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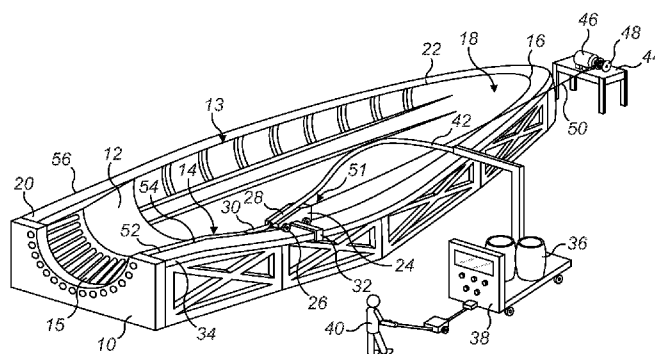


FIG. 1

(57) Abstract: Method of applying adhesive to a wind turbine part (12), defining a vehicle travel path (54) relative to the part (12) and providing a vehicle (24) on the vehicle travel path (54). The vehicle (24) is configured to apply adhesive (30) along a bond line (52) defined on a bond surface of the part (12). Supplying adhesive (30) to the vehicle (24), applying adhesive (30) along the bond line by causing the vehicle (24) to travel along the vehicle travel path (54), and varying the speed of the vehicle (24) along the vehicle travel path (54) so as to control the quantity of adhesive (30) applied at successive positions along the bond line (52).

Automated Manufacture of Wind Turbine Components

Technical Field

- 5 The present invention relates generally to wind turbines and more specifically to automated manufacturing techniques used in the production of wind turbine components, such as wind turbine blades.

Background

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There is a continual drive to produce larger wind turbines capable of outputting greater amounts of power. For example, the rotor blades of the latest generation of utility-scale wind turbines are more than eighty metres long. Manufacturing such large components presents significant challenges. There is also a drive to increase the production rate of
15 wind turbines, and a need to produce wind turbine components of consistently high quality.

In order to meet these challenges, automated and semi-automated manufacturing processes are being developed, which are capable of producing high quality wind turbine
20 components at ever increasing rates. For example, GB2483891 describes an automated method and apparatus for modifying a panel, such as a wind turbine blade, wherein a tool is provided for trimming the edge of a panel or for applying adhesive to the panel. The tool is configured to run along a track provided on the panel. In an alternative embodiment, the track is dispensed with, and the tool comprises caterpillar tracks, which
25 allow the tool to run freely across the panel itself.

Wind turbine blades are generally moulded from glass-fibre reinforced plastic (GRP). Typically the blades comprise two half shells, which are moulded separately before being bonded together to form the complete blade. To bond the half shells together, an
30 adhesive is applied along the leading and trailing edges of the shells, from the root to the tip of the shells. A spar structure comprising one or more longitudinally-extending shear webs may be bonded between the respective half shells to impart stiffness to the blade. The adhesive is manually applied to the shells and the shear webs by skilled personnel.

35 A significant quantity of adhesive is required to bond the shells together. In the case of very large blades, such as those mentioned above, one thousands kilogrammes or more

of adhesive may be required. The adhesive therefore adds significant weight to the blade and contributes significantly to the cost of the blades. It is therefore desirable to avoid using excess adhesive, whilst also ensuring that sufficient adhesive is applied to achieve a strong bond. The amount of adhesive required may vary along the length of the shells, with some regions requiring more adhesive than others, for example in order to fill gaps between the shells in these regions. The quantity of adhesive to apply is presently left to human judgement.

Summary of the invention

Against this background, the present invention provides a method of applying adhesive to a wind turbine part, the method comprising: defining a vehicle travel path relative to the part;

providing a vehicle on the vehicle travel path, the vehicle being configured to apply adhesive along a bond line defined on a bond surface of the part;

supplying adhesive to the vehicle;

applying adhesive along the bond line by causing the vehicle to travel along the vehicle travel path; and

varying the speed of the vehicle along the vehicle travel path so as to control the quantity of adhesive applied at successive positions along the bond line.

The present invention provides precise control over the position and quantity of adhesive applied to the part, and hence ensures a strong bond whilst avoiding wasting adhesive. The invention dispenses with the need for manual application of the adhesive, and hence facilitates adhesive application in confined regions or regions that are otherwise difficult to reach manually. The process is also semi-automated or may be fully automated, which provides consistent quality levels. The invention is less expensive to implement than other automated deposition alternatives such as those utilising robots, gantries or tracks.

The method may involve reducing the speed of the vehicle along the vehicle travel path so as to increase the quantity of adhesive applied along the bond line. The method may further involve increasing the speed of the vehicle along the vehicle travel path so as to decrease the quantity of adhesive applied along the bond line.

There may be significant latency in the process due to the requirement for long hoses or suchlike for supplying adhesive to the vehicle. This makes it difficult to control the flow

rate of the adhesive supplied to the vehicle and applied to the part. In a preferred embodiment of the invention, adhesive is supplied to the vehicle at a substantially constant rate, hence the present invention avoids the need to modify the flow rate of the adhesive supply.

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In other embodiments of the invention the flow rate could be varied to an extent if required whilst still using the varying speed of vehicle for more precise control over the quantity of adhesive applied along the bond line. For example, significantly more adhesive may be required in one region of the bond line than in another. In the case of a
10 wind turbine blade, more adhesive may be required towards the root of the blade shell than towards the tip. In this case, the adhesive may be supplied to the vehicle at a faster rate when the vehicle is at the root end than when it is at the tip end, yet precise control over the quantity of adhesive applied is still achieved by varying the speed of the vehicle.

