(54) Title: LIFTING BEAM FOR USE IN HOISTING A WIND TURBINE BLADE

(57) Abstract: Lifting beam adapted to be suspended from a crane for hoisting a wind turbine blade comprising a longitudinal beam extending between a first end and a second end, a root manipulation system provided near the first end, and a tip manipulation system provided near the second end, the root manipulation system comprising a first sling suitable to be fitted around a first blade portion at or near a blade root and a drive system for rotating the first sling, the tip manipulation system comprising a second sling suitable to be fitted around a second blade portion that is nearer to the blade tip than the first wind turbine blade portion, and a drive system for rotating the second sling, and the second sling comprising a cable portion and a cradle for being fitted underneath the second blade portion and being connected to both ends of the cable portion.
Lifting beam for use in hoisting a wind turbine blade

The present invention relates to a lifting beam for use in hoisting a wind turbine blade. More particularly, the invention relates to a lifting beam which can be suspended from a crane for hoisting a wind turbine blade.

BACKGROUND ART

Modern wind turbines are commonly used to supply electricity into the electrical grid. Wind turbines of this kind generally comprise a rotor with a rotor hub and a plurality of blades. The rotor is set into rotation under the influence of the wind on the blades. The rotation of the rotor shaft either directly drives the generator rotor ("directly driven") or through the use of a gearbox.

A clear trend in the field of wind energy has been to increase the size of the wind turbines. With the goal of converting more energy and producing more electricity, towers have become higher and blades have become longer. The increasing size of wind turbines can cause problems during the manufacture of certain components, their transport and their installation.

Wind turbine blades may be transported to their site upon the bed of a trailer of a truck. They may be secured on the bed of the trailer and parts of the blade (in particularly the blade root and the blade tip) may be transported in fixtures that serve to protect the blade.

When the wind turbine blades arrive at the site, they may first be offloaded from the trailer of the truck. The blade may be placed in a temporary local support structure and protective fixtures attached at e.g. the root and tip may be removed and optionally an extender may be attached at the blade root. Subsequently a system involving e.g. two cranes (one attached near the blade root and another one attached closer to the blade tip) may be used for lifting the blade to the hub. Large, heavy cranes are generally needed for the installation of a wind turbine. The use of these cranes can be very expensive.

When offloading the blade from the truck and placing them in a temporary support structure, the blades generally need to be rotated. This is due to the fact that the orientation of the blade during transport is generally different than the orientation needed for mounting the blade in a horizontal position.

During transportation, the blades are generally fixed with their leading edge substantially facing down. During lifting and mounting, blades are preferably kept with their leading edge substantially in a horizontal direction. With this
orientation, the wind turbine blades catch less wind, which improves the handling of the blade during the hoisting and mounting process.

To reduce the cost of installation it is known to use a lifting beam (also sometimes referred to as "spreader beam" or "yoke") suspended from a single crane. Such a lifting beam comprises a first sling which may be fitted around the blade at or near the blade root and a second sling which may be fitted around the blade closer to the blade tip. After the blades have been offloaded, positioned in their temporary supports and rotated, the blades can be lifted using a single crane. The lifting beam ensures a proper distribution of loads along the length of the blade. This process may however still be time-consuming and therefore expensive.

DE 20 201 0 003 033 U1 discloses hoisting equipment comprising a beam carrying a first cross-bar at a root end and a second cross-bar at the opposite end of the beam. A belt which is wrapped at least 1.5 times around a blade root portion is suspended from the first cross-bar. A sling is suspended from the second cross-bar and is fitted around the blade at a second blade portion. A drive system is included for rotating the first belt and thereby rotating the blade root. The blade rotates within the sling.

A disadvantage of this system is that the sling at the second end around the blade can only be provided at a relatively wide blade portion; it cannot be provided very close to the tip. This thus imposes limitation on the length and weight of blades that may be lifted using this system. There is therefore still a need to provide a system suitable for lifting a wind turbine blade using a single crane, which allows heavier and longer wind turbine blades to be hoisted. There is also still a need for a system suitable for lifting a wind turbine blade having an extender using a single crane.

