

Title: Tube element for floatable offshore support structure for wind turbine

5 FIELD

The present invention concerns a method of forming a tube element for use as a longitudinal section of a brace for a truss structure of a floatable offshore support structure for a wind turbine. The invention further concerns: a tube element formed by the method; a brace comprising the tube
10 element; a floatable offshore support structure comprising the brace; a wind turbine provided with the floatable offshore support structure; an offshore wind farm comprising the wind turbine; and a method of assembling the floatable offshore support structure.

15 BACKGROUND

Offshore support structures such as semi-submersible or floatable offshore support structures for wind turbines are known as such, for example from WO2022/086329A1. Such an offshore support structure may generally comprise a truss structure comprising several tubular braces as
20 truss members. The floatable offshore support structure is typically constructed on shore or at an offshore construction site, before being transported to an offshore location of use such as an offshore wind farm site, where the support structure may be floated to floatingly support a wind turbine supported thereon, in particular using semi-submersible columns of
25 the support structure for floatation.

During construction, the braces typically have to be welded at one or more of their ends to other elements, for example semi-submersible columns and/or a wind turbine receiving element, such that a strong and durable structure is formed. Realizing these connections in an efficient yet
30 effective manner tends to present challenges, in particular in view of the typically very large dimensions of the floatable offshore support structure.

For example, some braces may have to be connected while the brace is held at a height of about 35 m above ground, e.g. by cranes and/or a temporary support frame. Meanwhile, to facilitate welding, the brace typically has to be positioned very precisely with respect to the element to which it is to be
5 connected. Even if positioned precisely, the welding can be complicated, for example when limitations require the welding to be performed from below a non-vertical seam, resulting in disadvantageous gravitational effects for the welding and the safety of the welding process.

In view of the above, improvements are desired.

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SUMMARY

An object of the invention is to at least partly address at least one of the above mentioned challenges or a related challenge. An object is to provide a floatable offshore support structure for a wind turbine that is
15 sufficiently strong and durable yet relatively economical, in particular in terms of construction efforts. An object is to at least provide an alternative.

The present invention is based at least in part on the surprising insight that the above mentioned challenges can be addressed using an end section of the brace in the form of a tube element that presents a transition
20 between a circular transverse shape at a more proximal position along the brace, i.e. more towards the longitudinal center of the brace, and a rectangular transverse shape at a more distal position along the brace, i.e. more towards the longitudinal end of the brace. In particular, the circular transverse shape enables the brace to have a circular transverse shape
25 along most of its length, while the rectangular transverse shape can facilitate welding of the end of the brace to another element. More specifically, the rectangular transverse shape can enable the welding to be performed relatively safely and effectively: two vertical sides and a bottom side of the rectangle can be welded from within the tubular brace, and a top

side of the rectangle can be welded from a locally flat top surface of the brace.

In view of this insight, an aspect of the invention provides a brace for a truss structure of a floatable offshore support structure for a wind turbine, comprising a tube element as a longitudinal section of the brace, wherein, along a longitudinal direction of the tube element, a transverse shape of the tube element transitions from a circular shape to a rectangular shape.

Preferably, the rectangular transverse shape has a height-to-width ratio in the range of 2:1 to 1:2, more preferably in the range of 3:2 to 2:3, even more preferably in the range of 4:3 to 3:4, for example in the range of 5:4 to 4:5. The rectangular shape may thus be a square shape or a different rectangular shape. A tube element of this type may be referred to colloquially as a round-to-square tube element, even if the rectangular shape is formally non-square. In the present context, it shall be appreciated that the expressions rectangular shape and square shape encompass shapes that include slight deviations from a perfect rectangle or square, such as a slightly trapezoid rectangular shape. Thus, the expression rectangular shape may be understood as a quadrilateral shape whose four vertices all correspond to right angles or nearly-right angles, the angles for example being in the range of 80 to 100 degrees, or in the range of 85 to 95 degrees.

Meanwhile, in the present context, the expression circular transverse shape shall be understood as a transverse shape that approaches a perfect circle at least to an extent that is reasonably achievable given the circumstances, and/or reasonably meaningful in terms of load transmissions in the truss structure. For example, in case the circular transverse shape is formed by bending flat plates at discrete positions corresponding to circumferential positions along the circular transverse shape, a resulting curvature may be somewhat variable along the circumference, while still an overall transverse shape may be obtained that the skilled person would

regard as a circular shape in the present context. As a further example, it shall be appreciated that braces and tube elements may experience some deformation under loads, including under their own weight, possibly resulting in transverse shapes such as a circular transverse shape being
5 slightly deformed as well, e.g. resulting in a somewhat ellipsoid shape instead of a perfectly circular shape. As a result, in the present context, the expression circular transverse shape may encompass deviations from a perfect circle of up to 1% or 2% or 5%.

The transition between the circular transverse shape and the
10 rectangular transverse shape is preferably a smooth transition. Thereby, a relatively evenly distributed force transmission along the longitudinal direction can be promoted. By contrast, in known tube elements, a transition between a circular transverse shape and a rectangular transverse shape is not smooth, in particular presenting so-called knuckles along the
15 longitudinal direction, resulting in potential weaknesses and uneven force transmission along the longitudinal direction. The present invention is also based, at least in part, on surprising insights into how this disadvantage of known tube elements can be overcome, in particular using a method of forming a tube element as described below.

20 The tube element is preferably formed or formable by a method comprising: providing four elongate flat steel plates each extending along a longitudinal direction and having two opposite lateral edges; for each of the plates, deforming the plate such that, along the longitudinal direction, a transverse shape of the plate smoothly transitions between a rectilinear
25 shape and an arcuate shape; and forming the tube element by interconnecting the four deformed plates along their lateral edges. As part of the tube element, the interconnected deformed plates are mutually arranged such that each deformed plate forms a respective circumferential section of the tube element and such that, along the longitudinal direction, a
30 transverse shape of the tube element smoothly transitions from a circular

shape, namely where the transverse shapes of the deformed plates are arcuate shapes, to a rectangular shape, namely where the transverse shapes of the deformed plates are rectilinear shapes.

In the present context, a transition between transverse shapes along a longitudinal direction being smooth may be understood as that the transition is free from longitudinal shape discontinuities such as so-called knuckles or similar corners. If present, such discontinuities can typically be observed as corners in the shapes of longitudinal cross sections of the respective element. In known round-to-square tube elements, such discontinuities are common, resulting in uneven force transmission and potential weaknesses as explained above.