15 The vehicle travel path may be defined on a surface of the first part itself. Alternatively, the vehicle travel path may be defined on another surface, for example on the surface of a mould in which the part is supported. The vehicle travel path may be defined by referencing the vehicle to a contour of the part or the mould. For example, in certain embodiments, the vehicle includes a locating device that hooks over the edge of the part
20 or mould and the vehicle travel path follows the contour of this edge. Alternatively, a guide rail may be provided on the part or the mould, and the vehicle may reference from this.

In another embodiment, the vehicle travel path may be defined by means of visual
25 indicators provided on a surface of the part or a surface of the mould, and the vehicle may have an optical system for detecting these indicators. The indicators may include lines or other such marks, which are suitably placed to define the vehicle travel path. Alternatively the visual indicators may be projected onto the surface, for example by means of lasers. In a particularly advantageous configuration, the visual indicators may
30 be provided by the contrast in colour between different materials in the blade. For example, in a central region of the shells, the shear webs are bonded to carbon pultrusions. An adhesive bond line is applied to the carbon pultrusion, which is black, and contrasts with the adjacent polyethylene terephthalate (PET) foam, which is white.

35 Visual indicators may also be used to determine the speed of the vehicle along the travel path, and hence to determine the quantity of adhesive to apply. For example, a first set

of visual indicators may be used in a first region of the vehicle travel path and a second set of visual indicators may be used in a second region of the vehicle travel path. The vehicle may be programmed to move at a first speed when the first set of indicators is detected and at a second speed when the second set of indicators is detected. The first speed may be faster or slower than the second speed. Other indicators may also be used along the vehicle travel path indicative of particular vehicle speeds. Rather than using visual indicators, radio-frequency identification (RFID) tags may be used along the vehicle travel path to signify the required speed at those points. Other alternative indicating means will also be readily apparent to the skilled person.

The bond line may be defined by the vehicle travel path. In certain embodiments, the bond line may coincide with the vehicle travel path. For example, the vehicle may be configured to travel along the bond line whilst depositing adhesive on the bond line. This arrangement is particularly convenient where the vehicle is travelling over the bond surface itself. In other embodiments, the vehicle may travel alongside the part, for example if the travel path is defined on a mould surface or if the vehicle is applying adhesive to a vertical surface whilst travelling over a horizontal surface, say.

The vehicle is preferably controlled automatically and/or remotely so that an operator is not required at the point of adhesive deposition. This allows adhesive to be applied remotely and in positions that are currently unreachable.

The speed of the vehicle is preferably controlled in accordance with a predefined speed profile. Alternatively, the vehicle may be radio controlled and the speed and/or position of the vehicle may be controlled by a human operator.

Once the adhesive has been applied to the part, the part may be bonded to another part to form a wind turbine component. Hence, the invention provides a method of making a wind turbine component, the method comprising:

- (a) providing first and second parts, each part having a respective bond surface;
- (b) applying adhesive along a bond line defined on the bond surface of the first part, the adhesive being applied by a vehicle in accordance with the method described above; and
- (c) arranging the first and second parts together such that the bond surface of the first part abuts the bond surface of the second part, the adhesive thereby serving to bond the two parts together along the bond line to form the wind turbine component.

In order to determine the required speed of the vehicle along the vehicle travel path, the method may involve performing a 'dry-fit' initially and assessing the bond line. Hence, prior to applying the adhesive in step (b), the method may comprise:

- 5 (d) arranging the first and second parts together such that the bond surface of the first part abuts the bond surface of the second part;
 - (e) determining the size and position of any gaps between the parts along the bond line;
 - (f) determining the quantity of adhesive required at successive positions along the bond line based upon the size of any gaps at those positions; and
 - 10 (g) determining the speed profile of the vehicle along the vehicle travel path based upon the quantity of adhesive required at the successive positions along the bond line.
- 15 Once the parts have been bonded together, as described in step (c) above, the method may further comprise:
- (h) inspecting the bond line between the first and second bonded parts;
 - (i) determining positions along the bond line where more or less adhesive should be used in subsequent production runs; and
 - 20 (j) updating the speed profile of the vehicle for subsequent production runs to reduce the speed of the vehicle when applying adhesive at positions along the bond line where more adhesive is required, and to increase the speed of the vehicle when applying adhesive at positions along the bond line where less adhesive is required.

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The component is preferably a wind turbine blade. The first part may be a half shell of the blade, for example a windward or leeward shell. Alternatively, the first part may be another component part of the blade, for example a shear web. The method preferably involves applying adhesive in this way to the first half shell and to one or more shear webs before bringing the two half shells together. Adhesive may also be applied to the second half shell in the same way.

The invention also includes a wind turbine having a blade manufactured according to the above method.

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Further, the invention provides an apparatus for applying adhesive to a wind turbine part, the apparatus comprising:

a vehicle configured to move relative to the part along a vehicle travel path, the vehicle being configured to apply adhesive to the part along a bond line when moving
5 along the vehicle travel path; and

a control system for varying the speed of the vehicle along the vehicle travel path according to a predefined speed profile so as to control the quantity of adhesive applied at successive positions along the bond line.

- 10 The vehicle preferably comprises wheels for running over a surface of the part or the mould. The vehicle may comprise a locating device for locating its position relative to the part. Examples of this have already been discussed above, and specific examples will be described in more detail later. The control system may be configured to control the speed of the vehicle automatically in accordance with the predefined speed profile.
- 15 Alternatively, the vehicle may be controlled manually, for example by remote control in accordance with the predefined speed profile. The vehicle may be arranged to run on horizontal or vertical surfaces, or surfaces inclines at any angle in-between. When running on vertical surfaces, the vehicle may attach to the surface. For example, the locating means may also serve to support the weight of the vehicle. Alternatively,
- 20 the vehicle may have sprung loaded wheels that provide a clamping force on either side of the part. As a further alternative, the vehicle may be supported on the end of a support arm or crane, or alternatively the vehicle may be held in place by magnets provided on both sides of the part or by means of suction, i.e. vacuum assisted.

