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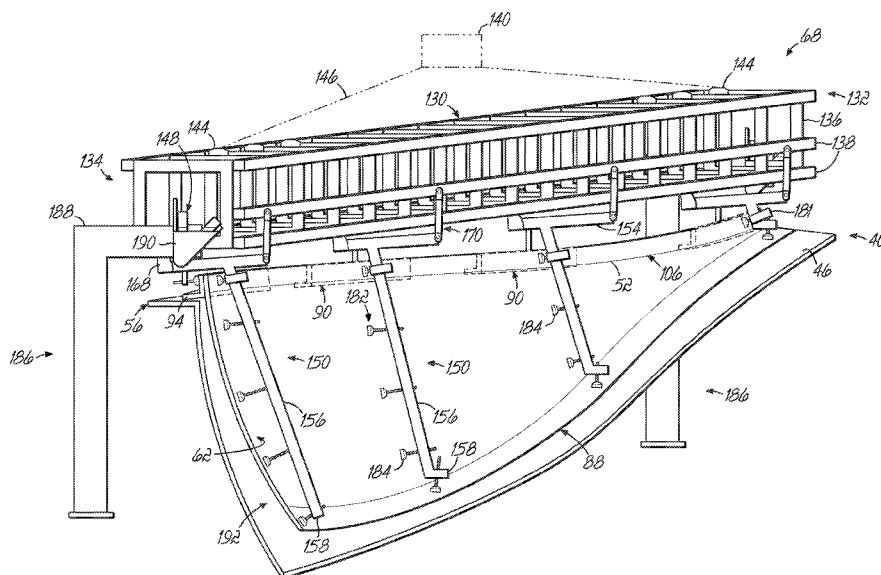


FIG. 6

(57) Abstract: A method of making a wind turbine blade (20) using a blade mould (40) to form at least a portion of the wind turbine blade (20) is disclosed. The method includes providing a flatback pre-mould (66) defining a mould surface (80), at least one mouldlette (90) removably attached to the flatback pre-mould (66) to form part of the mould surface (80), and a flatback lifting tool (68). The method further includes forming a flatback preform (62) on the mould surface (80) of the flatback pre-mould (66) and securing the flatback preform (62) to the at least one mouldlette (90) to form a flatback assembly (92). Next, detaching the at least one mouldlette (90) from the flatback pre-mould (66), transferring the flatback assembly (92) from the flatback pre-mould (66) to the blade mould (40) using the flatback lifting tool (68), and arranging the flatback assembly (92) on the blade mould (40) such that the flatback preform (62) is positioned adjacent to a mould surface (46) of the blade mould (40).



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METHOD OF MAKING A WIND TURBINE BLADE HAVING A FLATBACK PREFORM AND SYSTEM FOR MAKING SAME

Technical Field

- 5 This application relates generally to wind turbines, and more particularly to a system and method of manufacturing a half-shell portion of a wind turbine blade using a pre-made flatback preform.

Background

- 10 Wind turbines are used to produce electrical energy using a renewable resource and without combusting a fossil fuel. Generally, a wind turbine converts kinetic energy from the wind into electrical power. A horizontal-axis wind turbine includes a tower, a nacelle located at the apex of the tower, and a rotor having a plurality of blades and supported in the nacelle by means of a shaft. The shaft couples the rotor either directly or
- 15 indirectly with a generator, which is housed inside the nacelle. Consequently, as wind forces the blades to rotate the rotor, electrical energy is produced by the generator. To this end, wind turbines may be located either on a land mass (onshore) or within a body of water (offshore).
- 20 A wind turbine blade typically consists of an outer shell, which may be divided into a first (e.g., windward) half-shell portion and a second (leeward) half-shell portion. The first and second half-shell portions that form the outer shell of a wind turbine blade are typically manufactured as separate pieces. The half-shell portions are then joined together along the leading edge and trailing edge to form the complete outer shell of
- 25 the blade.

- In the process of manufacturing half-shell portions of a wind turbine blade, half-shell moulds are employed to create the complex shapes of each half-shell portion that are required for efficient wind energy conversion by the blade. In that regard, half-shell
- 30 moulds may possess steep contact surfaces, particularly on the trailing edge. During the manufacturing process of a half-shell portion of a blade, various fiber layers (e.g., fabric or scrim layers), including any core materials such as foam, are layered atop one another before being infused with resin and cured to create a composite structure. As this layering takes place, the fabric layers are particularly prone to easy slipping,

especially at the steep points of the half-shell moulds. This unintended movement of the fabric layers can result in bridging, rippling, and resin richness, all of which can compromise the structural integrity of the wind turbine blade.

- 5 In view of the above, one objective of the present invention is to provide a method for producing a steep portion or part of a half-shell portion of a wind turbine blade (otherwise referred to as a flatback portion) in a first mould. It is another objective of the present invention to provide an improved tool for manufacturing the flatback portion.

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Summary

According to a first aspect of the invention, a method of making a wind turbine blade using a blade mould to form at least a portion of the wind turbine blade is disclosed.

The method includes providing a flatback pre-mould defining a mould surface, at

- 15 least one mouldette removably attached to the flatback pre-mould to form part of the mould surface, and a flatback lifting tool. The method further includes forming a flatback preform on the mould surface of the flatback pre-mould and securing the flatback preform to the at least one mouldette to form a flatback assembly. Next, the method includes detaching the at least one mouldette from the flatback pre-mould,
- 20 transferring the flatback assembly from the flatback pre-mould to the blade mould using the flatback lifting tool, and arranging the flatback assembly on the blade mould such that the flatback preform is positioned adjacent to a mould surface of the blade mould.

- 25 Forming of the flatback preform in a separate mould optimizes the manufacturing process by addressing the challenges related to fabric layer slippage, thereby ensuring the structural integrity of the wind turbine blade. Advantageously, the mouldette provides an improved means for precisely locating the flatback preform within the half-shell mould.

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According to one embodiment of the invention, the method may further include attaching the at least one mouldette to the blade mould to secure the flatback assembly in place relative to the blade mould such that the mouldette forms an extension of the mould surface of the blade mould. Additionally, the at least one

mouldette may include at least one datum feature and the blade mould may include at least one datum feature. In that regard, the method may further include aligning the at least one datum feature of the mouldette with the at least one datum feature of the blade mould to align the flatback preform along the mould surface of the blade mould. In one embodiment, the at least one datum feature of the mouldette may be a bore and the at least one datum feature of the blade mould may be a bore. In another embodiment, the at least one datum feature of the mouldette may be a flange and the at least one datum feature of the blade mould may be a shoulder configured to receive the flange of the mouldette.

According to another embodiment of the invention, the method may further include moving the flatback pre-mould from a first position where the flatback preform is substantially horizontally positioned to a second position where the flatback preform is substantially vertically positioned, and lifting the flatback assembly from the flatback pre-mould while the flatback preform is substantially vertically positioned. In yet another embodiment, arranging the flatback assembly on the blade mould may further include securing the lifting tool in place relative to the blade mould and operating the lifting tool to rotate the flatback preform into contact against the mould surface of the blade mould.

According to one embodiment of the invention, the flatback lifting tool may include a plurality of mouldette workholding devices. In that regard, the method may further include operating the lifting tool to clamp the mouldette and the flatback preform between the plurality of mouldette workholding devices. Moreover, in one embodiment, the lifting tool may include a plurality of rotatable support arms suspended from the lifting tool. Each rotatable support arm may include at least one support workholding device. The method may further include operating the lifting tool to engage the flatback preform with the at least one support workholding device of each rotatable support arm. For example, the method may further include operating the lifting tool to rotate the plurality of rotatable support arms to press the flatback preform into contact against the mould surface of the blade mould. In one embodiment, the flatback preform may be rotated within a range of between about 2° and about 10° relative to vertical.

According to one aspect of the invention, a system for making at least a portion of a wind turbine blade is disclosed. The system includes a flatback pre-mould which includes a body that defines a mould surface for forming a flatback preform and at least one mouldette removably attached to the flatback pre-mould such that a portion of the mouldette forms part of the mould surface. The at least one mouldette may be configured to be removed from the flatback pre-mould together with the flatback preform. Additionally, the flatback preform may be configured to be installed in a blade mould to form the at least a portion of the wind turbine blade.

According to one embodiment of the invention, the body of the flatback pre-mould may include an angled portion that defines an extension of the mould surface. For example, the angled portion may be angled within a range including a lower angle of about 50° and an upper angle relative to the body of the flatback pre-mould. The upper angle may be 70° , 90° , or greater, for example. According to another embodiment, the body of the flatback pre-mould may be movable between a first position where the mould surface of the body is substantially horizontally positioned and a second position where the mould surface of the body is substantially vertically positioned.

According to yet another embodiment of the invention, the system may include a flatback lifting tool configured to transfer the flatback preform from the flatback pre-mould to the blade mould. In one embodiment, the flatback lifting tool may include a plurality of mouldette workholding devices configured to clamp the mouldette and the flatback preform. In another embodiment, the flatback lifting tool may include a plurality of rotatable support arms suspended from the lifting tool. Each rotatable support arm may include at least one support workholding device configured to secure the flatback preform to the flatback lifting tool. For example, the plurality of rotatable support arms may be configured to rotate the flatback preform within a range of between about 2° and about 10° relative to vertical.

According to one embodiment of the invention, the system may include a plurality of mouldette workholding devices configured to secure the flatback preform to the at

least one mouldette to define a flatback assembly. In that regard, the flatback assembly may be transferable as a single piece to the blade mould. In one embodiment, the at least one mouldette includes at least one datum feature that is configured to be aligned with a corresponding datum feature of the blade mould to align the flatback preform within the blade mould. For example, the at least one datum feature of the at least one mouldette may include one of a bore or a flange.

According to yet another embodiment, the system may include the blade mould.

According to another aspect of the invention, a system for making a wind turbine blade is disclosed. The system includes a flatback preform, at least one mouldette, and a flatback lifting tool for lifting the flatback assembly. The flatback lifting tool further includes a plurality of mouldette workholding devices configured to secure the mouldette and the flatback preform. The flatback preform is configured to be installed in a blade mould to form part of a shell section of the wind turbine blade. In one embodiment, the system may include the blade mould.

According to yet another aspect of the invention, a wind turbine blade includes at least a portion formed using any one of the embodiments of the system described above.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one or more embodiments of the invention and, together with a general description of the invention given above, and the detailed description given below, serve to explain the invention.

Fig. 1 is a perspective view of a wind turbine according to an embodiment of the invention.

Fig. 2 is a perspective view of a wind turbine blade of the wind turbine of Fig. 1.

Fig. 3 is a perspective view of a half-shell mould used to form a half-shell portion of the wind turbine blade of Fig. 2, illustrating a location of a flatback preform within the half-shell mould in accordance with an embodiment of the invention.

- 5 Fig. 4 is a partial cross-sectional end view of a flatback pre-mould rotated to a substantially horizontal position for forming a flatback preform in accordance with an embodiment of the invention.

- 10 Fig. 5 is a view similar to Fig. 4, illustrating the flatback pre-mould rotated to a substantially vertical position.

Fig. 5A is a view similar to Figs. 4 and 5, illustrating a flatback lifting tool for removing the flatback preform from the flatback pre-mould.

- 15 Fig. 6 is a perspective view the flatback lifting tool and the flatback preform being lowered into the half-shell mould.

- 20 Fig. 7A is an end view of the flatback lifting tool, illustrating the flatback preform being lowered into place relative to the mould surface of the half-shell mould.

Fig. 7B is a view similar to Fig. 7A, illustrating the flatback lifting tool and the flatback preform lowered into place relative to the mould surface of the half-shell mould.

