeve **102** described above with reference to FIGS. **2**-**6**. Thus, the joint sleeve **202** may define a cavity **136** (FIG. **4**) extending between a tip end **240** and a root end **238** of the joint sleeve **202**. The portion of the cavity **136** defined at the tip end **240** may generally be configured to receive a joint end **231** of the tip section **206**. For example, the joint sleeve **202** and the joint end **231** of the tip section **206** may define corresponding tapered profiles such that the joint end **231** may be inserted into the joint sleeve **202** and attached therein using a plurality of fasteners **242**. Additionally, the joint sleeve **202** may define an aerodynamic profile generally corresponding to the aerodynamic profile of the tip section **206**. As such, when the tip section **206** is inserted within the joint sleeve **202**, the tip assembly **200** may generally define a substantially continuous aerodynamic profile between the joint sleeve **202** and the tip section **206**.

[0047] In general, the tip section **206** may extend from the joint end **231** to a blade tip **210** and may have any suitable tip configuration known in the art. For example, in one embodiment, the tip section **206** may be configured as a straight tip section, such as by being configured similar to the second blade section **106** described above with reference to FIGS. **2** and **3** and extending in a substantially spanwise direction between the joint end **231** and the blade tip **210**. In another embodiment, shown in FIG. **7**, the tip section **206** may be configured as a winglet-type tip section. As such, a winglet **290** may generally be defined between the joint end **231** and the blade tip **210**. It should be appreciated that the winglet **290** may have any suitable configuration known in the art. For example, the winglet **290** may be configured as a suction side winglet or as a pressure side winglet. Additionally, the winglet **290** may define any suitable sweep angle, cant angle, toe angle and/or twist angle, all of which are commonly known terms in the aerodynamic art. Further, the winglet **290** may define any suitable radius of curvature and may have any suitable aspect ratio (i.e., ratio of the span of the winglet **290** to the planform area of the winglet **290**).

[0048] It should be appreciated that the disclosed tip assembly **200** may generally be configured as a replaceable tip for a rotor blade. Thus, the tip assembly **200** may be configured to be attached to any suitable inboard blade segment or section of a rotor blade. For example, the portion of the cavity **136** (FIG. **4**) defined at the root end **238** of the joint sleeve **202** may be configured to receive an end (not shown) of an inboard blade section (not shown), such as by being configured to receive the joint end **130** of the first blade section **104** described above with references to FIGS. **2**-**6**. Thus, in one embodiment, the end of the inboard blade section may be formed, machined or otherwise shaped so as to define a tapered profile corresponding to a tapered profile defined in the cavity **136** at the root end **238** such that the blade section may be inserted into the joint sleeve **202**. Similar to the embodiments described above, the blade section may then be attached within the joint sleeve **202** using a plurality of fasteners **242** inserted through the openings **244** defined along the root end **238**.

[0049] 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 assembly for a wind turbine, the rotor blade assembly comprising:
- a first blade section including a joint end and defining an aerodynamic profile;
- a second blade section including a joint end and defining an aerodynamic profile;
- a joint sleeve having an inner surface and an outer surface, the inner surface defining a cavity configured to receive the joint ends of the first and second blade sections; and,
- a plurality of fasteners configured to secure the joint ends of the first and second blade sections within the cavity,
- wherein a profile of the outer surface of the joint sleeve generally corresponds to the aerodynamic profiles of the first and second blade sections such that a substantially continuous aerodynamic profile is defined between the first and second blade sections when the joint ends are inserted within the cavity.

2. The rotor blade assembly of claim **1**, wherein the second blade section is configured as a tip section of the rotor blade assembly.

3. The rotor blade assembly of claim **2**, wherein the tip section defines a winglet.

4. The rotor blade assembly of claim **1**, wherein a tapered profile is defined at the joint ends of the first and second blade sections, the joint sleeve defining a tapered width generally corresponding to the tapered profile.

5. The rotor blade assembly of claim **1**, wherein a stepped profile is defined at the joint ends of the first and second blade sections.

6. The rotor blade assembly of claim **1**, wherein the plurality of fasteners comprises a plurality of threaded fasteners.

7. The rotor blade assembly of claim **6**, further comprising a plurality of threaded members disposed at the joint ends of the first and second blade sections, the plurality of threaded members being configured to receive the plurality of threaded fasteners.

8. The rotor blade assembly of claim **1**, further comprising a plurality of openings defined between the inner and outer surfaces of the joint sleeve, each of the plurality of openings defining a recessed feature configured to recess the plurality of fasteners within the joint sleeve.

9. The rotor blade assembly of claim **1**, further comprising a divider configured to separate the joint ends of the first and second blade sections within the cavity.

10. A joint sleeve for assembling together a first blade section and a second blade section of a rotor blade assembly, the sleeve comprising:
- an outer surface;
- an inner surface defining a cavity, the cavity having a root end configured to receive a joint end of the first blade section and a tip end configured to receive a joint end of the second blade section; and,
- a plurality of openings defined between the outer and inner surfaces, the plurality of openings being configured to receive a plurality of fasteners for securing the joint ends of the first and second blade sections within the cavity,
- wherein a profile of the outer surface is configured to generally correspond to an aerodynamic profile of the first and second blade sections such that a substantially continuous aerodynamic profile is defined between the first and second blade sections when the joint ends are inserted within the cavity.

11. The joint sleeve of claim **10**, wherein a tapered width is defined between the outer and inner surfaces.

12. The joint sleeve of claim **10**, wherein each of the plurality of openings defines a recessed feature between the outer and inner surfaces.

13. The joint sleeve of claim **10**, further comprising a divider configured to separate the joint ends of the first and second blade sections within the cavity.

14. The joint sleeve of claim **10**, wherein the divider extends substantially perpendicularly from the inner surface.

15. The joint sleeve of claim **10**, wherein an aerodynamic profile of the root end generally corresponds to the aerodynamic profile of the first blade section and an aerodynamic profile of the tip end generally corresponds to the aerodynamic profile of the second blade section.

16. A tip assembly for a rotor blade of a wind turbine, the tip assembly comprising:
- a joint sleeve including an inner surface defining a cavity and an outer surface defining an aerodynamic profile, the joint sleeve further including a tip end and a root end,
- a tip section extending between a joint end and a blade tip and defining an aerodynamic profile generally corresponding to the aerodynamic profile of the joint sleeve at the tip end, the joint end of the tip section being disposed within the cavity; and,
- a plurality of fasteners configured to secure the joint end of the tip section within the cavity,
- wherein a portion of the cavity disposed at the root end of the joint sleeve is configured to receive an end of a separate section of the rotor blade.

17. The tip assembly of claim **16**, wherein the tip section defines a winglet.

18. The tip assembly of claim **16**, wherein a tapered profile is defined at the joint end of the tip section, the joint sleeve defining a tapered width generally corresponding to the tapered profile.

19. The tip assembly of claim **16**, further comprising a plurality of openings defined along the tip end of the joint sleeve and configured to receive the plurality of fasteners, each of the plurality of openings defining a recessed feature configured to recess the plurality of fasteners within the joint sleeve.

20. The tip assembly of claim **16**, further comprising a plurality of openings defined along the root end of the joint sleeve, the plurality of openings being configured to receive a plurality of fasteners for securing the end of the separate section of the rotor blade within the cavity.

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