25 Brief description of the drawings

In order that the invention may be more readily understood, specific embodiments of the invention will now be described, by way of example only, with reference to the following drawings in which:

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Figure 1 is a perspective view of a mould for a wind turbine blade shell showing adhesive being applied to an edge of the shell by an adhesive supply vehicle travelling along the edge in accordance with the present invention, wherein the speed of the vehicle is controlled by a cord extending between the vehicle and a
35 motor;

Figure 2 shows a first variant of the adhesive supply vehicle of Figure 1, in which the speed of the vehicle is controlled by a servo motor;

5 Figure 3 shows a second variant of the adhesive supply vehicle of Figure 1, in which the vehicle is radio controlled;

Figure 4A is a perspective view of the mould of Figure 1 showing a guide rail provided on a flange of the mould for defining the path of the vehicle along the edge of the shell;

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Figure 4B is a rear view of the vehicle showing a locating device coupled to the vehicle for referencing to the guide rail;

15 Figure 5 shows the vehicle travelling along a vertical surface with the weight of the vehicle being supported by a guide rail clamped to an upper edge of the vertical surface;

Figure 6 shows a vehicle provided with sprung-loaded wheels for clamping the vehicle to a vertical surface;

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Figure 7 shows the vehicle travelling along a vertical surface, with the weight of the vehicle being supported by a guide rail clamped to a lower edge of the vertical surface;

25 Figure 8 shows the vehicle referencing its position from an outer edge of the mould flange;

Figure 9 shows the vehicle applying adhesive to a shear web and referencing to the edges of the shear web; and

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Figure 10 is a plan view of a vehicle provided with optical means for determining the position of the vehicle from guide lines provided on the shell.

Detailed description

Figure 1 shows a mould 10 for a windward shell 12 of a wind turbine blade. The windward shell 12, which is shown in the mould 10, has a leading edge 13 and a trailing edge 14 and extends longitudinally from root 15 to tip 16. The mould 10 has a mould surface 18 beneath the shell 12, and a mould flange 20 that surrounds an upper edge 22 of the mould surface 18.

A vehicle 24 is shown located on the trailing edge 14 of the windward shell 12. The vehicle 24 has four wheels 26, which allow it to move along the trailing edge 14 of the shell 12. The vehicle 24 also has a nozzle 28 through which adhesive 30 is applied to the trailing edge 14 of the shell 12. The vehicle 24 includes a locating device 32, in the form of an arm that extends from the side of the vehicle 24 and hooks over an edge 34 of the mould flange 20. A supply 36 of adhesive 30 is located on a moveable trolley 38 adjacent the mould 10. The trolley 38 moves alongside the vehicle 24 and is controlled by an operator 40. A hose 42 connects the adhesive supply 36 to nozzle 28 of the vehicle 24.

A platform 44 is located outboard of the mould 10, adjacent the tip 16 of the shell 12. The platform 44 supports a motor 46, which is configured to turn a spool 48 of cable 50. A free end 51 of the cable 50 is connected to the vehicle 24.

In use, the vehicle 24 is initially placed on the trailing edge 14 at the root end 15 of the shell 12. The free end 51 of the cable 50 is then extended from the spool 48 and attached to the vehicle 24 in this position. The locating arm 32 is hooked over the edge 34 of the mould flange 20. The motor 46 is activated to turn the spool 48 causing the extended length of cable 50 to wind back around the spool 48 and draw the vehicle 24 along the trailing edge 14 of the shell 12 towards the tip 16 of the shell 12.

The mould flange 20 has a curved profile that follows the curvature of the trailing edge 14 of the shell 12. As the vehicle 24 moves towards the tip 16 of the shell 12, the locating arm 32 remains hooked over the edge 34 of the mould flange 20. The locating arm 32 maintains the vehicle 24 at a fixed distance from the edge 34 of the flange 20. Hence the vehicle follows the curvature of the trailing edge 14 as it is drawn towards the tip 16 of the shell 12.

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Adhesive 30 from the supply 36 is supplied to the vehicle 24 at a substantially constant rate through the hose 42. As the vehicle 24 moves, the adhesive 30 is applied to the trailing edge 14 through the nozzle 28. The nozzle 28 is located at the rear of the vehicle 24, such that the adhesive 30 is applied along a bond line 52 that coincides with a vehicle travel path 54 on the trailing edge 14.

As the vehicle 24 moves, the operator 40 controls the movement of the trolley 38 so that it remains alongside the vehicle 24. The speed of the motor 46 is varied as the vehicle moves along the vehicle travel path 54 to control the speed of the vehicle 24, and hence to control the quantity of adhesive 30 that is applied at particular points along the bond line 54. To increase the quantity of adhesive 30 applied, the motor 46 is turned more slowly so that the speed of the vehicle 24 is decreased. Conversely, to decrease the quantity of adhesive 30 applied to the trailing edge 14, the speed of the motor 46 is increased to increase the speed of the vehicle 24. The speed of the motor 46 is continually adjusted as the vehicle 24 moves along the trailing edge 14 so that the quantity of adhesive 30 applied to the trailing edge 14 varies along the length of the trailing edge 14. The motor 46 may be controlled manually or automatically by a suitably-programmed computer, for example in accordance with a predefined speed profile.

Once the adhesive 30 has been applied to the trailing edge 14, the vehicle 24 may be placed on the leading edge 13 and a similar process followed to apply adhesive to the leading edge 13. In this example, the locating arm 32 would need to be placed on the other side of the vehicle 24 so that it can hook around an edge 56 of the mould flange 20 adjacent the leading edge 13. Alternatively, multiple vehicles 24 may be used simultaneously to apply adhesive 30 to the leading and trailing edges 13, 14 respectively.