- 25 Fig. 8A is an end view of the flatback lifting tool and the flatback preform, illustrating the flatback preform being rotated into place relative to the mould surface of the half-shell mould.

Fig. 8B is a view similar to Fig. 8A, illustrating the flatback preform rotated into place against the mould surface of the half-shell mould.

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Fig. 9 is an end view of the half-shell mould, illustrating the flatback preform arranged on the mould surface of the half-shell.

Detailed Description

With reference to Figs. 1 through 9, a system and method of forming part of a wind turbine blade, otherwise referred to as a flatback preform, are shown in accordance with embodiments of the invention. The flatback preform is configured to be installed
5 in a blade mould that is used to form a half-shell portion of a wind turbine blade. In particular, the flatback preform forms part of the half-shell portion of the wind turbine blade. In that regard, the wind turbine blade may be formed of a first (e.g., windward) half-shell portion and a second (leeward) half-shell portion, and each half-shell portion may be formed with one or more flatback preforms. While the flatback preform may
10 form any part of a half-shell portion of a blade, the flatback preform may be strategically implemented in steep or inclined regions of the half-shell portion to prevent unintended movement of fabric layers or plies during the layup process when forming the half-shell portion of the blade. For example, these steep or inclined regions typically coincide with the trailing edge of the half-shell portion. As described above, unwanted
15 movement or slippage of fabric layers can lead to issues such as bridging, rippling, and resin irregularities, all of which can compromise the structural integrity of the wind turbine blade.

According to embodiments of the invention, the flatback preform is formed in a pre-mould that is separate from the blade mould, or half-shell mould, in which the half-shell portion of the blade is formed. In that regard, the flatback preform may be formed
20 in the pre-mould before being transferred to the half-shell mould with a flatback lifting tool. The flatback lifting tool may be used to properly orient and align the flatback preform within the half-shell mould. The flatback preform may be fully formed (i.e., cured) in the flatback pre-mould or partially formed (i.e., tacked together with powder
25 binder and uncured resin so as to remain relatively soft and pliable) in the flatback pre-mould. In either case, to prevent unwanted movement of fabric layers during the layup process, the flatback pre-mould is arranged horizontally to form the flatback preform. Subsequently, the flatback pre-mould is moved to vertically orient the flatback preform
30 for transfer to the half-shell mould. The vertical orientation of the flatback preform is maintained while the flatback preform is transferred and installed in the half-shell mould. As a result of the pre-moulding operation, the flatback preform may be installed into the half-shell mould in a vertical orientation with no unintended movement of the fabric layers, thereby preventing the aforementioned issues which can compromise

the structural integrity of the wind turbine blade. Furthermore, the flatback preform may include at least one datum feature that is configured to be aligned with a corresponding datum feature of the half-shell mould. The datum features allow for precise alignment of the flatback preform within the half-shell mould for installation. These and other
5 benefits of the present invention will be described more fully below.

Turning now with reference to Fig. 1, an exemplary wind turbine 10 is shown which includes a tower 12, a nacelle 14 disposed at the apex of the tower 12, and a rotor 16 operatively coupled to a generator (not shown) housed inside the nacelle 14, and a
10 gearbox (not shown) housed inside the nacelle 14. In addition to the generator and gearbox, the nacelle 14 may house various components needed to convert wind energy into electrical energy and to operate and optimize the performance of the wind turbine 10. The tower 12 supports the load presented by the nacelle 14, rotor 16, and other wind turbine components housed inside or external to the nacelle 14. The tower
15 12 operates to elevate the nacelle 14 and the rotor 16 to a height above ground level or sea level, as may be the case, where air currents with lower turbulence and higher velocity are typically found.

The rotor 16 includes a central hub 18 and a plurality of wind turbine blades 20
20 ("blades") attached to the central hub 18 at locations distributed about the circumference of the central hub 18. In the representative embodiment, the rotor 16 includes three blades 20, however the number of blades 20 may vary. The blades 20, which project radially outward from the central hub 18, are configured to interact with passing air currents to produce rotational forces that cause the central hub 18 to spin
25 about its longitudinal axis 22. The design, construction, and operation of the blades 20 are familiar to a person having ordinary skill in the art of wind turbine design and may include additional functional aspects to optimize performance.

The rotor 16 may be coupled to the gearbox directly or indirectly by a drive shaft (not
30 shown) to form a rotor assembly. Either way, the gearbox transfers the rotation of the rotor 16 through a coupling (not shown) to the generator. Wind exceeding a minimum speed may activate the rotor 16, causing the rotor 16 to rotate in a direction substantially perpendicular to the wind, and applying torque to the input shaft of the generator. The electrical power produced by the generator may be supplied to a power

grid (not shown) or an energy storage system (not shown) for later release to the grid as understood by a person having ordinary skill in the art. In this way, the kinetic energy of the wind may be harnessed by the wind turbine 10 for power generation.

5 Fig. 2 is a perspective view of an exemplary one of the wind turbine blades 20 of the wind turbine 10. As shown, the blade 20 extends longitudinally in a spanwise direction S between a root end 24 and a tip end 26, and transversely in a chordwise C direction between a leading edge 28 and a trailing edge 30. In that regard, the blade 20 has a length in the spanwise S direction extending from the root end 24 to the tip end 26.

10 The blade 20 includes an outer shell 32 which may be divided into a first (e.g., windward) half-shell portion or section 34 and a second (leeward) half-shell portion or section 36. The outer shell 32 may be moulded from glass-fiber reinforced plastic (GRP), for example. As described in further detail below, the first half-shell portion 34 and the second half-shell portion 36 may be formed as separate pieces that are joined

15 together along the leading edge 28 and trailing edge 30 to form the outer shell 32 of the blade 20. Alternatively, the outer shell 32 of the blade 20 may be formed as a single piece without any glue joints. In either case, the first half shell portion 34 and the second half shell portion 36 of the outer shell 32 define a generally hollow interior of the wind turbine blade 20 where at least one spar structure 38 is located. Each spar

20 structure 38 may include a pair of spar caps associated with respective first and second half-shell portions 34, 36 and a shear web that extends between a corresponding pair of opposed spar caps.

As briefly described above, the half-shell portions 34, 36 are moulded in separate half-

25 shell moulds. The moulded half-shell portions 34, 36 are then assembled together to form a complete wind turbine blade 20. Fig. 3 illustrates an exemplary half-shell mould 40 for forming one of the half-shell portions 34, 36 of the blade 20, such as the leeward half-shell portion 36. As shown, the half-shell mould 40 extends a length from a mould tip end 42 to a mould root end 44 and includes a mould surface 46 that is recessed

30 from an upper surface 48 of the mould 40 to define a mould cavity 50. The mould surface 46 and the upper surface 48 of the mould 40 intersect at a mould trailing edge 52 and a mould leading edge 54. As shown, the upper surface 48 of the mould 40 defines a shoulder 56 that extends along the mould leading edge 52 and the mould trailing edge 54 and generally about the mould cavity 50. The shoulder 56 is configured

to receive and support various components during the moulding process. In that regard, the shoulder 56 includes a plurality of attachment points 58, otherwise referred to as datum features, spaced apart along a length of at least the mould trailing edge 52 to assist with locating the flatback preform within the half-shell mould 40, as will be described in further detail below. To this end, the half-shell portion 36 of the wind turbine blade 20 is formed on the mould surface 46 which has a shape that corresponds to a desired shape of the half-shell portion 36 to be formed.

A conventional layup process for forming a half-shell portion 36 of a wind turbine blade 20 includes placing of one or more layers or plies of glass-fibre fabric onto the mould surface 46 of the half-shell mould 40. These first layers will later form an outer skin of the blade 20. Structural elements, including spar caps and sandwich core panels are then arranged on top of the outer fabric layers. The process includes placing one or more additional layers of glass-fibre fabric over the structural elements. These additional, second layers will form an inner skin of the blade 20. The fabric layers may be pre-impregnated with resin or installed dry and later infused with resin using a vacuum-assisted resin transfer moulding (VARTM) process. A person of ordinary skill in the art of wind turbine blade manufacture is familiar with both of these manufacturing methods.

With continued reference to Fig. 3, the mould surface 46 of the half-shell mould 40 includes several regions having steep contact surfaces, generally at the mould root end 44 adjacent the mould trailing edge 52. At these steep regions, the mould surface 46 can have slopes as steep as 90 degrees relative to the ground. The dashed outline in Fig. 3 illustrates an exemplary steep region 60 of the mould surface 46 of the half-shell mould 40 where the fabric layers are particularly prone to easy slipping during the layup process described above. To eliminate fabric layer slippage and the associated issues which can compromise the structural integrity of the wind turbine blade 20, a flatback preform 62 (e.g., Fig. 6) is manufactured using a separate mould from the half-shell mould 40 (i.e., the flatback preform 62 is manufactured offline). Once formed, the flatback preform 62 may be installed in the steep region 60 of the half-shell mould 40 using a flatback lifting tool, as will be described in further detail below. In particular, the flatback preform 62 may be spaced some distance in the spanwise S direction from the root end 24 of the wind turbine blade 20, which may be

circular in shape. In other words, the circular root end 24 of the blade 20 may transition into the flatback preform 62 a distance in the spanwise S direction from the root end 24 of the blade 20.

- 5 The flatback preform 62 may be installed at the steep region 60 of the mould surface 46 of the half-shell mould 40 as a single, preformed piece. In that regard, the flatback preform 62 is preformed such that the fabric layers of the flatback preform 62 are resilient against slippage, especially when the flatback preform 62 is arranged in a vertical or near-vertical position within the half-shell mould 40. To this end, the steep
10 region 60 schematically represents at least one part of the half-shell portion of the wind turbine blade 20 that may be formed by a flatback preform.

Referring now to Figs. 4-9, a system and method of forming and transferring the flatback preform 62 to the half-shell mould 40 is shown and will now be described in
15 detail. The system employed to form, transfer, and install the flatback preform 62 includes a flatback pre-mould 66 (e.g., Fig. 4) and a flatback lifting tool 68 (e.g., Fig. 6).

With respect to Figs. 4-5A, the flatback pre-mould 66 according to a preferred
20 embodiment of the invention is shaped to form the flatback preform 62 which, as described above, is difficult to properly form in the half-shell mould 40 since the fabric layers tend to slide down the steep mould surfaces 46. In particular, the flatback pre-mould 66 includes a mould body 70 that extends a height between a top end 72 and a base end 74. The mould body 70 may have a length that generally corresponds to
25 the length L of the flatback preform 62. The mould body 70 includes a mould tool 76 positioned on one side 78 of the mould body 70 that defines a mould surface 80 on which the flatback preform 62 may be formed. The mould body 70 is movably supported off the ground by a frame 82. In particular, the mould body 70 is rotatable relative to the frame 82 about an axis of rotation A1. As shown, the axis of rotation A1
30 may be located at an attachment point of the mould body 70 to the frame 82. While the axis of rotation A1 is positioned generally at a central location between the top end 72 and the base end 74 of the mould body 70, the axis of rotation A1 may be located elsewhere, such as at or near the base end 74 of the mould body 70, for example. The mould body 70 may be manually rotatable about the axis of rotation A1, or rotation of

the mould body 70 may be mechanically driven, for example, using a linear actuator. The flatback pre-mould 66 may be configured as a stationary or a movable arrangement. For example, the frame 82 of the flatback pre-mould 66 may include wheels, allowing for easy movement of the flatback pre-mould 66.