It has been found that the above described method of forming the tube element advantageously enables the formation of the tube element with such a smooth transition of the transverse shape, in particular in a relatively economical manner, resulting in a particularly effective and economical tube element for the brace that may be free from longitudinal shape discontinuities such as knuckles. Specifically, the tube element may thus comprise the smooth transition while being formable from four initially flat plates that can each form a respective side of the rectangular transverse shape as well as a respective arc segment, e.g. of about 90 degrees, of the circular transverse shape, the resulting four arc segments together forming the circular transverse shape. Each of the plates itself can be free from corners along the longitudinal direction, whereas the interconnected lateral edges of the plates can each extend along a corner-free curve or line extending only in non-circumferential directions.

It shall be appreciated that the transition between the rectangular transverse shape and the circular transverse shape being smooth does not necessarily require that such smoothness is continued beyond the transition or is even present at the end of the transition. For example, at the end of the transition where the transverse shape is a circular shape, the tube element

may be connected to a cylindrical further tube element, wherein at the connection a longitudinal shape discontinuity may be present, which may be visible as corners in some longitudinal cross sections. Such corners, if present, may for example deviate from a straight angle by at most 20
5 degrees, preferably at most 15 degrees.

Preferably, interconnecting the four deformed plates along their lateral edges comprises welding adjacent ones of the lateral edges of adjacent ones of the deformed plates together, at least along the transition. This method of interconnecting can provide a particularly strong and
10 durable tube element, especially since the plates are steel plates. Where the transverse shape of the tube element is a circular shape, the edges of the plates are preferably welded together by butt joints. Where the transverse shape of the tube element is a rectangular shape, the plates are preferably welded together by corner joints. At intermediate positions along the
15 transition, correspondingly intermediate types of weld joints may be applied. Additional types of weld joints such as tee joint may be applied, as will be explained further elsewhere herein.

Preferably, the four deformed plates each extend in the longitudinal direction beyond the end of the transition of the transverse
20 shape of the plate at a longitudinal side of said transition where the transverse shape of the plate is a rectilinear shape. The interconnected deformed plates may then be mutually arranged such that the tube element extends in the longitudinal direction beyond the end of the transition of the transverse shape of the tube element at a longitudinal side of said transition
25 where the transverse shape of the tube element is a rectangular shape.

In this way, advantageously, the tube element and the brace can be connected to a further element of the truss structure at some distance from the end of the transition having the rectangular transverse shape, wherein such a connection may be formed at a corresponding end of the tube element
30 that is longitudinally beyond the transition. This allows the tube element to

be cut to size, in particular to a fitting length and/or to a fitting shape and position of the end to be connected, at the time of construction of the truss structure, without affecting the transition. Moreover, this allows a welded connection between the adjacent plates to be formed as a corner joint at the
5 end of the transition while being formed as a possibly stronger tee joint at the end of the tube element. Between the transition and said end of the tube element, the tube element may have a rectangular transverse shape, which may for example be constant or variable along the longitudinal direction between the transition and said end of the tube element.

10 Preferably, the smooth transition of the transverse shape of the tube element matches a constant or smoothly changing transverse shape of the tube element adjacent said transition at a longitudinal side of said transition where the transverse shape of the tube element is a rectangular shape, so as to provide a continuing smoothness along the longitudinal
15 direction across the respective end of said transition, wherein the plates are deformed and mutually arranged so as to provide said matching.

In this way, advantages discussed above of the transition itself being smooth can be correspondingly provided across the end of the transition where the transverse shape is a rectangular shape. By contrast,
20 known round-to-square tube elements commonly have longitudinal shape discontinuities at such an end of a transition, in particular in the form of knuckles.

Preferably, to provide said matching, the plates are deformed and mutually arranged such that, along the transition, the plates bulge
25 outwardly at their interconnected lateral edges, in particular compared to imaginary straight lines interconnecting the circular shape and the rectangular shape at positions corresponding to the respective lateral edges.

Using such bulging, the lateral edges of the plates can be smoothly formed along the longitudinal direction, wherein said smoothness can
30 continue across the end of the transition where the transverse shape of the

plate is a rectilinear shape, for example continuing all the way to the longitudinal end of the plate.

Preferably, at the side of the transition where the transverse shape of the tube element is a rectangular shape, adjacent ones of the interconnected deformed plates extend at right angles to each other along the circumferential direction of the tube element, in particular to conform to the rectangular shape. Preferably, at the side of the transition where the transverse shape of the tube element is a circular shape, adjacent ones of the interconnected deformed plates extend at straight angles to each other along the circumferential direction of the tube element, at least at the interconnected lateral edges, in particular to conform to respective local tangents of the circular shape at the interconnected lateral edges.

Preferably, along the transition, the angles between the plates at the interconnected lateral edges gradually monotonically change between the right angles and the straight angles. Such a gradual monotonic change can advantageously contribute to the overall smoothness of the transition.

Preferably, longitudinal center lines of the plates remain undeformed by the deformation of the plates, at least along the transition. Advantageously, such center lines can provide force transmission along straight lines in the longitudinal direction.

Preferably, for each of the plates, a triangular section of the plate remains undeformed by the deformation of the plate, the triangular section being defined by a triangle base and a triangle tip. The triangle base preferably corresponds to the rectilinear transverse shape of the plate at the end of the transition where the transverse shape of the tube element is a rectangular shape. The triangle tip preferably corresponds to an intersection of the longitudinal center line of the plate with the arcuate transverse shape of the plate at the end of the transition where the transverse shape of the tube element is a circular shape.

A relatively strong and stable tube element can be provided in this way. Meanwhile, the required deformation of the plate may thus be relatively limited, allowing relatively easy formation of the tube element.

Preferably, along the transition, the triangular section is the only
5 section of the plate that remains undeformed by the deformation of the plate prior to the interconnection of the deformed plates.

In this way, the transition between the arcuate and rectilinear transverse shapes of the plates can be realized particularly effectively, for example by a symmetric or near-symmetric deformation with respect to the
10 center line, gradually curving away from the lateral sides of the triangle to form the arcuate transverse shape at a longitudinal position corresponding to the tip of the triangle.

Preferably, when viewed in the longitudinal direction, the circular transverse shape does not extend outside the rectangular transverse shape.
15 The sides of the rectangular transverse shape may for example correspond to respective tangents of the circular transverse shape.

In this way, the above mentioned undeformed center lines and triangular sections can be incorporated in the design of the tube element.

Preferably, the method further comprises attaching one or more
20 reinforcement structures to the tube element at an inside of the tube element, in particular where the transverse shape of the tube element is a rectangular shape.