To form a complete wind turbine blade, a leeward shell (not shown) is lifted and placed on top of the windward shell 12. The adhesive 30 applied to the windward shell serves to bond the two shells together. A spar structure (not shown) may also be bonded between the shells. Once the blade has been assembled, the bond line 52 between the windward and leeward shells is inspected. If there are any gaps between the shells then this signifies that more adhesive is required at these locations. Conversely, any excess of adhesive or significant adhesive 'spew' indicates that less adhesive could be used in these locations. This information is fed back to an operator or used to update the computer program controlling the speed of the motor 46 so that the speed profile is

optimised for subsequent production runs. This is an iterative process with the bond line data of previous runs being used to optimise the speed profile for subsequent runs.

5 In order to determine the initial speed profile required, a 'dry fit' is performed. This involves placing the leeward shell on top of the windward shell 12 prior to applying adhesive 30 and measuring the clearance between the shells along the leading and trailing edges 13, 14. The clearance may be measured manually or automatically, for example using a laser measuring device. Alternatively, putty or a similar substance may be applied around the leading and trailing edges 13, 14 of the windward shell 12 prior to
10 placing the leeward shell on top. The leeward shell is then assembled on top of the windward shell 12 and lifted off again. Any gaps between the shells can be identified where the putty has not compressed significantly. Relatively more adhesive must be applied at positions where there are gaps between the shells. This information is used to define the speed profile of the vehicle 24, such that the vehicle 24 is programmed to run
15 more slowly at the positions where there are known to be gap, i.e. where more adhesive is required.

Referring to Figure 2, this shows a variant of the vehicle 24. In this example, rather than being attached to a cable, the vehicle 24 includes a servo motor 60 arranged to drive the
20 rear wheels 26 of the vehicle 24 via a drive belt 62. The vehicle 24 also includes a control unit 64 that is paired with the servo motor 60. Under the control of the control unit 64, the servo motor 60 drives the vehicle 24 at the correct speed according to the current position of the vehicle 24. The position of the vehicle can be determined from the distance travelled along the vehicle travel path 54. The control unit 64 accesses a look-
25 up table correlating the vehicle's position with the required speed of the vehicle 24 at that position. The speed of the vehicle at a particular position will depend upon the required quantity of adhesive 30 to be applied at that position and upon the rate at which the adhesive 30 is supplied to the vehicle 24.

30 Referring to Figure 3, this shows a further variant of the vehicle 24. In this example, the vehicle 24 is radio controlled and accordingly comprises an antenna 66 for receiving control data. The speed and position of the vehicle 24 is controlled remotely, either by a human operator or by a computer. The vehicle 24 in this example also includes caterpillar tracks 68. In this embodiment, the locating arm is not required.

Referring to Figure 4A, this shows a variant of the mould 12 described above with reference to Figure 1. In this example, a guide rail 70 is coupled to the mould flange 20. The guide rail 70 includes a longitudinal slot 72, which follows the curvature of the trailing edge 14 of the mould 12. As shown in Figure 4B, the locating arm 32 of the vehicle 24 is received in the slot 72, and this coupling serves to define the vehicle travel path 54 and maintains the vehicle 24 on the trailing edge 14 of the shell 12 as the vehicle 24 moves.

Referring to Figure 5, this shows the vehicle 24 applying adhesive 30 to an upper edge region 74 of a vertical part 76 of the shell 12. In this example, a guide rail 78 is provided close to an upper edge 80 on an inner surface 82 of the shell 12. The guide rail 78 is clamped to the shell 12 by a clamp 84 that bears against an outer surface 86 of the shell 12. The guide rail 78 is similar to the guide rail 70 described above in relation to Figures 4A and 4B, and features a longitudinal slot 88. The locating arm 32 of the vehicle 24 is received in the slot 88, and this coupling performs the dual purpose of defining the travel path of the vehicle 24 and supporting the weight of the vehicle 24 such that the vehicle 24 is retained against the vertical inner surface 82 and prevented from falling under gravity. The upper edge region 74 of large wind turbine blade shells is difficult to reach manually, so this invention provides a convenient solution for applying adhesive to relatively inaccessible places such as this.

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Figure 6 shows a further variant of the vehicle 24. In this example, the wheels 26 of the vehicle 24 are sprung loaded such that the wheels 26 run on both sides of the vertical part of the shell 12 and provide a clamping force against the inner and outer surfaces 82, 86 to maintain the vehicle 24 against the inner surface 82. The vehicle 24 is also attached to an arm 90, which supports the weight of the vehicle 24.

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Referring to Figure 7, this shows the vehicle 24 applying adhesive 30 to a lower edge region 92 of a vertical part of the shell 12. Here a guide rail 94 with a longitudinal slot 96 is mounted to a lower edge 98 of the shell 12. On a lowermost side of the slot 96, as shown, the guide rail 94 includes a flange 100 that projects perpendicular to the vertical inner surface 82, i.e. in a substantially horizontal plane. The locating arm 32 is received in the slot 96 and abuts this flange 100 such that the flange 100 supports the weight of the vehicle 24 as it travels against the vertical surface 82.

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Referring to Figure 8, this shows the vehicle 24 travelling along the mould flange 20 and applying adhesive 30 to an outer surface 102 of a vertical part of the shell 12. In this

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example the vertical part of the shell 12 is a leading edge upstand, which overlaps the leeward shell when the shells are bonded together. The locating arm 32 is hooked over the outer edge 56 of the mould flange 20, hence in this example the vehicle 24 references to the mould flange 20, and the mould flange 20 defines the vehicle travel path. The nozzle 28 is mounted perpendicular to the nozzle in the other examples, i.e. parallel to the wheel axes, such that it supplies adhesive in a direction perpendicular to the direction of travel of the vehicle 24. The bond line 104 in this example is therefore offset from the vehicle travel path.