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With continued reference to Figs. 4-5A, the mould tool 76 includes a generally flat tool body 84 that extends from the top end 72 of the mould body 70 generally to the base end 74 of the mould body 70. The tool body 84 may have a length that is generally similar to the length of the mould body 70. Adjacent the base end 74 of the mould body 70, the tool body 84 includes an angled portion 86 that is outwardly bent (i.e., bent or angled in a direction away from the mould body 70) so as to be angled relative to the remainder of the tool body 84 of the mould tool 76, and the mould body 70, to define a mould tool angle θ_1 . The mould tool angle θ_1 may be within a range of about 30° or about 50° to about 70° or about 90°, for example. The angled portion 86 of the mould tool 76 provides the ability to form the flatback preform 62 with an angled lower extension 88, as shown in e.g., Fig. 4. The lower extension 88 of the flatback preform 62 may be used to facilitate integration of the flatback preform 62 within the half-shell mould 40. For example, fabric plies may be arranged over the lower extension 88 once the flatback preform 62 is installed within the half-shell mould 40 to integrate the flatback preform 62 with the remainder of the half-shell portion 36 of the blade 20, as will be described in further detail below. To this end, the lower extension 88 of the flatback preform 62 may extend along a fraction of the entire length of the flatback preform 62 or may extend for the entire length of the flatback preform 62.

With continued reference to Figs. 4-5A, at least one mouldette 90 is removably attached to the top end 72 of the mould body 70 of the flatback pre-mould 66. In that regard, the flatback pre-mould 66 may include a single mouldette 90 that extends along a length of the top end 72 of the pre-mould 66 or a plurality of mouldettes 90 spaced apart along a length of the top end 72 of the pre-mould 66. In either case, each mouldette 90 is configured to be attached to the body 70 of the pre-mould 66 so as to form an extension of the mould surface 80 on which the flatback preform 62 is formed. That is, a portion of the mouldette 90 forms part of the mould surface 80 of the flatback pre-mould 66. Each mouldette 90 is a removable component that is configured to

create specific features or shapes in the final flatback preform 62 that cannot be formed using the main pre-mold body 70 alone. As such, each mouldette 90 may alternatively be referred to as a mould insert or a mould bracket. As will be described in further detail below, the one or more mouldettes 90 and the flatback preform 62

5 define a flatback assembly 92 that is configured to be transferred from the flatback pre-mould 66 to the half-shell mould 40. Stated differently, the one or more mouldettes 90 are configured to be removed from the pre-mould 66 and transferred together with the flatback preform 62 to the half-shell mould 40.

10 Each mouldette 90 is generally "L"-shaped and includes a base flange 94 and an upstand 96. Each mouldette 90 is configured to be attachable to the pre-mould 66 via the base flange 94. As shown in Fig. 4, the upstand 96 is angled in relation to the base flange 94. Consequently, when the mouldette 90 is affixed to the mould body 70, the upstand 96 assumes an angled position with respect to the side 78 of the mould body

15 70 and the mould tool 76. In particular, the upstand 96 may be angled relative to the mould tool 76 and the mould body 70 in a manner similar to the mould tool angle θ_1 . Hence, the upstand 96 may be angled within a range of about 30° to about 70°, for example, relative to the mould tool 76 and the side 78 of the mould body 70. The base flange 94 of the mouldette 90 includes a plurality of apertures or bores 98 distributed

20 in a row along a length of the base flange 94. The plurality of bores 98 are for locating and removably securing the mouldette 90 to the mould body 70 of the flatback pre-mould 66. In that regard, the plurality of bores 98 may be aligned with a corresponding plurality of bores 100 formed in the top end 72 of the mould body 70, as shown in Fig. 4. Each pair of aligned bores 98, 100 is configured to receive a fastener 102, such as

25 a screw or bolt, for removably securing the mouldette 90 to the mould body 70 of the pre-mould 66. In one embodiment, the bore 100 in the mould body 70 may be internally threaded. In another embodiment, both bores 98, 100 may be internally threaded. As described in further detail below, the base flange 94 and/or the plurality of bores 98 may be used in conjunction with the datum features 58 on the half-shell mould 40 to

30 precisely align the flatback preform 62 within the half-shell mould 40. Accordingly, the bores 98 and/or the base flange 94 may also be referred to as datum features.

With continued reference to Figs. 4-5A, each mouldette 90 is attached to the top end 72 of the mould body 70 such that the upstand 96 forms an extension of the mould

body 70 of the pre-mould 66, and in particular the mould tool 76. Specifically, a contact surface 104 of the upstand 96 forms an extension of the mould surface 80 of the mould tool 76. In that regard, the upstand 96 of the mouldette 90 provides the ability to form the flatback preform 62 with an angled upper extension 106, as shown in e.g., Fig. 4.

5 The upper extension 106 of the flatback preform 62 may be used to secure the flatback preform 62 to the pre-mould 66. In particular, one or more removable clamp devices 108 may be used to secure the upper extension 106 of the flatback preform 62 in place against the upstand 96 of each mouldette 90. In the embodiment shown, the clamp device 108 is a removable “C”-clamp. As shown, each clamp device 108 includes one
10 or more adjustable clamping pads 110 supported by a generally “C”-shaped frame member 112. The clamp devices 108 are configured to secure the flatback preform 62 in place against the mouldette 90, particularly as the mould body 70 of the pre-mould 66 is rotated between a first, generally horizontal position (e.g., Fig. 4) and a second, generally vertical position (e.g., Fig. 5).

15 As described above, the flatback preform 62 is formed on the mould surface 80 of the flatback pre-mould 66. However, before the flatback preform 62 may be formed, the one or more mouldettes 90 are first attached to the top end 72 of the mould body 70 using fasteners 102, as previously described. Additionally, the mould body 70 is
20 moved or rotated into the horizontal position, as shown in Fig. 4. The horizontal position may also be referred to as the moulding position. When so positioned, the mould body 70 is positioned generally horizontally so that the flatback preform 62 may be formed. The layup process to form the flatback preform 62 includes placing one or more first fabric layers or plies 114 of glass-fibre fabric onto the mould surface 80.
25 These first layers 114 will later form an outer skin of the flatback preform 62 and thus the blade 20. Structural elements, including core material 116 are then arranged on first fabric layers 114. Next, one or more second fabric layers 118 of glass-fibre fabric are placed over the core material 116. These additional second fabric layers 118 will form an inner skin of the flatback preform 62 and thus the blade 20. The fabric layers
30 114, 116 may be pre-impregnated with resin or installed dry and later infused with resin using a VARTM process. The flatback preform 62 may be cured in the pre-mould 66 or later cured in the half-shell mould 40. As the flatback preform 62 ultimately forms part of the outer shell 32 of a wind turbine blade 20, the flatback preform 62 includes a sandwich panel construction which includes the core material 116, which may be a

lightweight foam (e.g., polyurethane) sandwiched between inner and outer GRP layers or skins 114, 118, respectively.

Once the flatback preform 62 has been formed, the flatback preform 62 is ready to be transferred from the flatback pre-mould 66 to the half-shell mould 40 for installation. In that regard, the one or more clamp devices 108 are applied to secure the flatback preform 62 in place against each mouldette 90, as shown in Fig. 4. The pre-mould 66, and in particular the mould body 70 is then rotated about the axis of rotation A1 from the first, generally horizontal position to the second, generally vertical position, as shown in Fig. 5. The vertical position may also be referred to as the transfer position. When in the transfer position, the mould surface 80 of the tool body 84 may be arranged in a near parallel relationship to the vertical direction (i.e., the local gravity vector). However, in certain instances, it may be preferable for the mould surface 80 of the tool body 84 to be slightly angled relative to the vertical direction when in the transfer position. For example, the mould surface 80 of the tool body 84 may be angled up to 30° relative to the vertical direction when in the transfer position. When in the transfer position, the flatback preform 62 is supported from the pre-mould 66 via the clamped engagement with the one or more mouldettes 90. When so positioned, the flatback preform 62, and in particular the flatback assembly 92 is presented for removal from the pre-mould 66 by the flatback lifting tool 68. As will be described in further detail below, the flatback lifting tool 68 is configured to remove the flatback assembly 92 from the pre-mould 66, transfer the flatback assembly 92 to the half-shell mould 40, and install the flatback assembly 92 into the half-shell mould 40.

Turning now with reference to Figs. 5A and 6, details of the flatback lifting tool 68 are shown and will now be described in accordance with a preferred embodiment of the invention. In that regard, the flatback lifting tool 68 includes an elongate lifting beam 130 that extends a length from a first end 132 to an opposite second end 134. As shown in Fig. 6, the length of the lifting beam 130 may be the same or greater than the length of the flatback preform 62. The lifting beam 130 is formed of a plurality of tubular frame members 136 interconnected with a plurality of tubular cross-members 138. While the lifting beam 130 is provided with a generally square transverse cross sectional shape, it will be understood that other configurations of the lifting beam 130

are possible. For example, the lifting beam 130 may have a triangular, rectangular, or other polygonal transverse cross-sectional shape. The lifting tool 68 is configured to be lifted by a lifting device 140, such as a crane or hoist, for example. In that regard, a top 142 of the lifting beam 130 includes one or more lift points 144 configured to receive lifting cables 146 for suspending the lifting tool 68 from the lifting device 140. The lift points 144 may be configured as a bracket or lifting lug, for example, that is attached to one of the frame members 136 of the lifting tool 68. Additionally, the first and second ends 132, 134 of the lifting beam 130 each include an alignment element 148, which is configured to facilitate centering of the lifting beam 130 over the half-shell mould 40, as described in further detail below.

With continued reference to Figs. 5A and 6, the lifting tool 68 further includes a plurality of support arms 150 movably supported from the lifting beam 130 of the lifting tool 68. Each of the plurality of support arms 150 is suspended beneath the lifting beam 130 and configured to engage the flatback preform 62 so that the flatback preform 62 may be lifted with the lifting tool 68. Furthermore, the plurality of support arms 150 provide the lifting tool 68 with the ability to manipulate or adjust a position of the flatback preform 62. In particular, each of the plurality of support arms 150 is rotatable relative to the lifting beam 130 between a retracted position (e.g., Fig. 8A) and an extended position (e.g., Fig. 8B). In that regard, each support arm 150 is rotatable about a hinge joint 152 to thereby adjust a position of the flatback preform 62, as will be described in further detail below. To this end, each hinge joint 152 may define an axis of rotation of a corresponding support arm 150. While the exemplary lifting tool 68 includes four support arms 150, it will be understood that the lifting tool 68 may include fewer or more support arms 150 as desired. The amount of support arms 150 may depend on a length of the flatback preform 62, for example. In this respect, the drawings are not intended to be limiting.

Each support arm 150 includes a crossbar 154 and a support bar 156 that extends a length downwardly from the crossbar 154 to a terminal end 158. The terminal end 158 of certain support bars 156 may be angled or bent to accommodate the lower extension part 88 of the flatback preform 62, as shown. Furthermore, the support bars 156 may have different lengths, depending on the location of the support arm 150 along the lifting beam 130. This is to accommodate the height H of the flatback preform

62, which varies along its length L. The crossbar 154 and the support bar 156 may be a single piece or two separate components connected together. In either case, the crossbar 154 is movably attached to the lifting beam 130. As shown in Fig. 5A, the crossbar 154 extends transverse to the lifting beam 130, with a first end 160 of the crossbar 154 being attached adjacent a back side 162 of the lifting beam 130 and an opposite, second end 164 of the crossbar 154 being attached adjacent a front side 166 of the lifting beam 130. The first end 160 of the crossbar 154 is attached to the lifting beam 130 at the hinge joint 152. Specifically, the first end 160 of the crossbar 154 may be movably attached to the lifting beam 130 with a pair of brackets 168 which define the hinge joint 152, for example. The second end 164 of the crossbar 154 is attached to the lifting beam 130 with an actuator 170, such as linear actuator, for example. As shown, a housing 172 of the linear actuator 170 may be attached to a crossmember 138 of the lifting beam 130 and a piston rod 174 of the linear actuator 170 may be attached to the second end 164 of the crossbar 154. To this end, actuation of the piston rod 174 of the linear actuator 170 causes the support arm 150, and in particular the support bar 156, to rotate about the hinge joint 152.