In an alternative method, it is known from e.g. US 7,207,777 to pre-mount two blades in a wind turbine hub, and subsequently use a crane to hoist the hub and blades to the top of the tower. Thereafter, a third blade is mounted in a vertical position in the bottom of the hub. This means, that the blade needs to be rotated from a horizontal position to a vertical position. Furthermore, there is relatively little control over the blade during the mounting process. Moreover, this method may not be suitable for wind turbines comprising very large and very heavy blades comprising e.g. extenders.

It is an object of the present invention to at least partially fulfil the before-mentioned needs.
SUMMARY OF THE INVENTION

In a first aspect, the invention provides a lifting beam adapted to be suspended from a crane for hoisting a wind turbine blade comprising a longitudinal beam extending between a first end and a second end, a root manipulation system provided near the first end, and a tip manipulation system provided near the second end, the root manipulation system comprising a first sling suitable to be fitted around a first wind turbine blade portion at or near a blade root and a drive system for rotating the first sling, the tip manipulation system comprising a second sling suitable to be fitted around a second wind turbine blade portion that is nearer to the blade tip than the first wind turbine blade portion, and a drive system for rotating the second sling, and the second sling comprising a cable portion and a cradle for being fitted underneath the second blade portion and being connected to both ends of the cable portion.

Drive systems are present for rotating the blade, both at the root end and at the tip end and a cradle is provided that supports and carries the blade at the tip end. This allows the second sling to be positioned closer to the tip, which is better for the distribution of the hoisting loads over the length of the blade. The lifting beam thus permits longer and heavier blades, and also e.g. blades with an extender to be hoisted. Additionally, the use of the lifting beam makes it possible to lift the blade directly from a trailer to the hub. The blade can be rotated to a suitable orientation while it is being lifted. No two separate lifting steps are needed. This can make the installation process less time-consuming and therefore cheaper.

In some embodiments, the root manipulation system may further comprise a cable carrying the first sling and a winch for pulling the cable in or letting it out. Using the winch for lifting or lowering the first sling, the inclination of the blade may be controlled.

In some embodiments, the longitudinal beam may have a length of between 50% - 100% of the length of the wind turbine blade to be lifted. In many implementations of the present invention, the longitudinal beam may have a length of between 75% - 100% of the length of the wind turbine blade.

In preferred embodiments, the length of the longitudinal beam is adjustable to adapt for different sizes and types of blades.

In some embodiments, the root manipulation system may comprise a release mechanism for releasing the first sling from the first blade portion. In some embodiments, the tip manipulation system may comprise a release mechanism for releasing the second sling from the second blade portion.
mechanism for releasing the second sling from the second blade portion. Preferably, such release mechanisms may be remotely controlled. In these embodiments, after mounting of the blade on the hub, the lifting beam may be easily moved away from the beam and may immediately be ready for lifting of a next wind turbine blade.

In another aspect, the invention provides a kit for assembly of a lifting beam substantially as hereinbefore described comprising a root module having a truss structure and comprising at least part of the root manipulation system, a tip module having a truss structure and comprising at least part of the tip manipulation system, a plurality of intermediate modules having a truss structure, wherein the modules are adapted to be coupled to each other. In this aspect of the invention, a kit is provided that may be adapted for different blades, with different lengths, weights and with or without an extender. A root module in this sense is to be understood as a module of the lifting beam that forms a first end of the lifting beam, namely the end that in use is attached close to the blade root. The tip module in this sense is to be understood as the module of the lifting beam that forms the other end of the lifting beam and in use will be attached closer to the blade tip (although not necessarily at a tip portion).

In some embodiments, the plurality of intermediate modules comprises modules of different lengths. To increase the versatility of the kit, intermediate modules of various different sizes may be provided.