Referring to Figure 9, this shows the vehicle 24 applying adhesive to an outer surface 106 of a shear web 108. The outer surface 106 of the shear web 108 bonds to an inner surface of the leeward shell when the leeward shell is placed on top of the windward shell 12. The vehicle 24 includes locating arms 32 on both sides of the vehicle 24. The locating arms 34 hook over the respective parallel longitudinal edges 36 of the shear web 108, such that the edges 36 of the shear web 108 define the vehicle travel path.

Referring to Figure 10, this shows a further variant of the vehicle 24. In this example, the vehicle 24 is provided with an optical guidance system in the form of an optical sensor 110 for detecting visual indicators on the surface 112 of the shell, mould or component part of the blade, such as a shear web. In this example, a pair of parallel lines 114 are provided on the surface 112. The optical sensor 110 scans the lines 114 and an onboard controller 116 steers the vehicle 24 so that it follows the lines 114. The lines vary in thickness along the vehicle travel path, and the thickness of the lines 114 indicates the required speed of the vehicle 114 at a particular position. Thicker lines 114 are used in regions of the surface 112 where relatively less adhesive is required, and thinner lines are used in regions where relatively more adhesive is required. If the sensor 110 detects that the thickness of the lines is increasing, the controller 116 increases the speed of the vehicle 24 so as to deposit relatively less adhesive 30 in that region. Conversely, if the sensor 110 detects that the thickness of the lines 114 is decreasing, the controller 116 decreases the speed of the vehicle 24 so as to deposit relatively more adhesive 30 in that region.

Many modifications may be made to the embodiments described above without departing from the scope of the invention as defined in the following claims.

Claims

1. A method of applying adhesive to a wind turbine part, the method comprising:
defining a vehicle travel path relative to the part;
5 providing a vehicle on the vehicle travel path, the vehicle being configured to
apply adhesive along a bond line defined on a bond surface of the part;
supplying adhesive to the vehicle;
applying adhesive along the bond line by causing the vehicle to travel along the
vehicle travel path; and
10 varying the speed of the vehicle along the vehicle travel path so as to control the
quantity of adhesive applied at successive positions along the bond line.
2. The method of Claim 1 comprising reducing the speed of the vehicle along the
vehicle travel path so as to increase the quantity of adhesive applied along the bond
15 line.
3. The method of Claim 1 or Claim 2 comprising increasing the speed of the vehicle
along the vehicle travel path so as to decrease the quantity of adhesive applied along
the bond line.
- 20 4. The method of any preceding claim further comprising supplying adhesive to the
vehicle at a substantially constant rate.
5. The method of any preceding claim wherein the bond line is defined by the vehicle
25 travel path.
6. The method of Claim 5, wherein the bond line coincides with the vehicle travel path.
7. The method of any preceding claim, wherein the vehicle travel path is defined on a
30 surface of the first part.
8. The method of any of Claims 1 to 6, wherein the vehicle travel path is defined on a
surface of a mould.
- 35 9. The method of any preceding claim, further comprising referencing the vehicle to a
contour of the part or a mould within which the part is supported, such that the
contour defines the vehicle travel path.

10. The method of any preceding claim, further comprising defining the vehicle travel path by means of visual indicators on a surface of the part or a mould within which the part is supported, and guiding the vehicle along the vehicle travel path by utilising an optical system to detect the visual indicators on the surface.
- 5 11. The method of any preceding claim, wherein the speed of the vehicle along the vehicle travel path is controlled in accordance with a predefined speed profile.
12. A method of making a wind turbine component, the method comprising:
- 10 (a) providing first and second parts, each part having a respective bond surface;
- (b) applying adhesive along a bond line defined on the bond surface of the first part, the adhesive being applied by a vehicle in accordance with the method of any preceding claim; and
- 15 (c) arranging the first and second parts together such that the bond surface of the first part abuts the bond surface of the second part, the adhesive thereby serving to bond the two parts together along the bond line to form the wind turbine component.
13. The method of Claim 12 when dependent upon Claim 11, wherein prior to applying the adhesive in step (b), the method comprises:
- 20 (d) arranging the first and second parts together such that the bond surface of the first part abuts the bond surface of the second part;
- (e) determining the size and position of any gaps between the parts along the bond line;
- 25 (f) determining the quantity of adhesive required at successive positions along the bond line based upon the size of any gaps at those positions; and
- (g) determining the speed profile of the vehicle along the vehicle travel path based upon the quantity of adhesive required at the successive positions along the bond line.
- 30 14. The method of Claim 13, or Claim 12 when dependent upon Claim 11, wherein following step (c), the method further comprises:
- (h) inspecting the bond line between the first and second bonded parts;
- (i) determining positions along the bond line where more or less adhesive should be used in subsequent production runs; and
- 35 (j) updating the speed profile of the vehicle for subsequent production runs to reduce the speed of the vehicle when applying adhesive at positions along

the bond line where more adhesive is required, and to increase the speed of the vehicle when applying adhesive at positions along the bond line where less adhesive is required.

- 5 15. The method of any of Claims 12 to 14, wherein the component is a wind turbine blade.
16. A wind turbine having a blade manufactured according to the method of any of Claims 12 to 15.
- 10 17. Apparatus for applying adhesive to a wind turbine part, the apparatus comprising:
a vehicle configured to move relative to the part along a vehicle travel path, the vehicle being configured to apply adhesive to the part along a bond line when moving along the vehicle travel path; and
- 15 a control system for varying the speed of the vehicle along the vehicle travel path according to a predefined speed profile so as to control the quantity of adhesive applied at successive positions along the bond line.
18. The apparatus of Claim 17, wherein the control system is configured to control the speed of the vehicle automatically in accordance with the predefined speed profile.
- 20 19. The apparatus of Claim 17 or Claim 18, wherein the vehicle comprises a locating device for referencing its position relative to the part.
- 25 20. The apparatus of Claim 19, wherein the locating means engages with a guide rail defining the vehicle travel path, the guide rail being provided on a surface of the part or a surface of a mould in which the part is supported.
- 30 21. The apparatus of Claim 19, wherein the vehicle comprises an optical sensor and the control system is configured to determine the position of the vehicle by sensing visual indicators on a surface of the part or a surface of a mould in which the part is supported.
- 35 22. The apparatus of any of Claims 17 to 21, wherein the vehicle comprises wheels for running over a surface of the part or a mould in which the part is supported.