In this way, stability and strength of the tube element can be promoted, in particular with respect to the rectangular transverse shape.
25 Meanwhile, although reinforcement structures may also be applied elsewhere along the tube element or brace, these may not be necessary due to the inherently larger stability and strength typically associated with a circular transverse shape of a tube element.

Preferably, the deforming of the plate is limited such that the
30 deformed plate as a surface is a developable or single-curved surface.

Preferably, the deforming of the plate is limited such that the deformed plate is free from any knuckles. Preferably, the deforming of the plate is limited so as to exclude that the deformed plate would have any radius that is smaller than ten times a local thickness of the plate. Preferably, the

5 deforming of the plate is limited so as to prevent the occurrence of any deformation of the plate that comprises more than 5% local elongation of the steel plate material of the plate.

Such limitations to the deforming of the plate can advantageously promote relatively even force transmission through the plate and strength of

10 the plate as part of the tube element, in particular when in use as part of a brace. In particular, weakening of the steel plate material by the deformation may thus be limited and disadvantageously large stresses in the steel plate material may thus be prevented. In the present context, transitions of shapes being smooth may be understood as conforming to one

15 or more of these limitations with respect to the plate, and/or conforming to one or more corresponding limitations with respect to the tube element.

Preferably, the tube element is formed to be free from any knuckles with respect to the longitudinal direction. Preferably, deformed sections of the plate are shaped according to respective conical surfaces each defining

20 an imaginary oblique cone having an apex that is positioned outside a longitudinal range and/or a transverse range of the transition and/or the plate. Preferably, a base of the imaginary oblique cone corresponds to the end of the transition having the circular transverse shape. Preferably, the position of the apex coincides with an imaginary extension of a triangle side

25 of the preferred flat undeformed triangular section of the plate.

In this way, disadvantageously large stresses in the tube element may be prevented, in particular when in use as part of the brace. In particular, the arrangement of the imaginary oblique cone advantageously allows the above described preferred limitations of the deformations of the

30 plates. By contrast, known tube elements are essentially shaped with a

conical or similar apex coinciding with the end of the transition, resulting locally in an excessively small radius of a plate material.

Preferably, an intersection of the interconnected lateral edges of the plates and the end of the transition where the transverse shape of the tube element is a rectangular shape is arranged at less than 90% from the base to the apex of the imaginary oblique cone, preferably less than 80%, more preferably less than 70%, even more preferably less than 60%. In this way, the above mentioned advantages of the arrangement of the imaginary oblique cone can be realized to a particularly large extent.

Preferably, the tube element, in particular at a side of the transition where the transverse shape of the tube element is a rectangular shape, forms a connector structure of the brace for connecting the brace to a further part of the floatable offshore support structure, in particular at a longitudinal end of the brace.

Such a connector structure may advantageously facilitate construction of the truss structure and/or the floatable offshore support structure. For example, the connector structure may be configured to engage with a matching connector structure that may be provided on a column assembly of the floatable offshore support structure, to allow the brace to form a truss member of the truss structure. As explained elsewhere herein, each connector structure may present rectilinear plate edges to facilitate welding.

Preferably, the brace further comprises a cylindrical further tube element as a further longitudinal section of the brace, the cylindrical further tube element being connected to the tube element at a side of the transition where the transverse shape of the tube element is a circular shape.

In this way, advantages of using cylindrical tubes as parts of truss members can be leveraged for the brace. This includes in particular a relatively high strength to weight ratio. Moreover, the cylindrical further tube element, when connected, can act as a reinforcement structure for the

tube element. The cylindrical further tube element preferably has a larger longitudinal size than the tube element, in particular forming a majority of the brace's length. The cylindrical further tube element is preferably welded to the tube element.

5 Preferably, a circular transverse shape of the cylindrical further tube element matches the circular transverse shape of the tube element.

 Thereby, the circular transverse shape of the tube element can essentially be continued by the cylindrical further tube element.

 A further aspect provides an offshore support structure for a wind
10 turbine comprising a brace as described herein. The offshore support structure is preferably a floatable offshore support structure. In the present context, a floatable offshore support structure shall be understood as a support structure that has its own flotation capacity in order to float during normal use while performing its supporting function such as by supporting a
15 wind turbine thereon. Such flotation capacity may in particular be provided by semi-submersible columns as described herein.

 Such a offshore support structure can provide advantages essentially corresponding to those described above for the brace. In particular, the offshore support structure can thus benefit from the
20 advantages provided by the described tube element. The brace may in particular form a truss member as part of a truss structure of the floatable offshore support structure, in particular a horizontal or diagonal truss member.

 The truss structure, and/or a connecting structure of which the
25 truss structure may form a part, preferably interconnects two, three, or more column assemblies of the floatable offshore support structure, each column assembly comprising a respective semi-submersible column. The brace may be connected to at least one of the column assemblies, in particular at an end of the brace. At the connection with the column
30 assembly, the brace may have a rectangular transverse shape, in particular

formed by the tube element at a side of the transition where the transverse shape of the tube element is a rectangular shape.

Preferably, in particular if the brace is used to form a horizontal or diagonal truss member, one or more interfaces between the column
5 assembly and the brace, for example mutually weldable plate edges, are slanted, in particular to provide space for maneuvering the end of the brace into position in a substantially downward direction, during assembly of the floatable offshore support structure. In this way, a relatively precise and well controlled maneuvering may be facilitated. It shall be appreciated that
10 the term slanted is here used in relation to the orientation of the brace when in use as a truss member. So, for example, in case of use as a horizontal truss member, also called horizontal brace herein, the term slanted implies an angle with respect to a plane that is transverse to the longitudinal direction of the brace.

15 The column assembly and the brace may be configured to help stabilize the brace with respect to the column assembly before and/or during formation of the connection between the column assembly and the brace, in particular by allowing the brace to be at least partly supported on the column assembly. In particular the aforementioned connector structures, if
20 present, may be configured to allow the connector structure of the brace to be at least partly supported on the connector structure of the column assembly.

Preferably, at the connection between the column assembly and the brace, the column has a polygonal, preferably hexagonal, transverse shape,
25 possibly with rounded vertices.

Such a transverse shape can enable relatively easy construction of the column and the column assembly.

The brace is preferably connected to the column assembly at a circumferential position corresponding to a vertex of the polygonal shape of
30 the column. In this way, longitudinal forces associated with the brace can be

transferred to the column relatively efficiently, and vice versa. Alternatively or additionally, the brace or a further brace may be connected to the column assembly at a different position, for example a position that is circumferentially between vertices of the polygonal shape.