In some embodiments, the root module and the tip module may comprise a securing member for securing a cable suspended from a crane. Provisions for the suspension of the lifting beam under a crane are hereby integrated in some of the modules. In some embodiments, at least one intermediate module comprises a securing member for securing a cable suspended from a crane. Depending on the size of the blade a cable of a crane may not necessarily be provided at the root module or the tip module.

In yet a further aspect, the invention provides the use of a lifting beam substantially as hereinbefore described in a method for hoisting a wind turbine blade. Such a method may preferably comprise lifting a wind turbine blade directly from a trailer. Such a method may furthermore on occasions comprise rotating the wind turbine blade using the root and tip manipulation systems for aligning the wind turbine blade with a hub. Such a method may furthermore comprise mounting the wind turbine blade to a hub with the blade in a substantially horizontal position.
Additional objects, advantages and features of embodiments of the invention will become apparent to those skilled in the art upon examination of the description, or may be learned by practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Particular embodiments of the present invention will be described in the following by way of non-limiting examples, with reference to the appended drawings, in which:

Figures 1a — 1h illustrate a first embodiment of a lifting beam according to the present invention;
Figures 2a - 2c illustrate other embodiments of lifting beams according to the present invention and further illustrate the use of a kit for assembly of lifting assembly;
Figure 3 illustrates a cradle which may be used in embodiments of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figures 1a — 1h illustrate a first embodiment of a lifting beam according to the present invention. Figure 1a illustrates a side view of the use of a lifting beam 100 suspended from a crane (not shown) to lift a first blade. The blade in this particular example has a length of approximately 53 meters and may have a weight of e.g. approximately 14 tons.

Figure 1b illustrates a more detailed side view of a root portion of the embodiment of figure 1a, and figure 1c shows a more detailed cross-sectional view. Figures 1d and 1e show more detailed cross-sectional views of the tip manipulation system, and figure 1f shows a side view of the same portion of the blade and beam. Figures 1g - 1i highlight some details of the blade and lifting beam according to the first embodiment.

With reference to figures 1a — 1i: A lifting beam 100 may be built-up from a kit comprising various different modules. In the embodiment of figure 1, lifting beam 100 comprises a root module 110, a tip module 120, and a plurality of intermediate modules 130, 140, 150 and 160 of different sizes.