23. The method of any of Claims 1 to 15, or the apparatus of any of Claims 17 to 22,
wherein the part to which adhesive is applied is a half shell of a wind turbine blade.
24. The method of any of Claims 1 to 15, or the apparatus of any of Claims 17 to 22,
5 wherein the part to which adhesive is applied is a shear web for a wind turbine blade.

1 / 4

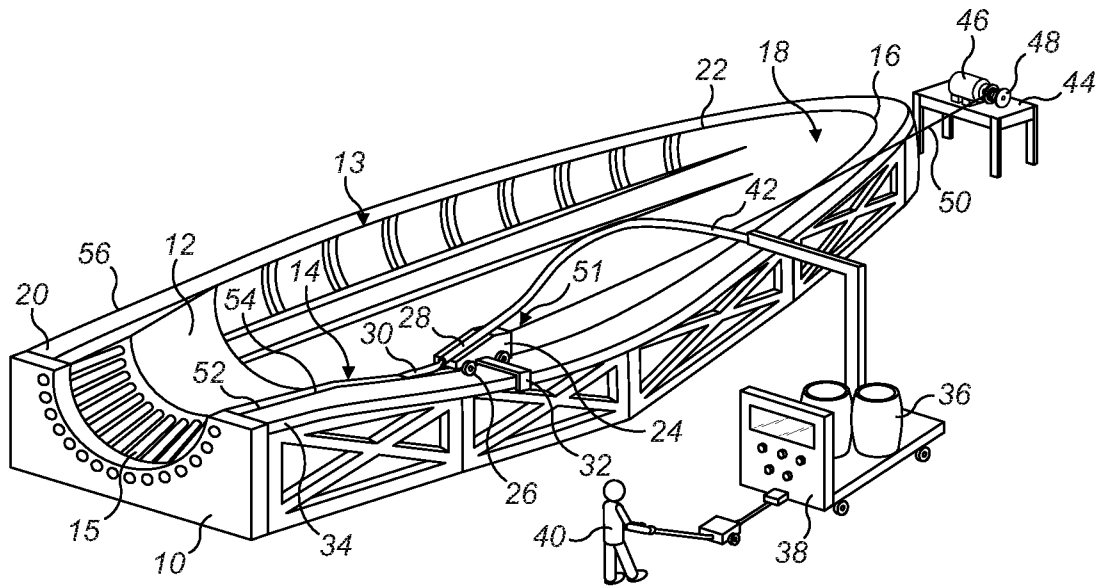


FIG. 1

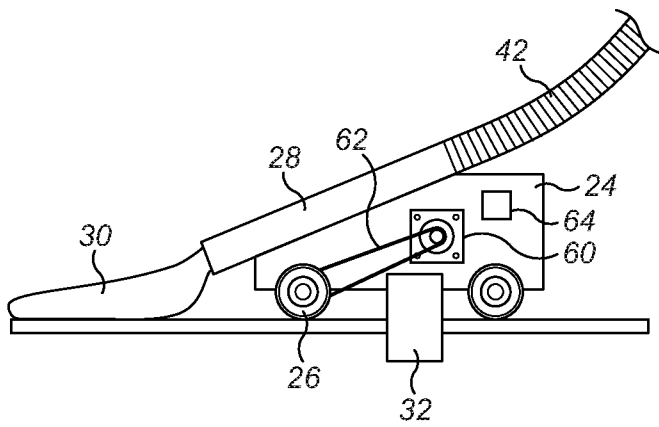


FIG. 2

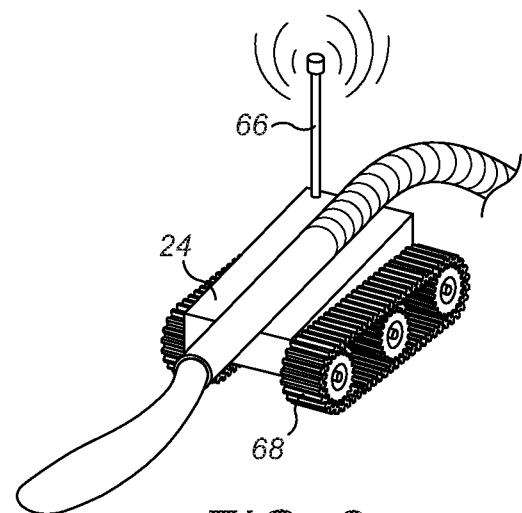


FIG. 3

2 / 4

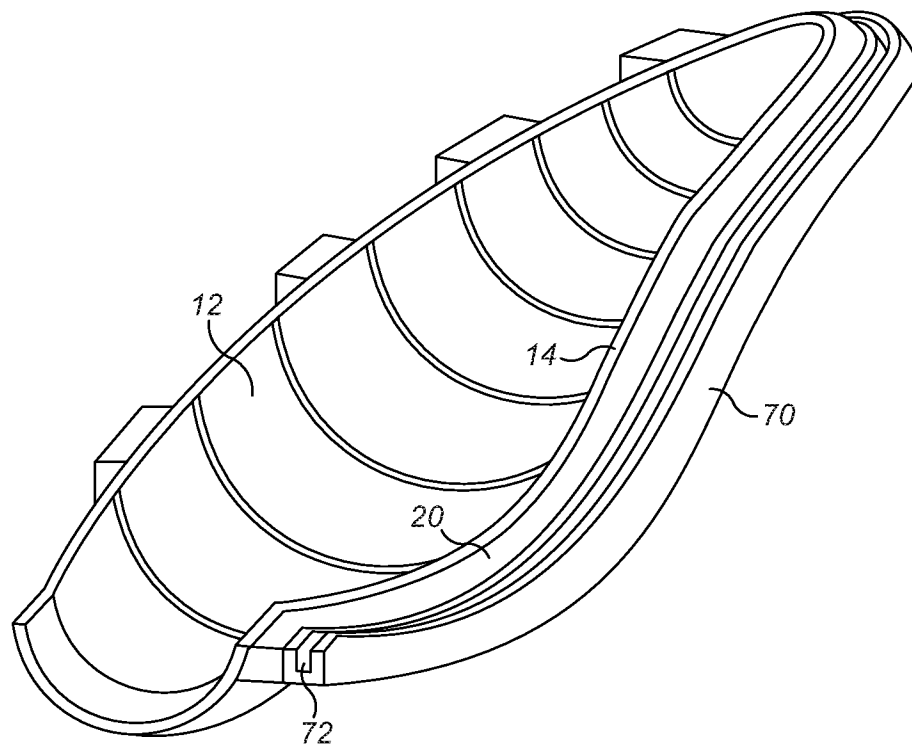


FIG. 4A

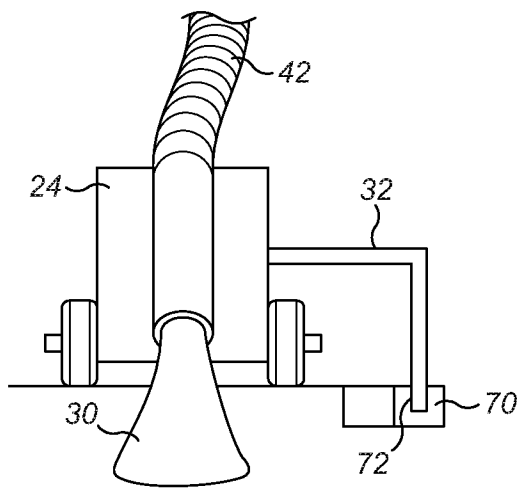


FIG. 4B

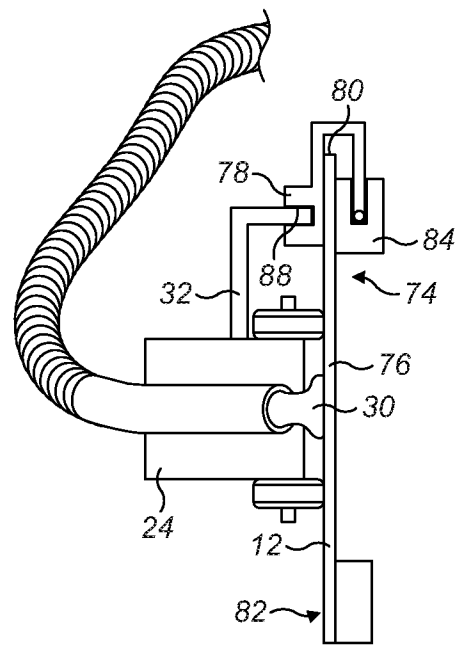


FIG. 5

3 / 4

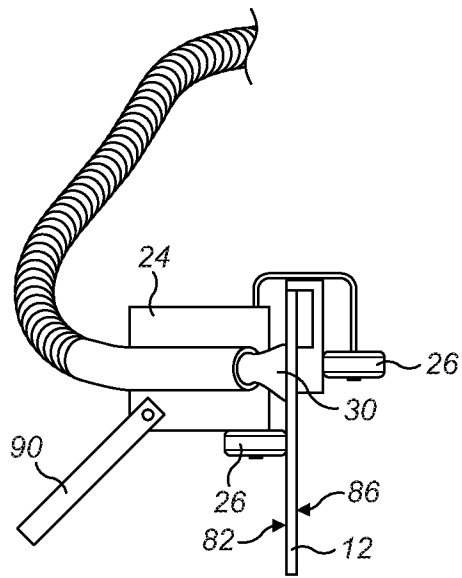