5 Preferably, the floatable offshore support structure comprises a damper box, in particular as part of a column assembly as mentioned above. The damper box may have a top plate and a bottom plate spaced apart from the top plate, wherein the top plate and the bottom plate are mutually interconnected by one or more side plates.

10 Such a damper box can advantageously promote low motions and accelerations of the floating offshore support structure, in particular in case of a semi-submersed offshore support structure.

 The brace may be connected to the damper box. In that case, the brace is preferably connected to the damper box at the one or more side
15 plates, in particular without overlapping either of the top plate and the bottom plate at an outside of the damper box.

 Thereby, longitudinal forces associated with the brace can be transferred to the damper box relatively efficiently, and vice versa.

 Preferably, at the connection with the damper box, the brace has a
20 rectangular transverse shape, in particular formed by the tube element at a side of the transition where the transverse shape of the tube element is a rectangular shape.

 In this way, construction of the connection between the brace and the damper box can be facilitated, in particular with respect to welding.

25 Preferably, one rectilinear side of the transverse shape of the brace is aligned or at least parallel with one of the top plate and the bottom plate of the damper box, wherein preferably an opposite rectilinear side of the transverse shape of the brace is aligned or at least parallel with the other one of the top plate and the bottom plate of the damper box.

Such an arrangement can advantageously facilitate efficient force transmission between the brace on the one hand and the top plate and/or bottom plate on the other hand, wherein the top plate and/or bottom plate may in turn facilitate force transmission to a further part of the column assembly.

A further aspect provides a wind turbine provided with a floatable offshore support structure as described herein, wherein the wind turbine is supported on the offshore support structure, in particular while the offshore support structure is floating. A further aspect provides an offshore wind farm comprising at least one such wind turbine with offshore support structure as described herein, wherein in particular the offshore support structure is floating to floatably support the wind turbine.

Such a wind turbine and wind farm can benefit from advantages described above with respect to the floatable offshore support structure, the truss structure, the brace and the tube element. In case the wind farm comprises multiple floating offshore support structures with wind turbines, the wind farm may be regarded as a floating wind farm. Still, an offshore wind farm may in some cases comprise a combination of floating and non-floating support structures, e.g. in case depth of the sea varies across the wind farm.

The wind turbine is preferably supported on the truss structure and/or spaced apart from any semi-submersible column of the floatable offshore support structure. With respect to such an arrangement as such, reference is made here to WO2022/086329A1, where associated advantages and possible elaborations are explained. For example, as explained therein, and as may be correspondingly applied in the context of the present invention, the wind turbine may be supported on a wind turbine receiving element which may be positioned on one of preferably three outer sides of the floatable offshore support structure, in between two semi-submersible

columns, wherein the three outer sides may be defined by the truss structure as a connection structure.

Preferably, the floatable offshore support structure floatingly supports the wind turbine. To that end, as explained elsewhere herein, the floatable offshore support structure has floating capacity, e.g. being semi-submersible, in particular using semi-submersible columns as described herein. During use, the floatable offshore support structure is preferably anchored to substantially maintain its position.

A further aspect provides a method of assembling a floatable offshore support structure as described herein. The method of assembling comprises: providing at least two, preferably three, column assemblies each comprising a respective semi-submersible column; providing at least one brace as described herein; interconnecting the at least two column assemblies by a truss structure, the truss structure comprising the at least one brace, in particular as a respective at least one truss member.

Such a method advantageously enables assembly of the floatable offshore support structure as described herein, in particular in a relatively economical manner, wherein the column assemblies may for example be arranged and interconnected by a truss structure mainly as described in WO2022/086329A1 but with additional advantages associated with the brace as described in the present disclosure.

Preferably, the interconnecting of the at least two column assemblies comprises connecting, in particular welding, an end of a brace of the at least one brace to one of the column assemblies, wherein preferably the end of the brace to be connected has a rectangular transverse shape formed by the tube element as described herein.

In this way, the truss structure can be formed relatively easily and effectively. It shall be appreciated that different braces of the at least one brace may be connected to a same one or different ones of the column assemblies, and that the offshore support structure may comprise one or

more braces not directly connected to any one of the column assemblies.
Such a brace may for example be connected to another brace that is
connected to a column assembly, and/or may be connected to a wind turbine
receiving element that may for part of a same connecting structure that the
5 truss structure may form part of.

Preferably the connecting of the end of the brace to the column
assembly comprises, and/or is performed by, welding of rectilinear plate
edges of the end of the brace to rectilinear plate edges formed on the column
assembly, wherein preferably the rectilinear plate edges are formed as parts
10 of respective connector structures of the brace and the column assembly.
The rectilinear plate edges to be mutually connected are preferably
arranged and/or shaped to be mutually aligned, in particular to extend in a
same plane and/or to determine an intermediate gap for welding with a gap
width in the range of 1 to 10 mm, preferably 2 to 7 mm, more preferably 3 to
15 5 mm. To facilitate the welding, the rectilinear plate edges as described
herein preferably extend horizontally or vertically when connected, wherein
it shall be appreciated that in the present context so-called vertical plate
edges may still be regarded as slanted, namely in the sense that the
respective plates extend vertically while the edge extends at a somewhat
20 slanted angle when viewed normal to the surface of the plate.

In this way, the end of the brace can be connected to the column
assembly particularly effectively and efficiently using welding.

Preferably, the end of the brace is cut to size prior to the connecting
to the column assembly, e.g. as alluded to elsewhere herein in the context of
25 the tube element. Such cutting to size can advantageously facilitate a
precise fit, e.g. with a connector structure of the column assembly, despite
possible variable conditions such a temperature changes that may affect the
exact length of the brace.

Preferably, the connecting of the end of the brace to the column
30 assembly comprises maneuvering the end of the brace into position at the

column assembly in a substantially downward direction. In this way, the maneuvering may be relatively well controlled, e.g. using a crane.

Preferably, to provide maneuvering space for said maneuvering, mutually weldable plate edges or one or more other interfaces between the column assembly and the brace are slanted, e.g. as alluded to elsewhere
5 herein. In particular, an interface of the column assembly may be slanted to face partly upwardly while an interface of the brace may be slanted to face partly downwardly, so as to allow the interfaces to approach each other when the brace is lowered with respect to the column assembly.

10 Optionally, an end of a horizontal brace is connected to the column assembly just above an end of a diagonal brace that is already connected to the column assembly. In this way, advantageously, an effective node of the truss structure may be formed at the connections to the column assembly. Alternatively or additionally, an end of a horizontal brace may be connected
15 to the column assembly at a distance from any diagonal brace that is or will be connected to the same column assembly.