The lifting beam 100 may be suspended from a crane (not shown) using two cables 51 and 52. Cable 51 may be attached at a fixing element integrated in
the root module and cable 52 may be attached at a fixing element integrated in the tip module. The total length of the lifting beam in this embodiment may be approx. 44 meters. The tip module 120 may have a length of approximately 10.1 meters and the root module 110 may have a length of approximately 5.7 meters. The intermediate modules, 130, 140, 150,160 and 170 in this particular embodiment may have the following respective lengths: 2.2 meters, 5.96 meters, 1.1 meters, 10.43 meters and 2.76 meters. One or more of the tip, root and intermediate modules may be provided with fixing elements so that, depending upon where they are positioned in the lifting beam, the cables from the crane can be attached at the modules. The fixing elements may e.g. comprise eyelets in which hooks at the end of cables 51 and 52 can be inserted. The modules may further be adapted to be coupled to each other: they may e.g. comprise holes which can be aligned with corresponding holes of neighbouring modules and in which suitable bolts can be fitted. Alternative coupling methods can also be foreseen. The modules may be provided with legs 101 so that the lifting beam can be positioned on the ground when it is not in use. The legs in certain embodiments may be provided at or near the ends of the modules. The tip module 120 may have a slightly different shape than the other modules in that it comprises an inclined portion of increasingly reduced cross-section / height. Support legs 121 of the tip module may thus be larger than the other support legs. All modules in this embodiment have a truss structure. The properties of truss structures are well known and it will be clear that alternative structure may be used without significantly affecting the advantages offered by the invention. The root module carries a root manipulation system. A cable 93 is connected to winch 61 which is provided in the root module. The winch 61 is operatively connected (optionally with suitable reduction gearing) with a motor 62. A hook 95 at the end of cable 93 carries a housing that comprises a pulley 91. Pulley 91 can be driven by a motor 96 through suitable gearing 98. Pulley 96 engages with a chain 94. Both extremes 99 of chain 94 is connected to an extreme of a fabric band 92 which is fitted around a portion of the wind turbine blade, which is near to the blade root. In this embodiment, chain 94 and band 92 together form a first sling which carries the wind turbine blade and can be used for rotating it. By actuation of the pulley 91, the first sling and the blade root portion is rotated. By actuation
of the winch 61, the height of the sling may be adjusted, so that the orientation of the blade can be adjusted by lowering or raising the root with respect to the tip.
The tip module 120 comprises a tip manipulation system for rotating the blade tip. To this end, a second sling is formed by a cable portion and a cradle 84. The cable portion comprises a chain 82 and bands 83. In alternative embodiments, the cable portion may be composed of e.g. only a chain, or a rope, combinations of a rope and bands, combinations of a chain and rope etc. A cable portion is used in its most general sense comprising e.g. chain, rope, wire, chord, and bands.
Chain 82 is connected at its ends at first ends of two bands 83. Loops 71 and 72 of the other ends of the bands 83 are arranged around pins 76 and 74 so as to carry a cradle 84.
In implementations of the invention, the cradle 84 may be longer than the blade chord of the blade root portion where the second sling is fitted. This implies that the second sling may be connected relatively close to the blade tip. The length of the lifting beam with respect to the blade length may thus be larger, which may lead to better distribution of loads.
In operation, motor 77 can drive motorized pulley 81 through gearing 85. Motorized pulley engages with chain 82 which further extends around pulleys 86 and 87 at either side of tip module 120. Cradle 84 in the shown embodiment comprises a central flat base portion. Inclined portions 84b and 84c extend from this base portion. At the front end and rear end of the cradle, the bands 83 may be connected around pins 76 and 78. By actuating the motor 77, the second sling can be rotated. The tip portion of the blade may thus also be rotated. This has been indicated particularly in figures 1d and 1e.
Upon rotation of the second sling, the cradle may achieve a non-horizontal orientation (figure 1e). Blade 10 is positioned on the cradle and may be supported on support structures 73, 74 and 75. In some embodiments, at least parts of these support structures may be made from a foam which may be arranged in a way to securely support the blade. A suitable foam may be selected that does not substantially damage the blade.
In order to allow the cradle 84 to assume a non-horizontal position and still properly support and protect blade 10, hinges 65 and 66 are provided, so that support structures 73 and 74 can rotate with respect to the base of the cradle 84. Cradle 84 may further comprise a number of support legs 84d for its
placement on the ground.
One aspect of this embodiment is that a blade may be lifted directly from the bed of a trailer and may be lifted towards a hub mounted on top of a turbine tower. During the lifting, the blade may be rotated so that it can assume a position in which it catches less wind and the wind can therefore not hinder the installation too much. Additionally, at the moment of mounting the blade on the hub, the rotation capabilities provided in the lifting beam may be used for proper alignment of holes provided in the hub and in the mounting flange of the blade root. Furthermore, in this embodiment of the invention, the first sling can be raised or lowered, so that the blade root may be raised or lowered with respect to the blade tip.

It will be clear that alternative slings can be used. In both described manipulation systems, the motorized pulleys engage with chains. However, motorized pulleys may be used in embodiments of the invention which engage with e.g. belts, chords, or different sorts of cables. Furthermore, although the provision of the winch to lower and raise the first sling offers certain advantages, in other embodiments of the invention, it is not necessarily provided.

In some embodiments, the root manipulation system may comprise a release mechanism for releasing the first sling from the first blade portion near the blade root. For example, chain 94 may comprise a remotely controlled hook for engaging a pin at the end of band 92. By moving the hook out of engagement with the pin, the band 92 may be released and the sling is unwrapped from around the blade. A similar mechanism may be included in the tip manipulation system (e.g. a hook at one end of cable 82 to engage and disengage a pin at the end of band 83).