With continued reference to Figs. 5A and 6, each support arm 150 includes a plurality of workholding devices configured to engage the flatback preform 62 so that the flatback preform 62 may be lifted and manipulated with the lifting tool 68. In that regard, the support bar 156 of each support arm 150 includes at least one clamp workholding device 176, otherwise referred to as a mouldette workholding device. As shown, the clamp workholding device 176 may be the workholding device located nearest to the crossbar 154 along the support bar 156. In that regard, the clamp workholding device 176 is configured to clamp the mouldette 90 and the flatback preform 62 therebetween, and may be a pneumatic clamp, for example. Each clamp workholding device 176 includes an actuatable clamp pad 178 and an adjustable, stationary clamp pad 180. The stationary clamp pad 180 is supported from the crossbar 154 so as to be spaced away from the actuatable clamp pad 178, which is located on the support bar 156. The actuatable clamp pad 178 is configured to be moved in a linear direction relative to the support bar 156 via an actuator 181. In that regard, movement of the actuatable clamp pad 178 causes the mouldette 90 and the flatback preform 62 to be clamped between the clamp pads 178, 180 of the clamp workholding device 176. Either one of the actuatable clamp pad 178 or the adjustable clamp pad 180 may comprise a vacuum

pad. To this end, while only one clamp workholding device 176 is shown on each support arm 150, it will be understood that each support arm 150 may include more clamp workholding devices 176, such as two or three, for example.

5 Each support bar 150 further includes one or more support workholding devices 182 spaced apart along a length of the support bar 156 and between the clamp workholding device 176 and the terminal end 158 of the support bar 156. Each support workholding device 182 may include an adjustable pad or a vacuum pad 184 that is configured to engage surfaces of the flatback preform 62. In that regard, one or more
10 vacuum pads 184 may be used to hold the flatback preform 62 against the support bar 156 so that movement of the support arm 150 results in movement of the flatback preform 62. One or more adjustable pads 184 may be used to press the flatback preform 62 against the mould surface 46 of the half-shell mould 40. For example, the support workholding device 182 located at the terminal end 158 of each support bar
15 156 may comprise a vacuum pad 184 while the remainder of the support workholding devices 182 may comprise a pad 184. Alternatively, the support workholding device 182 located at the terminal end 158 of each support bar 156 may be a mechanical clamp that is configured to clamp the flatback preform 62 on opposite sides, such as on opposite sides of the extension 88. The distance between the support bar 156 and
20 the mechanical clamps may be adjustable. The mechanical clamps may be similar to the actuatable clamp pad 178 described above. In another embodiment, the mechanical clamps may be replaced with magnetic or electromagnetic clamps. For example, an iron bar may be provided on the back side of the extension 88 of the flatback preform 62 to provide a clamping force together with a magnetic clamp pad
25 that is configured to engage the front side of the extension 88. The support bar 156 may include a combination of clamps, such as one or more vacuum pads in combination with one or more mechanical clamps.

As best shown in Fig. 6, the lifting beam 130 of the lifting tool 68 is configured to be
30 supported by one or more guide rails 186 over the half-shell mould 40 for installation of the flatback preform 62 within the half-shell mould 40. In particular, the lifting beam 130 is supported in a generally stationary position by the guide rails 186 so that fine adjustment to the position of the flatback preform 62 relative to the half-shell mould 40 may be achieved, particularly through rotation of the one or more of the support arms

150. In the embodiment shown, there are two guide rails 186 for receiving the lifting beam 130 of the lifting tool 68. For example, one guide rail 186 may be located at the root end 44 of the half-shell mould 40 and the second guide rail 186 may be located at the tip end 42 of the half-shell mould 40. Each guide rail 186 includes a brace member 188 configured to receive a corresponding alignment element 148 at each end 132, 134 of the lifting beam 130. In the embodiment shown, the free end of each brace member 188 includes a locating element 190 in the form of a locating cone that is configured to receive a corresponding alignment element 148 of the lifting beam 130. In that regard, each alignment element 148 is configured as a generally "V"-shaped bracket that is correspondingly sized to be received within a respective locating cone 190. The locating cones 190 are configured to center the lifting beam 130 over the half-shell mould 40. That is, once each alignment element 148 is fully seated within a respective lifting cone 190, the lifting beam 130 is supported between the guide rails 186 and generally centered over the mould trailing edge 52 of the half-shell mould 40 (e.g., Fig. 7B). In an alternative embodiment, the locating elements 190 may be in the form of an aperture or slot configured to receive a correspondingly sized alignment element 148 on the lifting beam 130.

Having described certain details of the system, the method of forming the flatback preform 62 and transferring the flatback preform 62 to the half-shell mould 40 will now be described in additional detail with respect to Figs. 5A-9. As shown in Fig. 5A, once the flatback preform 62 is formed, the flatback pre-mould 66 is rotated to the transfer position to vertically orient the flatback preform 62. In particular, each mouldette 90 and the upper extension 106 of the flatback preform 62 are presented for engagement by the lifting tool 68. The lifting tool 68 may then be lowered to the flatback pre-mould 66 to engage the flatback assembly 92. In particular, the plurality of support arms 150 are brought into engagement with the flatback assembly 92. In that regard, the clamp workholding device 176 of each support arm 150 is received over the mouldette 90 and the upper extension 106 of the flatback preform 62. The actuator 181 of each clamp workholding device 176 may be operated to clamp the mouldette 90 and the upper extension 106 of the flatback preform 62 between the clamp pads 178, 180. Additionally, the plurality of support workholding devices 182 are engaged with surfaces of the flatback preform 62. In that regard, the at least one vacuum pad 184 of each support arm 150 may be operated to hold the flatback preform 62 against each

support bar 156. The adjustable pads 184 of each support arm 150 may be brought into engagement with surfaces of the flatback preform 62 to maintain a shape of the flatback preform 62. Once each support arm 150 is fully engaged with the flatback assembly 92, as shown in Fig. 5A, the flatback assembly 92 is ready to be removed

5 from the pre-mould 66 and transferred to the half-shell mould 40.

Before the flatback assembly 92 may be removed from the pre-mould 66 by the lifting tool 68, the one or more mouldettes 90 must first be detached from the mould body 70 of the pre-mould 66. In that regard, the fasteners 102 are removed to release the
10 mouldette 90 and thus the flatback assembly 92 from the pre-mould 66. Removal of all the fasteners 102 may result in the weight of the flatback assembly 92 being partially or entirely borne by the lifting tool 68. During the process of securing the lifting tool 68 to the flatback assembly 92, the one or more clamp devices 108 may remain attached to the flatback assembly 92. To this end, the one or more clamp devices 108 may
15 remain attached to the flatback assembly 92 while the flatback assembly 92 is moved with the lifting tool 68 into the half-shell mould 40.

As shown in Figs. 6 and 7A, the lifting device 140 is operated to position the lifting tool 68 and the flatback assembly 92 over the half-shell mould 40 for installation of the
20 flatback preform 62 in the half-shell mould 40. In particular, the lifting tool 68 is positioned vertically over the steep region 60 of the mould surface 46 of the half-shell mould 40 where flatback preform 62 is to be located. The lifting beam 130 is then lowered into engagement with the guide rails 186, as indicated by directional arrow A2 in Fig. 7A. The lifting beam 130 is shown fully engaged with the guide rails 186 in Figs.
25 6 and 7B. In this position, the one or more mouldettes 90 are brought into a near-engaging or a partial-engaging relationship with the shoulder 56 that extends along the mould trailing edge 52 of the half-shell mould 40. While the lifting tool 68 and the flatback assembly 92 is being lowered, the base flange 94 of the one or more mouldettes 90 may be aligned with the shoulder 56 to effectively align the flatback
30 assembly 92 with the half-shell mould 40. In some embodiments, the base flange 94 of each mouldette 90 may be step-shaped and the shoulder 56 of the half-shell mould 40 may be similarly step-shaped to facilitate this alignment. For purposes of alignment, the base flange 94 of each mouldette 90 may be considered a datum feature, and

similarly, the shoulder 56 of the half-shell mould 40 may also be considered a datum feature.

As shown in Figs. 7A-7B, while the flatback assembly 92 is being transferred and positioned within the half-shell mould 40, each of the plurality of support arms 50 may be in the retracted position. As a result, when the lifting beam 130 is engaged with the guide rails 186, the flatback assembly 92, and in particular the flatback preform 92 may be angled away from the mould surface 46 which results in a gap or space 192 being formed between the flatback preform 92 and the mould surface 46. To precisely locate the flatback preform 62 within the half-shell mould 40, the actuator 170 of each support arm 150 may be operated to move or rotated the support arm 150 from the retracted position to rotate the flatback preform 62 into contact against the mould surface 46 of the half-shell mould 40, as indicated by directional arrow A3 in Fig. 8A. Rotation of the flatback preform 62 in that regard causes the gap 192 between the flatback preform 62 and the mould surface 46 to close, as shown in Fig. 8B. To this end, each support arm 150, and thus the flatback preform 62 may be rotated within a range of between about 2° and about 10° about the hinge axis 152 before the flatback preform 62 is pressed into contact against the mould surface 46 of the half-shell mould 40. As each support arm 150 is individually movable, each support arm 150 and thus portions of the flatback preform 62 may be rotated more or less about respective hinge joints 152 compared to others. This provides the lifting tool 68 with the ability to precisely conform the flatback preform 62 to the varying contours of the half-shell mould 40.

Referring now to Fig. 9, the one or more mouldettes 90 may be used to precisely position the flatback preform 62 within the half-shell mould 40. In that regard, the plurality of bores 98 formed in the base flange 94 of each mouldette 90 may be aligned with corresponding attachment points or bores 58 formed in the shoulder 56 of the half-shell mould 40. Thus, the bores 58, 98 may be used as datum features to precisely align the flatback preform 62 in both the chordwise and spanwise directions within the half-shell mould 40. Accordingly, the bores 98 in the base flange 94 of each mouldette 90 may be considered a datum feature, and similarly, the bores 58 formed in the shoulder 56 of the half-shell mould 40 may also be considered a datum feature. Once

the flatback assembly 92 is rotated to align the bores 98 of each mouldette 90 with respective bores 58 in the half-shell mould 40, fasteners 194 may be inserted through each pair of aligned bores 58, 98 to secure the mouldette 90 and thus the flatback assembly 92 to the half-shell mould 40. To this end, the mouldettes 90 may remain
5 attached to the half-shell mould 40 during the layup process to form the half-shell portion 34, 36 of the blade 20. The mouldettes 90 may be removed prior to the VARTM process, for example.

While the present invention has been illustrated by a description of various preferred
10 embodiments and while these embodiments have been described in some detail, it is not the intention of the Applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Thus, the various features of the invention may be used alone or in any combination depending on the needs and preferences of the user.