It shall be appreciated that various aspects and options described herein may be variously combined, wherein for example options described in the context of a structure may be correspondingly applied in the context of a
20 method and/or vice versa.

DETAILED DESCRIPTION

In the following, the invention will be explained further using examples of embodiments and drawings. The drawings are schematic and
25 merely show examples. In the drawings, corresponding elements are provided with corresponding reference signs. For clarity of the drawings, some reference signs have been omitted from some of the figures, wherein the presence of respective elements in those figures may nevertheless be understood, e.g. from one or more other figures, in particular when
30 considered together with the present detailed description.

In the drawings:

Fig. 1 shows a perspective view of a floatable offshore support structure with a wind turbine supported thereon;

Fig. 2 shows a transparent perspective view of a tube element with
5 a section of a connected cylindrical further tube element;

Fig. 3 shows a transparent perspective view of a tube element along with illustrations of preferred weld joints at different longitudinal positions in transverse cross sectional views;

Fig. 4 shows a plan view of a flat plate;

10 Figs. 5A to 5E show perspective views illustrating subsequent steps in a method of forming the tube element of Fig. 3 from four flat plates each of the design shown in Fig. 4, wherein in Fig. 5E also a connected cylindrical further tube element is shown;

Fig. 6 shows an axial view, i.e. a view in the longitudinal direction,
15 of the tube element of Fig. 3;

Fig. 7 shows a non-transparent perspective view of the tube element with connected further tube element of Fig. 5E;

Fig. 8 shows a view of the tube element with connected further tube element of Fig. 7, in a direction that is transverse to the longitudinal
20 direction of the tube element from a circumferential position corresponding to a corner of the rectangular transverse shape;

Fig. 9 shows an isometric view of a deformed plate for a tube element along with auxiliary lines that illustrate its geometry;

Figs. 10A to 10C show perspective views illustrating steps in
25 assembly of a floatable offshore support structure, in particular connection of two braces to a column assembly;

Figs. 11A and 11B show perspective views illustrating steps in assembly of a floatable offshore support structure, in particular connection of a brace to a damper box;

Fig. 12 shows a transparent perspective view of a tube element provided with reinforcement structures; and

Fig. 13 shows a cross sectional side view of an offshore wind farm comprising floatable offshore support structures and wind turbines supported thereon.

Fig. 1 shows a floatable offshore support structure 1 with a wind turbine 2 supported thereon. The floatable offshore support structure 1 comprises here three column assemblies 3 each comprising a semi-submersible column 4, the column assemblies 3 being interconnected by a truss structure 5 comprising braces 6, in particular horizontal braces 6a and diagonal braces 6b, as truss members. WO2022/086329A1 discloses a floatable offshore support structure having a similar overall configuration of semi-submersible columns interconnected by a truss structure, though without various improvements as provided by the present disclosure.

Fig. 13 shows an offshore wind farm 7 comprising floatable offshore support structures 1 of the type shown in Fig. 1 with respective wind turbines 2 supported thereon. The floatable offshore support structures 1 are preferably anchored to the sea floor. In Fig. 13, it can be seen that the columns 4 of the floatable offshore support structure 1 are semi-submerged so as to allow the wind turbine 2 to be floatingly supported at sea level S. A corresponding draft line D is indicated on the columns 4 and other elements in Fig. 1.

The braces 6 of the truss structure 5 are generally tubular, comprising cylindrical steel tube elements 8 that form most of the brace's length, as is typical as such for braces. In the examples of the present disclosure, advantageously, the braces 6 additionally comprise one or two steel tube elements 9 as a respective longitudinal end section of the brace 6, that provide the brace 6 with a rectangular transverse shape T_r at a respective end of the brace 6 while matching a circular transverse shape T_c of the cylindrical tube element 8 at the connection with said cylindrical tube

element 8, wherein a smooth transition X_t with respect to the transverse shape is formed therebetween.

Examples of tube elements 9 providing such a transition are shown in Figs. 1, 2, 3, 5E, 6, 7, 8, 10A-10C, 11B and 12. This type of tube element 9
5 may in particular be formed from four initially flat steel plates 10f, as will be explained below with particular reference to Fig. 4 and Figs. 5A-5E.

To form the tube element 9, four elongate flat steel plates 10f may be provided, each extending along a longitudinal direction L and having two opposite lateral edges 11. An example of such a plate 10f is shown in Figs. 4
10 and 5A. As can be seen e.g. in Fig. 5B in comparison to Fig. 5A, each of the plates 10f may be deformed such that, along the longitudinal direction L, a transverse shape of the deformed plate 10d smoothly transitions between a rectilinear shape P_r and an arcuate shape P_a . As illustrated in Figs. 5C-5E, the tube element 9 may then be formed by interconnecting the four
15 deformed plates 10d along their lateral edges 11. As part of the tube element 9, the interconnected deformed plates 10d are mutually arranged such that each deformed plate 10d forms a respective circumferential section of the tube element 9 and such that, along the longitudinal direction L, a transverse shape of the tube element 9 smoothly transitions from a
20 circular shape T_c , namely where the transverse shapes of the deformed plates 10d are arcuate shapes P_a , to a rectangular shape T_r , in particular a square shape, namely where the transverse shapes of the deformed plates 10d are rectilinear shapes P_r .

In the shown examples, the four deformed plates 10d each extend
25 in the longitudinal direction L beyond the end of the transition X_p of the transverse shape of the plate 10d at a longitudinal side of said transition X_p where the transverse shape of the plate 10d is a rectilinear shape P_r , wherein the interconnected deformed plates 10d are mutually arranged such that the tube element 9 extends in the longitudinal direction L beyond
30 the end of the transition X_t of the transverse shape of the tube element 9 at

a longitudinal side of said transition X_t where the transverse shape of the tube element 9 is a rectangular shape Tr .

In the shown examples, as may be best understood from Fig. 8, the smooth transition X_t of the transverse shape of the tube element 9 matches
5 a constant or smoothly changing transverse shape of the tube element 9 adjacent said transition X_t at a longitudinal side of said transition X_t where the transverse shape of the tube element 9 is a rectangular shape Tr , so as to provide a continuing smoothness along the longitudinal direction L across the respective end of said transition X_t , wherein the plates 10 are deformed
10 and mutually arranged so as to provide said matching.

In the shown examples, again with particular reference to Fig. 8, to provide said matching, the plates 10 are deformed and mutually arranged such that, along the transition X_t , the plates 10d bulge outwardly at their interconnected lateral edges 11, in particular compared to imaginary
15 straight lines interconnecting the circular shape T_c and the rectangular shape Tr at positions corresponding to the respective lateral edges 11.