The lifting beam may in these embodiments very easily be disengaged from the wind turbine blade and may thus readily be used for the lifting of another blade. Such a release mechanism is particularly advantageous for the root manipulation system. At the tip manipulation system namely, the lifting beam can more easily disengaged from the blade by simply moving the lifting beam. In other embodiments, manual intervention may be used to release the blade from the first sling and/or the second sling.

Depending on the distribution of weight of the beam and blade, it may be advantageous to attach a counterweight 111 to root module 110. In different embodiments, different counterweights may be used.

In embodiments of the invention, the tip manipulation system may be in
communication with the root manipulation system such that rotation of the two slings may be coordinated. In some embodiments, a single control is provided which actuates both motors simultaneously.

Alternative embodiments of lifting beams are shown in figures 2a - 2c. The lifting beams shown in these figures may be composed of the same modules used in the embodiment of figure 1.

Figures 2a and 2b show a side view and a top view respectively of a lifting beam of approximately 37 m length and comprising an extender 20. Extender 20 may be provided for increasing the diameter of a wind turbine without increasing the length of the blade. The extender may be coupled at a hub using its mounting flange 22. Such a blade may have a weight e.g. of approximately 10.780 kg. A lifting beam with an approximate length of 28.5 meters is provided in this embodiment.

The root module 110 and tip module 120 are the same as previously described with respect to figure 1. Intermediate modules 130 and 160 which were also used in the embodiment of figure 1 are used also in this embodiment. It is thus shown that by different arrangement of the modules, the lifting beam can be adapted to different blades.

Cables 51 and 52 are attached at securing elements 53 and 54. Securing element 53 is arranged in the root module and securing element 54 is arranged in tip module 120. In some embodiments, securing elements may be arranged in an intermediate module, such that the lifting beam may be connected to the crane at e.g. the root module and an intermediate module. In some embodiments, securing elements 53 may be partially movable along the length of a module. For the attachment of the cables from the crane, they may be fixed in appropriate positions.

Similarly to what was described with reference to figure 1, root manipulation and tip manipulation systems may be provided for rotating the blade. Band 92 may be lifted or lowered with respect to the lifting beam through chain 93 controlled by a motor comprised in the root module.

Similarly as before, a chain 82 engages with a pulley 81 driven by a motor. Chain 82 is attached at a band 83 which is connected to cradle 84. The cradle 84 may also be similar as in the previous embodiment.

In figure 2b the shape of the blade with respect to its longitudinal axis may be seen. It may further be seen that the lifting beam is arranged substantially along the longitudinal axis.

In some blades, the blade tip may deviate significantly from the longitudinal
axis, and the lifting beam may thus be offset with respect to the local centre of
the blade. This however does not affect the proper functioning because of the
provision of the cradle in the second sling.
Figure 2c shows a further lifting beam for lifting another blade 10" of
approximately 40 meters and comprising an extender 20. Because of the
provision of an extender, the weight of the total blade may be increased from
approximately 8.000 kg to approximately 11.800 kg.
With respect to the embodiment of figure 2b, an intermediate module 150 has
been added. The lifting beam is thus adapted with this extra intermediate
module 150 to the length and weight of the slightly larger blade and so is the
arrangement of cables 51 and 52.
Figure 3 shows an alternative cradle and alternative second sling which may
be used in embodiments of the invention. Cradle 84 in this embodiment
comprises a flat base portion 84 and an inclined rear portion 84c. Extensions
of the cradle 84b and 84e may be attached e.g. through screws. The
extensions in this embodiment comprise pins 76 and 78 around which the
loops 71 and 72 of the second sling are provided. Wheels 84f may be
provided for manoeuvring cradle 84.
Blade supports 73, 74 and 75 are provided which comprise foam parts 73b,
74b and 75b for supporting and protecting blade 10. The foam parts may e.g.
be made from polyethylene (PE). Supports 73 and 74 may be hingedly
connected to the base of the cradle.
In the embodiments shown, the lifting beam was built-up from various
modules. Although this is an advantageous arrangement, in that it allows the
lifting beam to be easily adjustable for lifting different blades, the lifting beam
may also have a non-modular arrangement. In modular designs, the number
of modules may also be freely varied within the scope of the invention. Also, it
will be clear that the lengths of the modules may be varied within the scope of
the invention. In preferred kits of modules, the number and dimensions of
modules are optimized with respect to e.g. versatility (the ability to be used in
the hoisting of many different wind turbine blades) and cost.