15

Claims

1. A method of making a wind turbine blade (20) using a blade mould (40) to form at least a portion of the wind turbine blade, comprising:

5 providing a flatback pre-mould (66) defining a mould surface (80), at least one mouldlette (90) removably attached to the flatback pre-mould (66) to form part of the mould surface (80), and a flatback lifting tool (68);

forming a flatback preform (62) on the mould surface (80) of the flatback pre-mould (66);

10 securing the flatback preform (62) to the at least one mouldlette (90) to form a flatback assembly (92);

detaching the at least one mouldlette (90) from the flatback pre-mould (66);

transferring the flatback assembly (92) from the flatback pre-mould (66) to the blade mould (40) using the flatback lifting tool (68); and

15 arranging the flatback assembly (92) on the blade mould (40) such that the flatback preform (62) is positioned adjacent to a mould surface (46) of the blade mould (40).

2. The method of claim 1, further comprising:

20 attaching the at least one mouldlette (90) to the blade mould (40) to secure the flatback assembly (92) in place relative to the blade mould (40), wherein the mouldlette (90) forms an extension of the mould surface (46) of the blade mould (40).

3. The method of any of the preceding claims, wherein the at least one

25 mouldlette (90) includes at least one datum feature and the blade mould (40) includes at least one datum feature, the method further comprising:

aligning the at least one datum feature of the mouldlette (90) with the at least one datum feature of the blade mould (40) to align the flatback preform (62) along the mould surface (46) of the blade mould (40).

30 4. The method of claim 3, wherein the at least one datum feature of the mouldlette (90) is a bore (98) and the at least one datum feature of the blade mould (40) is a bore (58).

5. The method of claim 3, wherein the at least one datum feature of the mouldette (90) is a flange (94) and the at least one datum feature of the blade mould (40) is shoulder (56) configured to receive the flange (94) of the mouldette (90).

5 6. The method of any of the preceding claims, further comprising:
moving the flatback pre-mould (66) from a first position wherein the flatback preform (62) is substantially horizontally positioned to a second position wherein the flatback preform (62) is substantially vertically positioned; and
lifting the flatback assembly (92) from the flatback pre-mould (66) while the
10 flatback preform (62) is substantially vertically positioned.

7. The method of any of the preceding claims, wherein arranging the flatback assembly (92) on the blade mould (40) further comprises:
securing the lifting tool (68) in place relative to the blade mould (40); and
15 operating the lifting tool (68) to rotate the flatback preform (62) into contact against the mould surface (46) of the blade mould (40).

8. The method of any of the preceding claims, wherein the flatback lifting tool (68) includes a plurality of mouldette workholding devices (176), the method further
20 comprising:
operating the lifting tool (68) to clamp the mouldette (90) and the flatback preform (62) between the plurality of mouldette workholding devices (176).

9. The method of any one of claims 7-8, wherein the lifting tool (68) includes a
25 plurality of rotatable support arms (150) suspended from the lifting tool (68), each rotatable support arm (150) including at least one support workholding device (182), the method further comprising:

operating the lifting tool (68) to engage the flatback preform (62) with the at least one support workholding device (182) of each rotatable support arm (150).

30

10. The method of claim 9, further comprising:
operating the lifting tool (68) to rotate the plurality of rotatable support arms (150) to press the flatback preform (62) into contact against the mould surface (46) of the blade mould (40).

11. The method of any one of claims 7-10, wherein the flatback preform (62) is rotated within a range of between about 2° and about 10° relative to vertical.
- 5 12. A system for making at least a portion of a wind turbine blade, comprising:
a flatback pre-mould (66) including a body (70) that defines a mould surface (80) for forming a flatback preform (62); and
at least one mouldette (90) removably attached to the flatback pre-mould (66) such that a portion of the mouldette (90) forms part of the mould surface (90),
10 wherein the at least one mouldette (90) is configured to be removed from the flatback pre-mould (66) together with the flatback preform (62), and
wherein the flatback preform (62) is configured to be installed in a blade mould (40) to form the at least a portion of the wind turbine blade (20).
- 15 13. The system of claim 12, wherein the body (70) of the flatback pre-mould (66) includes an angled portion (86) that defines an extension of the mould surface (80), the angled portion (86) being angled within a range comprising a lower angle of about 50° and an upper angle relative to the body (70) of the flatback pre-mould (66).
- 20 14. The system of any one of claims 12-13, wherein the body (70) of the flatback pre-mould (66) is movable between a first position wherein the mould surface (80) of the body (70) is substantially horizontally positioned and a second position wherein the mould surface (80) of the body (70) is substantially vertically positioned.
- 25 15. The system of any one of claims 12-14, further comprising a flatback lifting tool (68) configured to transfer the flatback preform (62) from the flatback pre-mould (66) to the blade mould (40).
16. The system of claim 15, wherein the flatback lifting tool (68) includes a
30 plurality of mouldette workholding devices (176) configured to clamp the mouldette (90) and the flatback preform (62).

17 The system of claim 15 or 16, wherein the flatback lifting tool (68) includes a plurality of rotatable support arms (150) suspended from the lifting tool (68), each rotatable support arm (150) including at least one support workholding device (182) configured to secure the flatback preform (62) to the flatback lifting tool (68).

5

18. The system of claim 17, wherein the plurality of rotatable support arms (150) are configured to rotate the flatback preform (62) within a range of between about 2° and about 10° relative to vertical.

10 19. The system of any one of claims 12-18, further comprising a plurality of mouldette workholding devices (176) configured to secure the flatback preform (62) to the at least one mouldette (90) to define a flatback assembly (92), the flatback assembly (92) being transferable as a single piece to the blade mould (40).

15 20. The system of any of claims 12-18, wherein the at least one mouldette (90) includes at least one datum feature that is configured to be aligned with a corresponding datum feature of the blade mould (40) to align the flatback preform (62) within the blade mould (40).

20 21. The system of claim 18, wherein the at least one datum feature of the at least one mouldette (90) comprises one of a bore (98) or a flange (94).

22. The system of any of claims 12-18, further comprising the blade mould (40).

25 23. A wind turbine blade (20) at least a portion of which is formed using the system of any of claims 12-22.

24. A system for making a wind turbine blade (20), comprising:

a flatback assembly (92) including a flatback preform (62) and at least one
30 mouldette (90); and

a flatback lifting tool (68) for lifting the flatback assembly (92), the flatback lifting tool (68) including a plurality of mouldette workholding devices (176) configured to secure the mouldette (90) and the flatback preform (62),

wherein the flatback preform (62) is configured to be installed in a blade mould (40) to form part of a shell section of the wind turbine blade (20).

25. The system of claim 24, further comprising the blade mould (40).

5

26. A wind turbine blade (20) at least a portion of which is formed using the system of claim 25.

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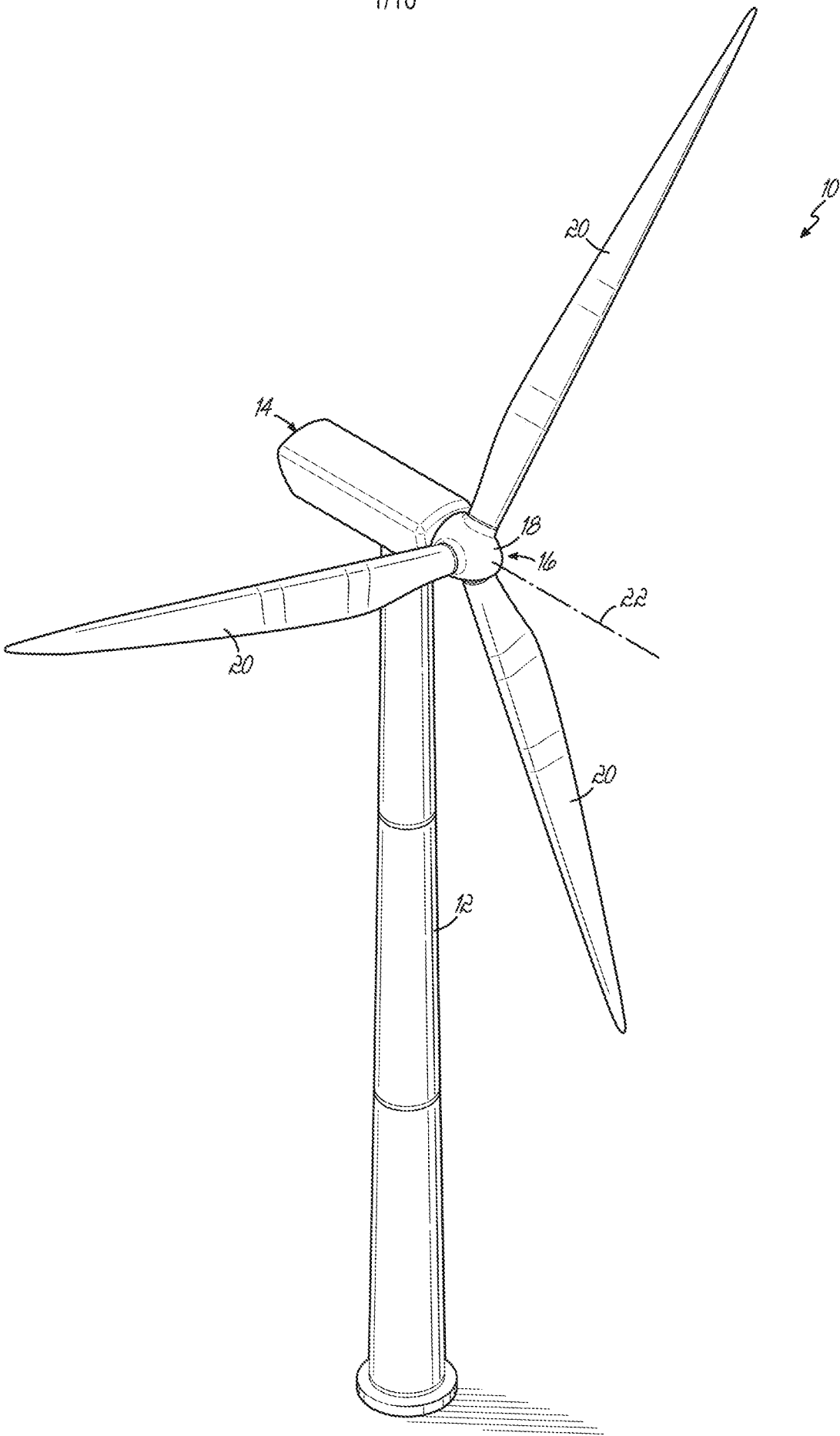