In the shown examples, at the side of the transition X_t where the transverse shape of the tube element 9 is a rectangular shape Tr , adjacent ones of the interconnected deformed plates 10d extend at right angles to
20 each other along the circumferential direction C of the tube element 9, in particular to conform to the rectangular shape Tr . In Fig. 3, a corresponding illustration of a corner weld II is shown, as explained further elsewhere herein.

In the shown examples, at the side of the transition X_t where the
25 transverse shape of the tube element 9 is a circular shape T_c , adjacent ones of the interconnected deformed plates 10d extend at straight angles to each other along the circumferential direction C of the tube element 9, at least at the interconnected lateral edges 11, in particular to conform to respective local tangents of the circular shape T_c at the interconnected lateral edges

11. In Fig. 3, a corresponding illustration of a butt weld IV is shown, as explained further elsewhere herein.

In the shown examples, along the transition X_t, the angles between the plates 10d at the interconnected lateral edges 11 gradually
5 monotonically change between the right angles and the straight angles. In Fig. 3, a corresponding illustration of a weld III of an intermediate type between a corner weld and a butt weld is shown, as explained further elsewhere herein.

With particular reference to Figs. 4 and 5A-B, longitudinal center
10 lines M of the plates 10 may remain undeformed by the deformation of the plates 10. Alternatively, one or more deformations of the center lines M may be present, for example at an end of the transition X_t where the tube element 9 has a rectangular transverse shape Tr. In this way, for example, a variation of the transverse shape of the tube element 9 outside the
15 aforementioned transition X_t may be realized, for example to provide a different rectangular shape at an end of the tube element 9 compared to at the end of the transition X_t, as is the case in the example of Figs. 10B-C. In this example, the tube element 9 of horizontal brace 6a has a diameter of 2 meters where the transverse shape is a circular shape, to match a diameter
20 of the cylindrical further tube element 8. However, at the end of the tube element 9 that forms a connector structure 17 for connection with the column assembly 3, the tube element 9 has a transverse width of 2 meters and a transverse height of 2.5 meters, i.e. a non-square rectangular transverse shape, to match corresponding dimensions of a respective
25 connector structure 18 of the column assembly 3. Thereto, as indicated in Fig. 10C in a detail D in a longitudinal cross sectional view, a curvature may be formed in one or more of the deformed plates 10d, providing a smooth transition along the longitudinal direction between a here horizontal section of the plate 10d that extends towards the connection with the
30 column assembly 3 and a here sloping section of the plate 10d that extends

towards the cylindrical further tube element 8. Such a curvature may for example be arranged at some distance from the transition Xt. It shall be appreciated that the sections mentioned here as horizontal or sloping may be oriented differently depending on further design choices and/or

5 circumstances, for example in case such an arrangement is applied to a diagonal brace rather than a horizontal brace.

In the shown examples, with particular reference to Figs. 4 and 5A-B, for each of the plates 10, a triangular section 12 of the plate 10 remains undeformed by the deformation of the plate 10, the triangular section 12

10 being defined by a triangle base and a triangle tip, wherein the triangle base corresponds to the rectilinear transverse shape Pr of the plate 10d at the side of the transition Xp where the transverse shape of the tube element 9 is a rectangular shape Tr, wherein the triangle tip corresponds to an intersection of the longitudinal center line M with the arcuate transverse

15 shape Pa of the plate 10d at the side of the transition Xp where the transverse shape of the tube element 9 is a circular shape Tc. Along the transition Xp, the triangular section 12 is here the only section of the plate 10d that remains undeformed by the deformation of the plate 10 prior to the interconnection of the deformed plates 10d. Still, as explained above, further

20 deformations of the plate 10 may be present outside the transition Xp.

With particular reference to Fig. 6, when viewed in the longitudinal direction L, the circular transverse shape Tc here does not extend outside the rectangular transverse shape Tr. Here, the sides of the rectangular transverse shape Tr correspond to respective tangents of the

25 circular transverse shape Tc. Alternatively, the sides of the rectangular transverse shape could be spaced apart from the circular transverse shape when viewed in the longitudinal direction.

With particular reference to Fig. 3, interconnecting the four deformed plates 10d along their lateral edges 11 here comprises welding

30 adjacent ones of the lateral edges 11 of adjacent ones of the deformed plates

10d together, at least along the transition X_t , and preferably along the full length of where the two lateral edges 11 are together. As may be understood from the illustrations I to IV in Fig. 3 relating to different positions along the longitudinal direction L of the tube element 9, where the transverse

5 shape of the tube element 9 is a circular shape T_c , the edges of the plates 10d are preferably welded together by butt joints IV. Where the transverse shape of the tube element 9 is a rectangular shape T_r , the plates 10d are preferably welded together by corner joints II. At intermediate positions along the transition X_t , correspondingly, intermediate types of weld joints

10 III may be applied. At the end of the tube element 9, tee joints I may be applied. Although not explicitly shown, it shall be appreciated that further intermediate types of weld joints may be applied between the tee joints I and the corner joints II. It shall also be appreciated that for clarity of the drawing the illustrations I to IV in Fig. 3 show each of the plate edges as

15 straight, whereas the plates may actually be curved, also at their edges, as is described herein.

With particular reference to Fig. 12, the method may further comprise attaching one or more reinforcement structures 13 to the tube element 9 at an inside of the tube element 9, in particular where the

20 transverse shape of the tube element 9 is a rectangular shape T_r .

In the shown examples, the deforming of the plate 10 is limited: such that the deformed plate 10d as a surface is a developable or single-curved surface; such that the deformed plate 10d is free from any knuckles; so as to exclude that the deformed plate 10d would have any radius that is

25 smaller than ten times a local thickness of the plate 10d; and so as to prevent the occurrence of any deformation of the plate 10 that comprises more than 5% local elongation of the steel plate material of the plate 10.

In the shown examples: the tube element 9 is formed to be free from any knuckles with respect to the longitudinal direction L ; and

30 deformed sections of the plate 10d are shaped according to respective conical

surfaces 14 each defining an imaginary oblique cone having an apex 15 that is positioned outside a longitudinal range and/or a transverse range of the transition Xt and/or the plate 10d, wherein preferably a base 16 of the imaginary oblique cone corresponds to the end of the transition Xt having
5 the circular transverse shape Tc. Such an apex 15 and base 16 have been indicated in Fig. 9 as example, wherein the surface of the deformed plate 10d has been hatched to better distinguish the plate 10d from various auxiliary lines in Fig. 9. From the auxiliary lines in Fig. 9, it may be understood that in view of the apex 15 being relatively far away, the radius
10 of curvature of the deformed plate 10d can be relatively large throughout the plate 10d, in particular also near the end of the transition Xp where the transverse shape is a rectilinear shape Pr. By contrast, known tube elements tend to have excessively small radii in such areas.