Although only a number of particular embodiments and examples of the
invention have been disclosed herein, it will be understood by those skilled in
the art that other alternative embodiments and/or uses of the invention and
obvious modifications and equivalents thereof are possible. Furthermore, the
present invention covers all possible combinations of the particular
embodiments described. Thus, the scope of the present invention should not be limited by particular embodiments, but should be determined only by a fair reading of the claims that follow.
1. Lifting beam adapted to be suspended from a crane for hoisting a wind turbine blade comprising a longitudinal beam extending between a first end and a second end, a root manipulation system provided near the first end, and a tip manipulation system provided near the second end,

   the root manipulation system comprising a first sling suitable to be fitted around a first wind turbine blade portion at or near a blade root and a drive system for rotating the first sling,

   the tip manipulation system comprising a second sling suitable to be fitted around a second wind turbine blade portion that is nearer to the blade tip than the first wind turbine blade portion, and a drive system for rotating the second sling, and

   the second sling comprising a cable portion and a cradle for being fitted underneath the second blade portion and being connected to both ends of the cable portion.

2. Lifting beam according to claim 1, wherein the root manipulation system comprises a cable carrying the first sling and a winch for pulling the cable in or letting the cable out.

3. Lifting beam according to claim 1 or 2, wherein the drive system for rotating the first sling comprises a first motor driven pulley and the first sling is engaged with the first motor driven pulley.

4. Lifting beam according to any previous claim, wherein the drive system for rotating the second sling comprises a second motor driven pulley and the second sling is engaged with the second motor driven pulley.

5. Lifting beam according to any previous claim, wherein the longitudinal beam has a truss structure.

6. Lifting beam according to any previous claim wherein the longitudinal beam has a length of between 50% - 100% of the wind turbine blade to be lifted.
7. Lifting beam according to any previous claim, wherein the length of the longitudinal beam is adjustable.

8. Lifting beam according to any previous claim, wherein the length of the cradle is greater than the chord of the second blade portion under which it is to be fitted.

9. Lifting beam according to any previous claim, wherein the longitudinal beam comprises a root module, a tip module and one or more intermediate modules, the modules being adapted to be coupled to each other to form the longitudinal beam.

10. Lifting beam according to claim 9, wherein the root module comprises at least part of the root manipulation system and the tip module comprises at least part of the tip manipulation system.

11. A kit for assembly of a lifting beam according to claim 9 or 10 comprising
    a root module having a truss structure and comprising at least part of the root manipulation system,
    a tip module having a truss structure and comprising at least part of the tip manipulation system,
    a plurality of intermediate modules having a truss structure, wherein the modules are adapted to be coupled to each other.

12. A kit according to claim 11, wherein the plurality of intermediate modules comprises modules of different lengths.

13. A kit according to claim 11 or 12, wherein the root module and the tip module comprise a securing member for securing a cable suspended from a crane.

14. A kit according to any of claims 11 - 13, wherein at least one intermediate module comprises a securing member for securing a cable suspended from a crane.

15. A kit according to any of claims 11 - 14, wherein the root module is
adapted to carry a counterweight.

16. Use of a lifting beam according to any of claims 1 - 10 in a method for hoisting a wind turbine blade.
A. CLASSIFICATION OF SUBJECT MATTER

INV. B66C1/16 F03D1/00 F03D11/04

ADD.

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)

B66C F03D

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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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