FIG. 1

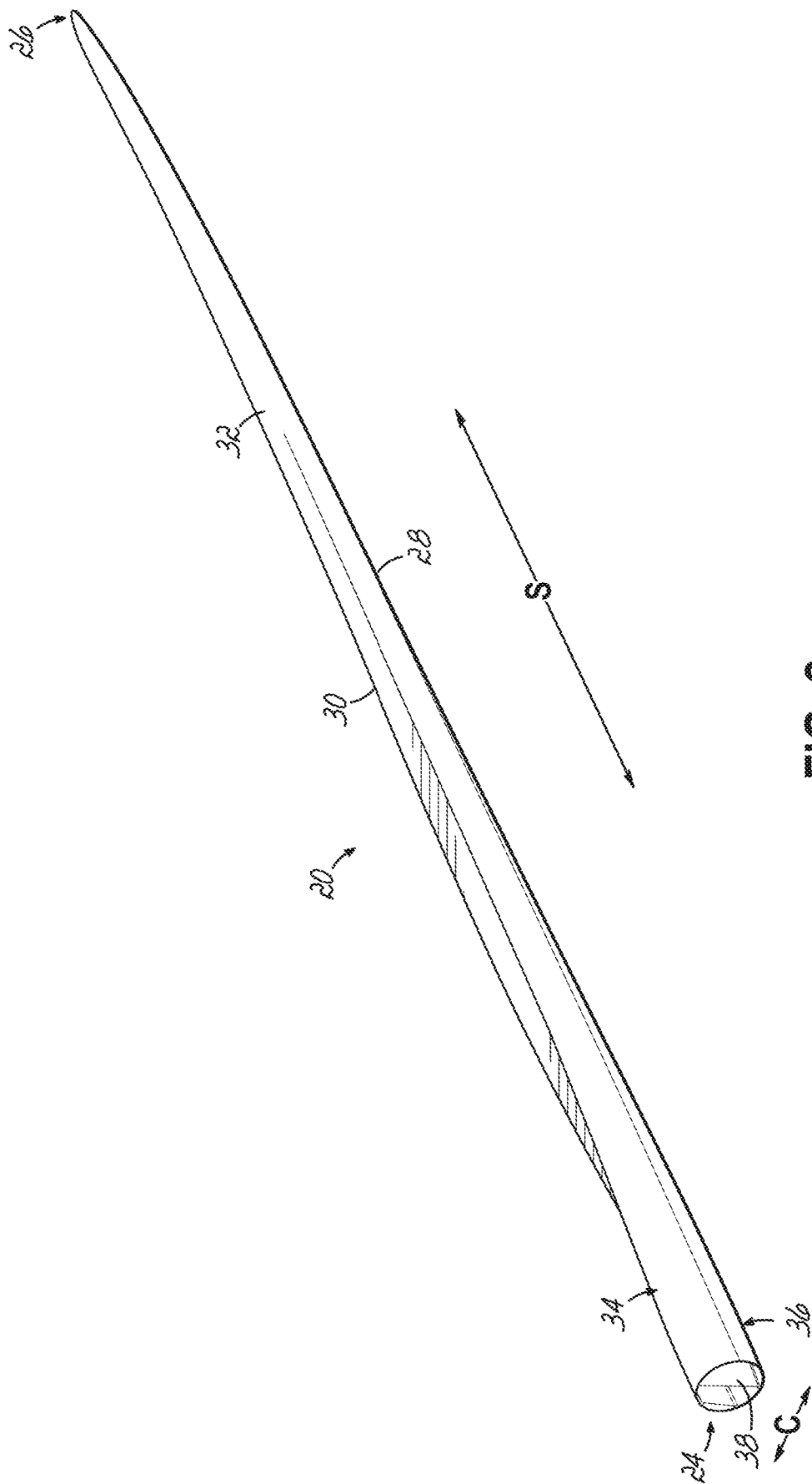
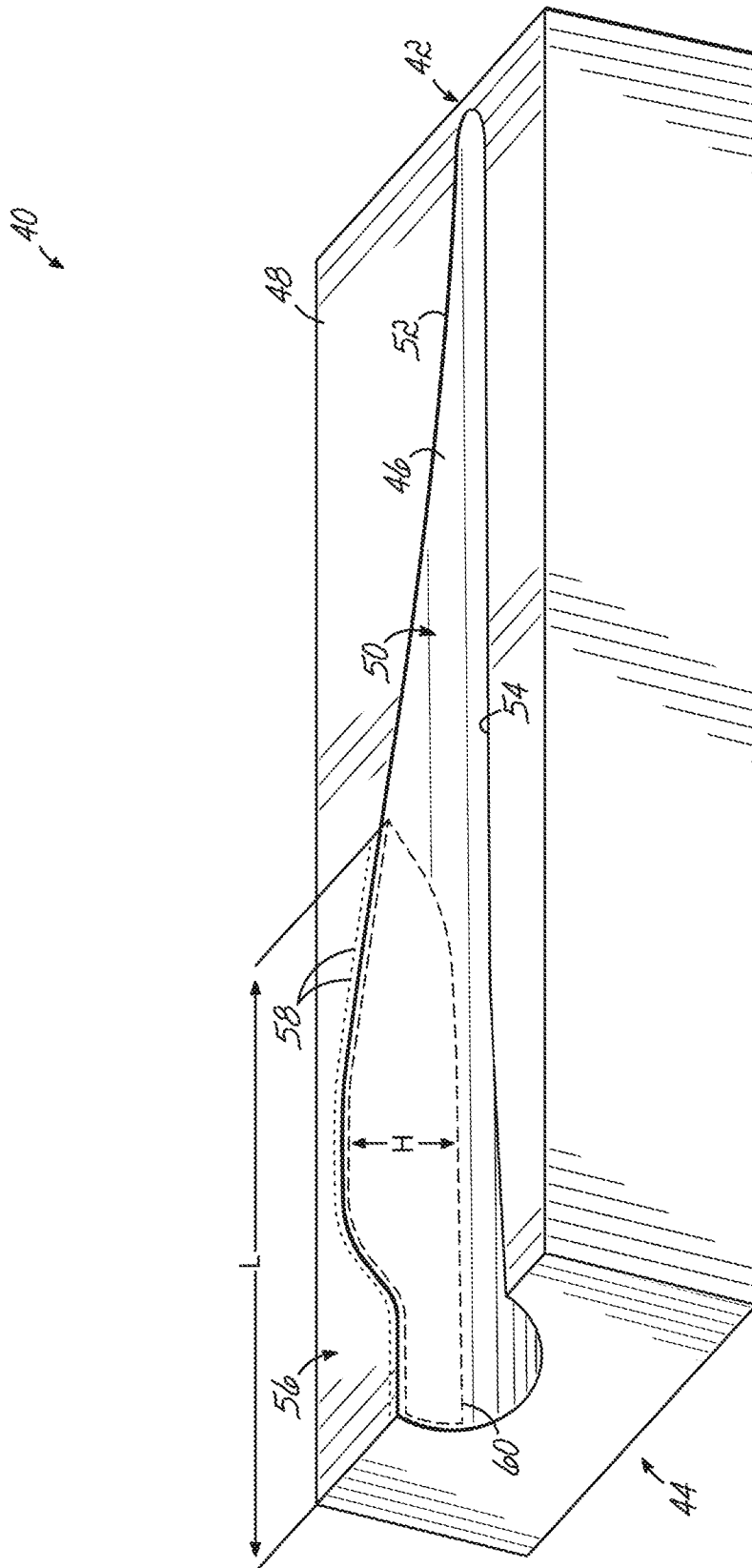
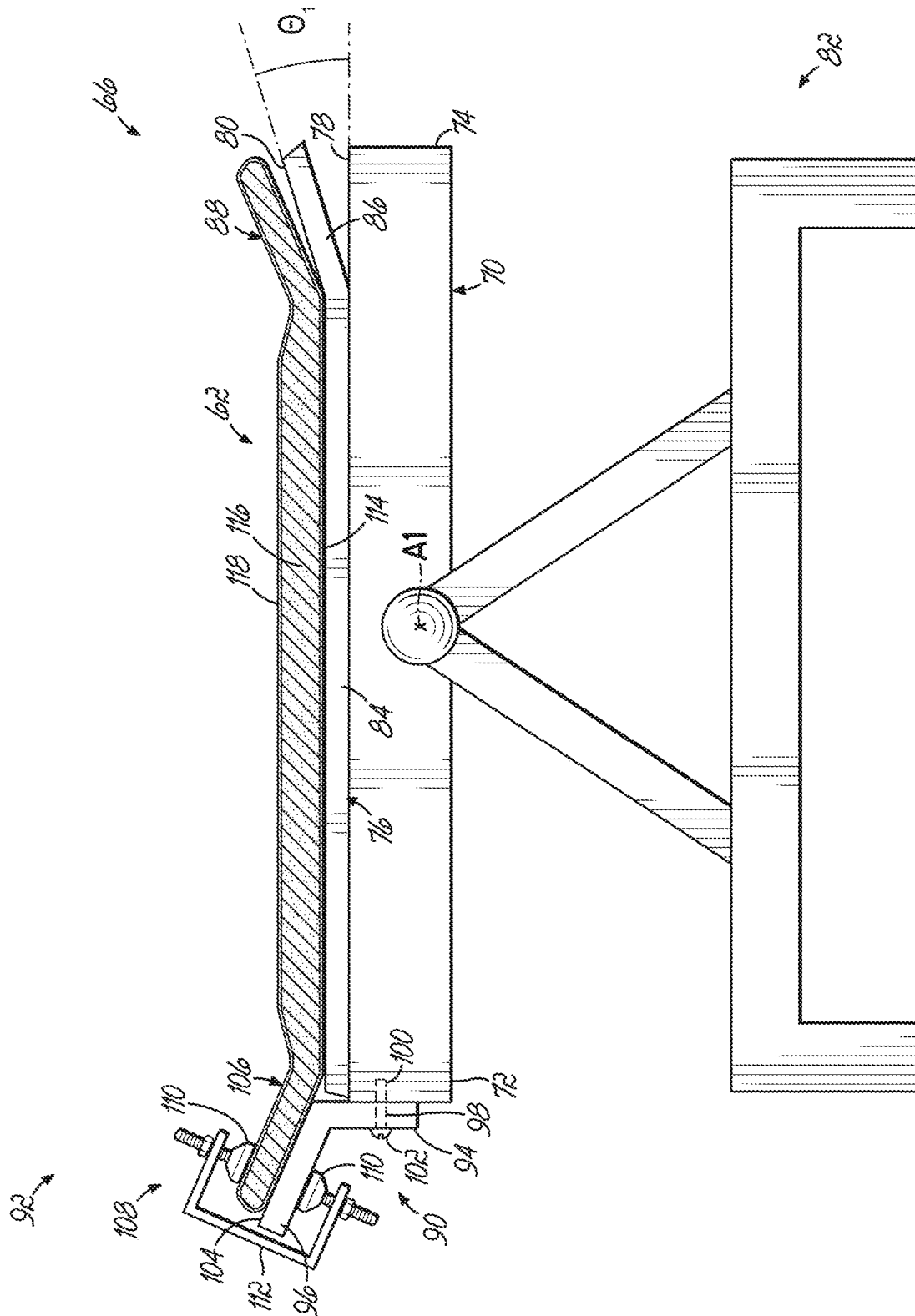