In Figs. 3, 4, 5A-5E, 6, 7 and 8, to clarify the shape of the conical
15 surfaces 14, lines have been drawn across those surfaces, namely lines following curvatures of the surface in respective transverse planes, as well as lines following straight trajectories across the surface. The lines following the straight trajectories cross the lines following the curvatures, forming a grid. In Figs. 4 and 5A, the lines following the curvatures have been
20 omitted, since these figures show the plate 10f in its flat state before being deformed. It can be seen that the lines following the straight trajectories extend from the lateral edge 11 of the plate 10 to the end of the plate 10 that has the arcuate transverse shape Pa after the plate 10 has been deformed. It shall be appreciated that the lines following the curvatures are shown in
25 Fig. 8 as vertical lines, in accordance with the view of Fig. 8.

As alluded to above, in the shown examples, the brace 6 further comprises a cylindrical further tube element 8 as a further longitudinal section of the brace 6, the cylindrical further tube element 8 being connected to the tube element 9 at a side of the transition Xt where the transverse
30 shape of the tube element 9 is a circular shape Tc. In the shown examples, a

circular transverse shape of the cylindrical further tube element 8 matches the circular transverse shape T_c of the tube element 9.

In the shown examples, the tube element 9, at a side of the transition where the transverse shape of the tube element 9 is a rectangular shape T_r , forms a connector structure 17 of the brace 6 for connecting the brace 6 to a column assembly 3, in particular to a connector structure 18 thereof, as a further part of the floatable offshore support structure 1, in particular at a longitudinal end of the brace 6. Such connector structures 17, 18 and connections are shown for example in Figs. 10A-C and 11A-B. Here, it can be seen that at the connection with the column assembly 3, the brace 6 has a rectangular transverse shape formed by the tube element 9, facilitating welding. Suitable respective connector structures 18 can be seen on the column assembly 3. The connector structures 17 of the brace 6 and the connector structures 18 of the column assembly 3 here in particular present rectilinear plate edges 19, 20 that can be welded together to form the connection.

As can be seen in Figs. 10A-C and 11A-B, one or more interfaces between the column assembly 3 and the brace 6a, in particular vertically extending ones 20 of the rectilinear plate edges, may be slanted, in particular to provide maneuvering space for maneuvering the end of the brace 6 into position in a substantially downward direction, for assembly of the floatable offshore support structure 1.

Furthermore, it can be seen that the column assembly 3 and the braces 6 are here configured to help stabilize the braces 6 with respect to the column assembly 3 before and/or during formation of the connection between the column assembly 3 and the braces 6, in particular by allowing the braces 6 to be at least partly supported on the column assembly 3, e.g. using partial horizontal overlapping of the connector structure 17 of the brace 6 over the connector structure 18 of the column assembly 3.

With particular reference to Fig. 1, at the connection between the column assembly 3 and the brace 6, the column 4 here has a polygonal, in particular hexagonal, transverse shape, with rounded vertices, wherein most of the braces 6 are connected to a column assembly 3 at a

5 circumferential position corresponding to a vertex of the polygonal shape of the column 4. Meanwhile, in the example of Fig. 1, three of the braces 6 are connected to a column assembly 3, at a different circumferential position, in particular a circumferential position corresponding to a side of the polygonal shape of the column 4. Specifically, in this example, the respective column

10 assembly 3 is arranged opposite the side of the floatable offshore support structure 1 having the wind turbine receiving element 25, i.e. towards the top right corner of the figure in Fig. 1.

It can also be seen in Fig. 1 that each column assembly 3 here comprises a damper box 21 at its lower end. Part of such a damper box 21 is

15 also seen in Figs. 11A-B. In these examples, the damper box 21 has a top plate 22 and a bottom plate 23 spaced apart from the top plate 22, wherein the top plate 22 and the bottom plate 23 are mutually interconnected by one or more side plates 24, wherein the brace 6a is connected to the damper box 21 at the one or more side plates 24, in particular without overlapping

20 either of the top plate 22 and the bottom plate 23 at an outside of the damper box 21. At the connection with the damper box 21, the brace 6a here has a rectangular transverse shape, in particular formed by the tube element 9 at a side of the transition X_t where the transverse shape of the tube element 9 is a rectangular shape Tr . One rectilinear side of the

25 transverse shape of the brace 9, in particular corresponding to a horizontal plate edge 19, is here aligned with the top plate 22 of the damper box 21, wherein an opposite rectilinear side of the transverse shape of the brace 9, in particular corresponding to a further horizontal plate edge 19, is aligned with the bottom plate 23 of the damper box 21. In Fig. 1, it can be seen that

30 as a further possibility a diagonal brace 6b may be connected to a column

assembly 3 at a corner of the top plate 22 of the damper box and a side of the column 4.

A floatable offshore support structure 1, such as the example shown in Fig. 1, may be assembled using a method comprising: providing
5 three column assemblies 3 each comprising a respective semi-submersible column 4; providing several braces 6 as described therein; and interconnecting the column assemblies 3 by a truss structure 5, the truss structure 5 comprising the braces 6, in particular as respective truss members, here including horizontal braces 6a and diagonal braces 6b.

10 Here, the interconnecting of the column assemblies 3 comprises connecting an end of a brace 6 to one of the column assemblies 3. Before or after connecting said end, an opposite end of the same brace 6 may be connected to a further column assembly 3, or to another one of the braces 6, or to a wind turbine receiving element 25. The wind turbine receiving
15 element 25 is preferably positioned between two of the column assemblies 3. The element to which a specific brace 6 is to be connected generally depends on the design of the specific brace and its place in the design of the truss structure 5, as may be understood from the example shown in Fig. 1.

Here, the connecting of the end of the brace 6 to the column
20 assembly 3 is performed by welding of rectilinear plate edges 19, 20 of the end of the brace 6 to rectilinear plate edges 19, 20 formed on the column assembly 3, wherein the rectilinear plate edges 19, 20 are formed as parts of respective connector structures 17, 18 of the brace 6 and of the column assembly 3. The aforementioned connecting of a further end of such a brace
25 6 as part of forming the truss structure 5 may or may not involve such welding of rectilinear plate edges. As explained elsewhere herein, the rectilinear plate edges are preferably horizontal plate edges 19 and vertical plate edges 20, wherein the in particular vertical plate edges 20 may be slanted to facilitate maneuvering during assembly. Alternatively,

traditional methods of connecting ends of braces to form a truss structure may be used for some ends of some braces.