FIG. 6

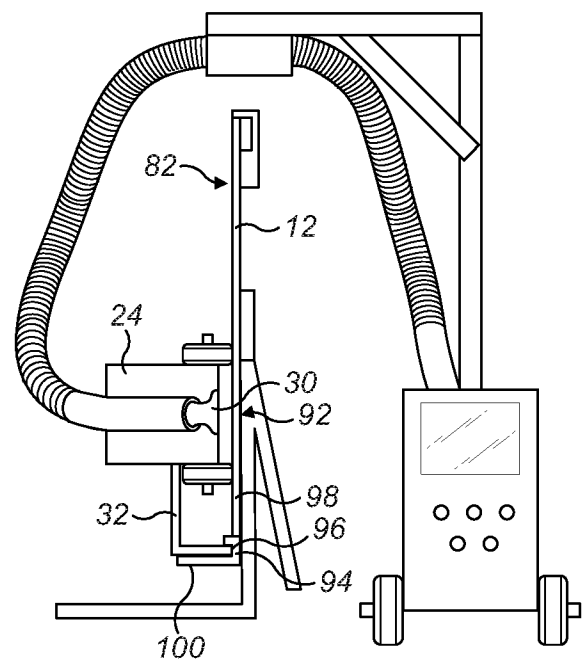


FIG. 7

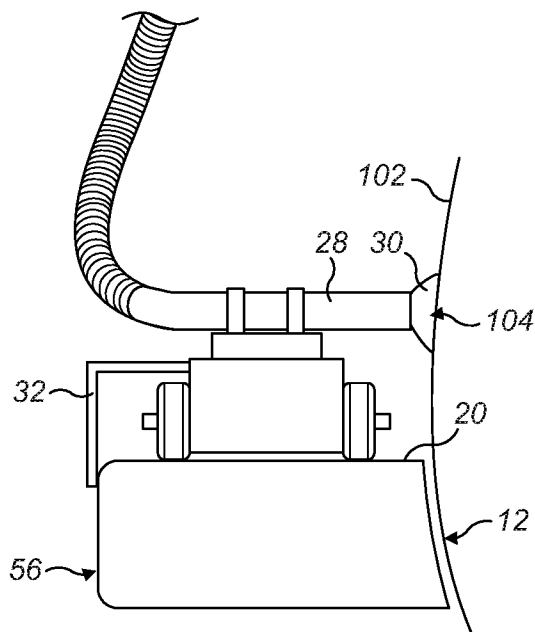


FIG. 8

4 / 4

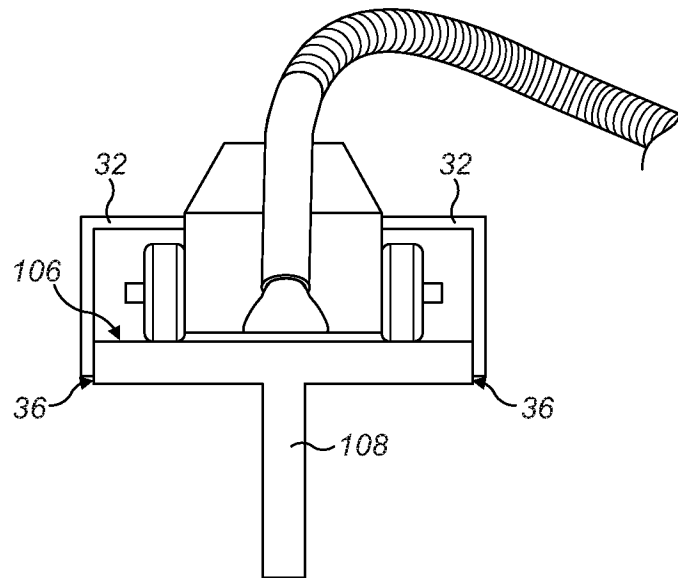


FIG. 9

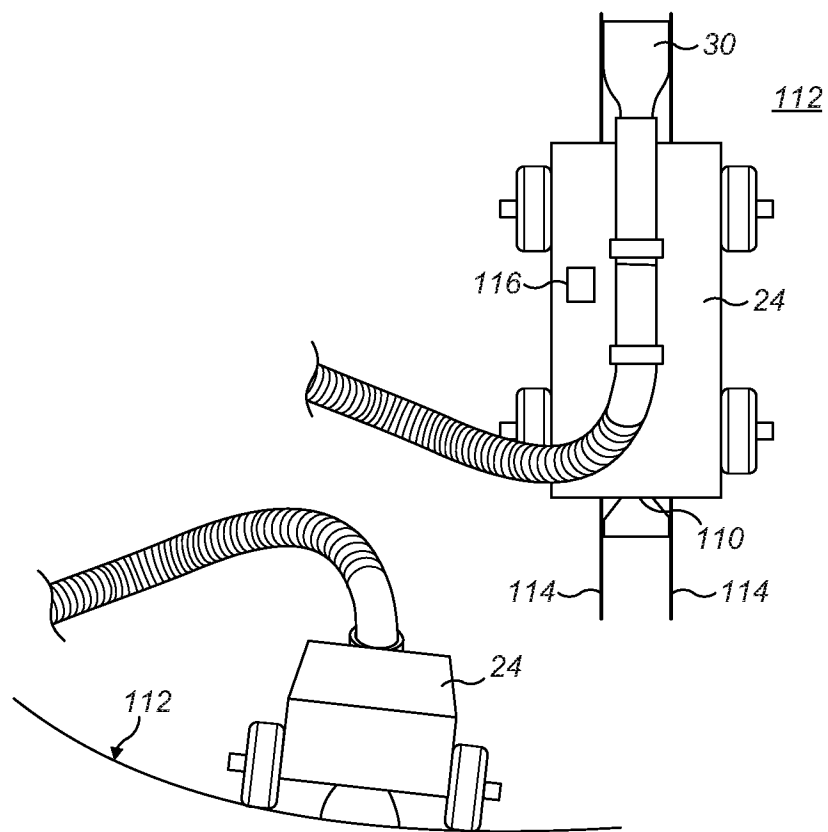


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2013/050307

A. CLASSIFICATION OF SUBJECT MATTER
 INV. B29C65/52 F03D1/06
 ADD. B05C5/02

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 B29L F03D B05C

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 447 521 A2 (WOBBEN ALOYS [DE]) 2 May 2012 (2012-05-02) the whole document	1-24
X	----- KR 2012 0065044 A (SAMSUNG HEAVY IND [KR]) 20 June 2012 (2012-06-20) paragraph [0030] - paragraph [0045]; figure 1	1-24
A	----- US 6 001 181 A (BULLEN GEORGE NICHOLAS [US]) 14 December 1999 (1999-12-14) the whole document	17-22



Further documents are listed in the continuation of Box C.



See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search

9 January 2014

Date of mailing of the international search report

20/01/2014

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Authorized officer

Peña, Alejandro

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/DK2013/050307

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
EP 2447521	A2	02-05-2012	DE 102010043201 A1	03-05-2012
			EP 2447521 A2	02-05-2012

KR 20120065044	A	20-06-2012	KR 20120065044 A	20-06-2012
			US 2013247821 A1	26-09-2013
			WO 2012077940 A2	14-06-2012

US 6001181	A	14-12-1999	NONE	