FIG. 2



364



406

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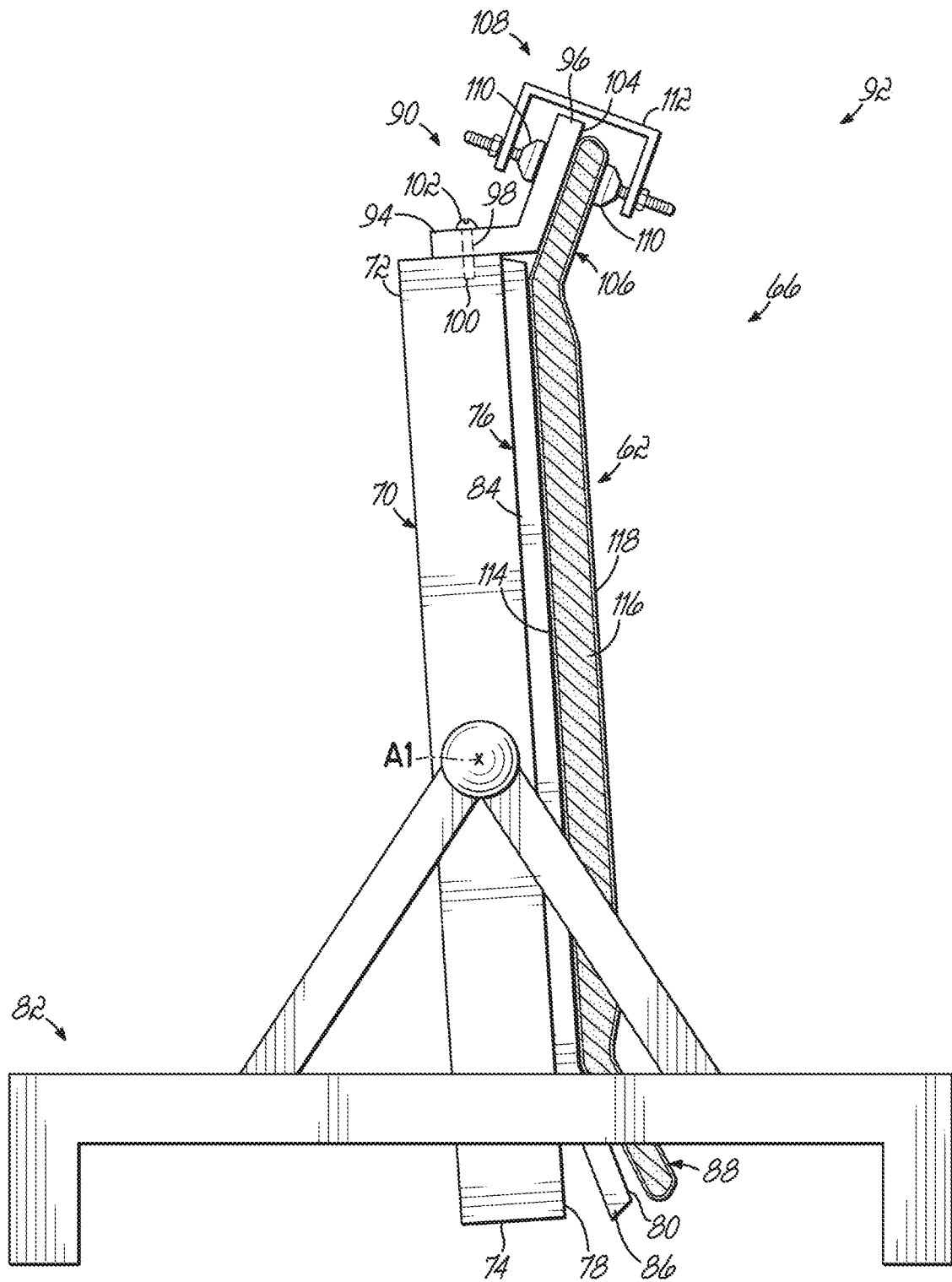


FIG. 5

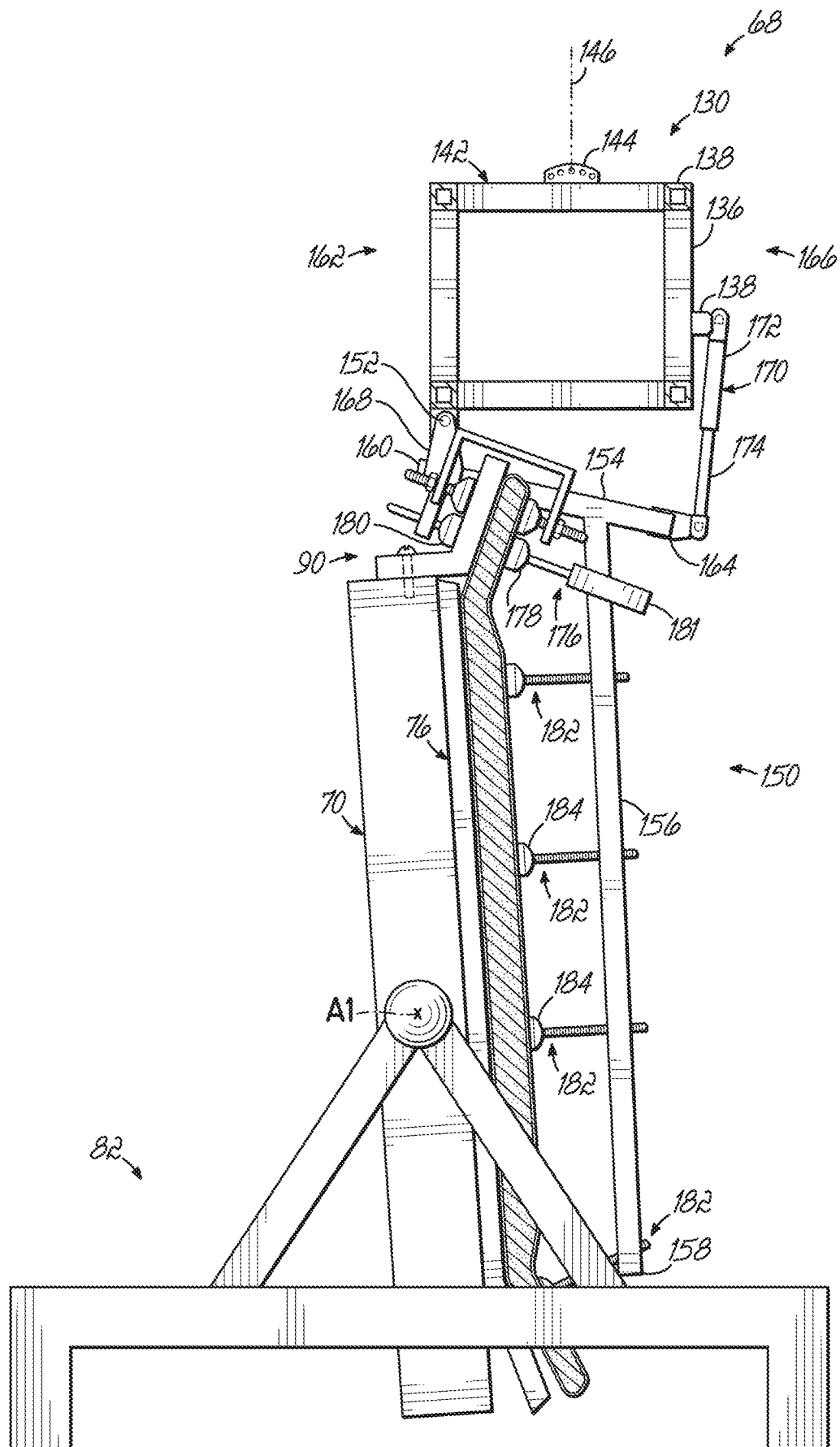
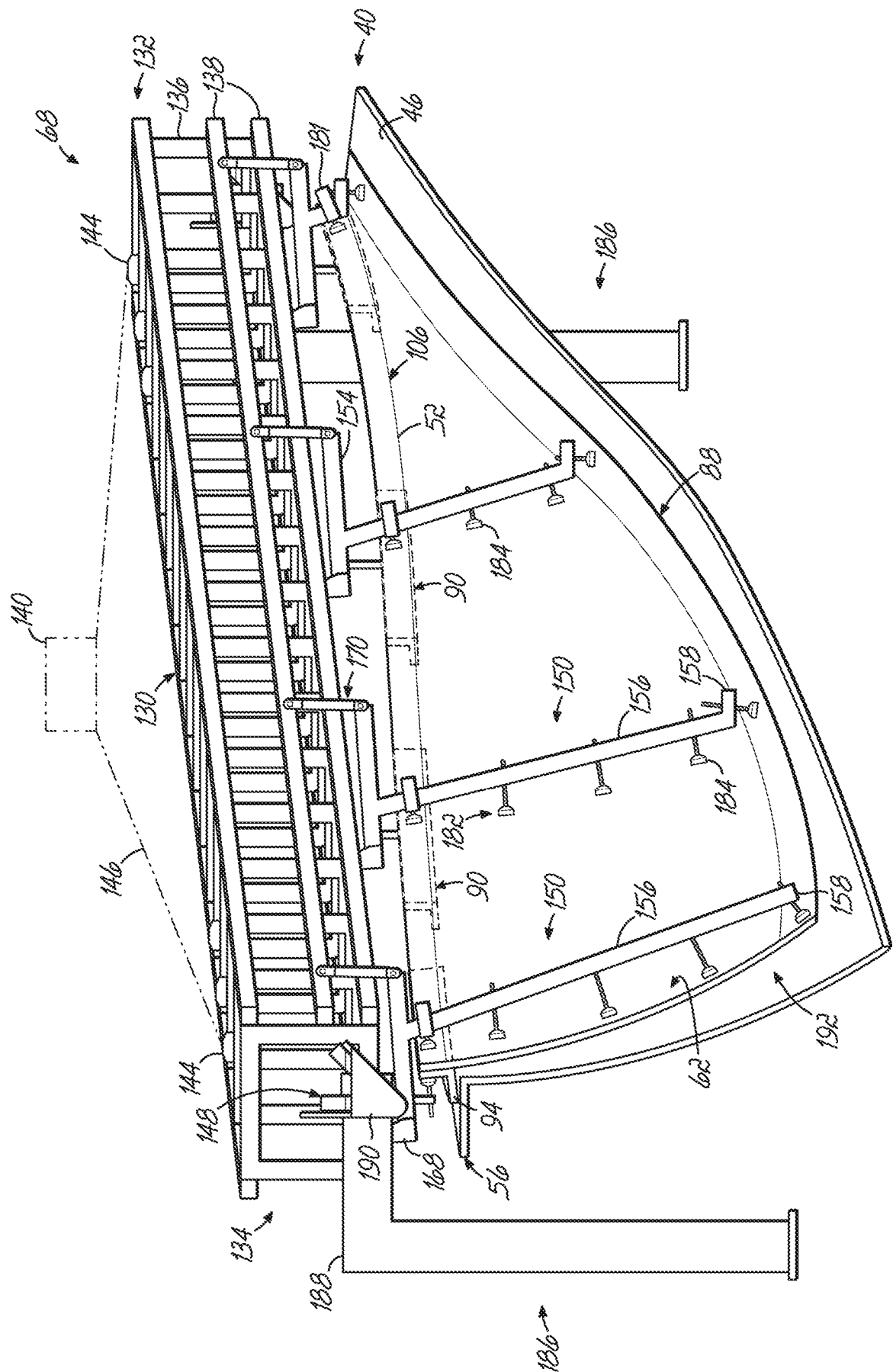


FIG. 5A



GO
OR
G
L

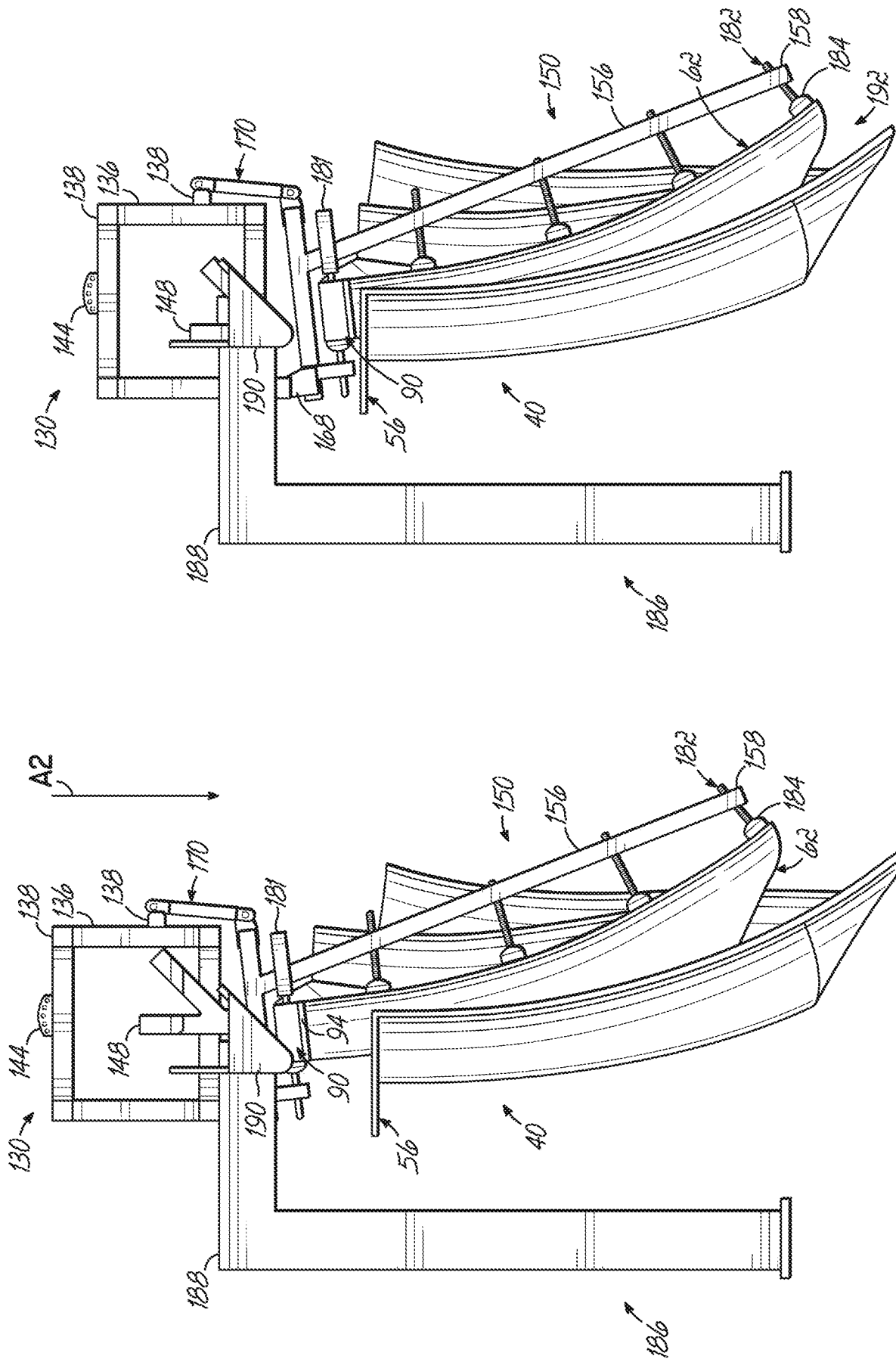


FIG. 7B

FIG. 7A

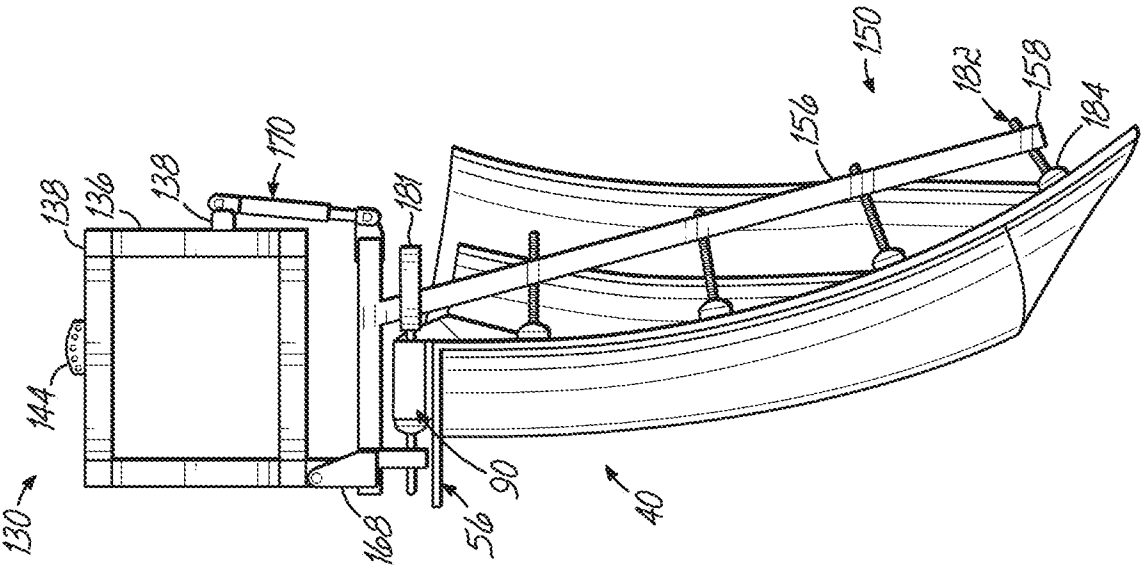


FIG. 8B

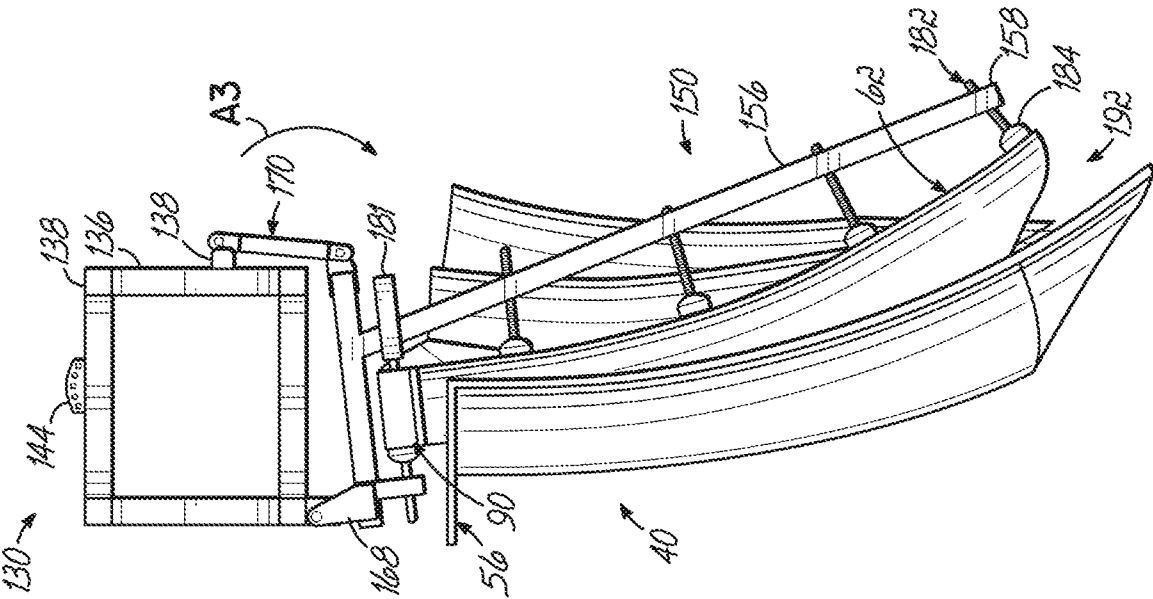


FIG. 8A

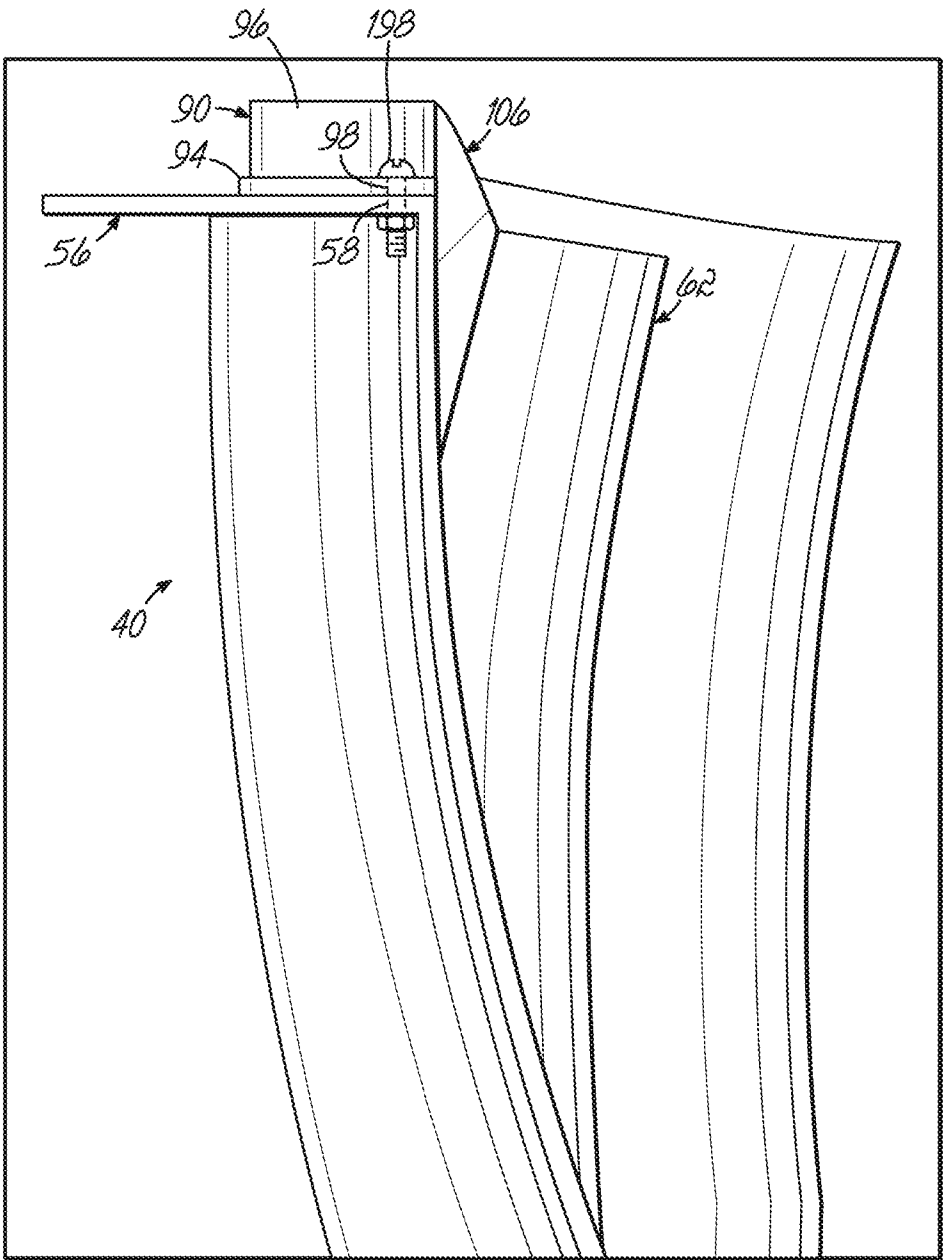


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2024/050199

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29C31/08 B29C70/54 B29D99/00
ADD. B29L31/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B29C B29D B29L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2022/143874 A1 (MADSEN KRISTIAN LEHMANN [DK]) 12 May 2022 (2022-05-12)	23, 26
A	paragraph [0001] paragraph [0082] - paragraph [0085] paragraph [0091] - paragraph [0098] figures -----	1-22, 24, 25
X	US 2015/314536 A1 (SMITH JONATHAN [GB] ET AL) 5 November 2015 (2015-11-05)	23-26
A	paragraph [0001] paragraph [0045] - paragraph [0062] figures -----	1-22
X	EP 4 155 064 A1 (LM WIND POWER AS [DK]) 29 March 2023 (2023-03-29)	23-26
A	paragraph [0001] - paragraph [0007] paragraph [0089] - paragraph [0101] figures -----	1-22



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

18 November 2024

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2024/050199

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