As needed, the end of the brace 6, in particular the respective connector structure 17, may be cut to size prior to the connecting to the column assembly 3, wherein the cutting may effectively result in a repositioning of the respective rectilinear plate edges by cutting off the original plate edges to form new plate edges at the cut. To facilitate this, the brace 6, in particular the connector structure 17, may be initially constructed to be oversized, allowing a precise dimensioning of the brace 6 shortly before the time of forming the connection with the column assembly 3.

With particular reference to Figs. 10B and 10C, the connecting of the end of the brace 6a to the column assembly 3 here comprises maneuvering the end of the brace 6a into position at the column assembly 3 in a substantially downward direction, such a downward direction being indicated in Fig. 10B by a dashed arrow.

As alluded to elsewhere herein, to provide maneuvering space for said maneuvering, mutually weldable plate edges 20 as interfaces between the column assembly 3 and the brace 6a are here slanted. A similar configuration using slanted edges can be seen in Figs. 11A and 11B for a connection between a horizontal brace 6a to a damper box 21. Although not shown, it shall be appreciated that a similar configuration using slanted edges may be applied with respect to diagonal braces 6b.

Further in Figs. 10B and 10C, it can be seen that an end of a horizontal brace 6a is here connected to the column assembly 3 just above an end of a diagonal brace 6b that is already connected to the column assembly 3, in particular at a top of the column assembly 3. In particular, as shown, a horizontal brace 6a and a diagonal brace 6b may thus mutually abut and/or be joined at the connections with the column assembly 3, wherein at the abutment and/or joint the braces 6a, 6b may even be welded

together, in particular by welding of abutting and/or adjoining rectilinear plate edges. As shown in Figs. 10A and 10B, an intermediate connecting plate 26 may be provided that may form a common part of the two braces 6a, 6b. Such a connecting plate may for example extend mainly horizontally
5 and may form a horizontal plate edge 19 that may be common to the connector structures 17 of both braces 6a, 6b. The connecting plate 26 may for example be initially form part of the diagonal brace 6b, wherein the horizontal brace 6a may be connected to the connecting plate 26 (see Figs. 10B-C) so that the plate 26 then forms part of both braces 6a and 6b.

10 Although Figs. 10A-C show connections of a horizontal brace 6 and a diagonal brace 6b to a top end of a same column assembly 3 being close together, it shall be appreciated, e.g. in view of Fig. 1, that a connection of a horizontal brace 6a to a top end of the column assembly 3 need not always be close to a connection of a diagonal brace 6b to the same column assembly
15 3. In particular, in the example of Fig. 1, five ends of horizontal brace 6a are connected to a top end of a column assembly 3 without any diagonal brace being connected just below. Thus, in such cases, a lower one of the connector structures 18 shown in Fig. 10A may be omitted and/or a connector structure 18 similar to the design shown in Fig. 11A may be applied, e.g.
20 with a design of the brace 6a similar to the example shown in Fig. 11B, also shown in Fig. 2. Further in view of Fig. 1, it shall be appreciated that some braces 6a and/or 6b may be connected to a column assembly 3 at a position corresponding to a side rather than a vertex of a preferred polygonal transverse shape of the column 4.

25 Although the invention has been explained herein using examples of embodiments and drawings, these do not limit the scope of the invention as defined by the claims. Within said scope, many variations, combinations and extensions are possible, as will be appreciated by the skilled person having the benefit of the present disclosure. For example, compared to the
30 shown example, braces may be arranged differently in a truss structure, for

example with different numbers and/or positions of horizontal and/or diagonal braces, and some of the braces may be free from any rectangular transverse shape. Deformed plates need not necessarily be connected along the entirety of their lateral edges, for example in case a lateral edge of one

5 plate extends longitudinally beyond a lateral edge of an adjacent plate, as is for example the case in the horizontal brace 6a in Fig. 10B before that brace 6a is connected to the diagonal brace 6b in Fig. 10C. All such variants are included within the scope of the invention as defined by the appended claims.

LIST OF REFERENCE SIGNS

	1.	Floatable offshore support structure
	2.	Wind turbine
	3.	Column assembly
5	4.	Semi-submersible column
	5.	Truss structure
	6.	Brace (also: 6a, 6b)
	6a.	Horizontal brace
	6b.	Diagonal brace
10	7.	Offshore wind farm
	8.	Cylindrical tube element
	9.	Tube element providing transition between circular transverse shape and rectangular transverse shape
	10.	Elongate steel plate for tube element (also: 10d, 10f)
15	10d.	Deformed plate
	10f.	Flat plate
	11.	Lateral edge of plate
	12.	Triangular section of plate
	13.	Reinforcement structure
20	14.	Conical surface
	15.	Apex of imaginary oblique cone
	16.	Base of imaginary oblique cone
	17.	Connector structure of brace
	18.	Connector structure of column assembly
25	19.	Horizontal rectilinear plate edge of connector structure
	20.	Vertical rectilinear plate edge of connector structure
	21.	Damper box
	22.	Top plate of damper box
	23.	Bottom plate of damper box
30	24.	Side plate of damper box

	25.	Wind turbine receiving element
	26.	Connecting plate between horizontal and diagonal braces
	C.	Circumferential direction of tube element and brace
	D.	Draft line
5	L.	Longitudinal direction
	M.	Longitudinal center line of plate
	Pa.	Arcuate transverse shape of deformed plate
	Pr.	Rectilinear transverse shape of plate
	Tc.	Circular transverse shape of tube element
10	Tr.	Rectangular transverse shape of tube element
	S.	Sea level
	Xp.	Transition of transverse shape of plate
	Xt.	Transition of transverse shape of tube element
	I.	Tee joint
15	II.	Corner joint
	III.	Intermediate type joint
	IV.	Butt joint

Claims

1. Method of forming a tube element for use as a longitudinal section of a brace for a truss structure of a floatable offshore support structure for a wind turbine, comprising:
- providing four elongate flat steel plates each extending along a longitudinal direction and having two opposite lateral edges;
 - for each of the plates, deforming the plate such that, along the longitudinal direction, a transverse shape of the plate smoothly transitions between a rectilinear shape and an arcuate shape; and
 - forming the tube element by interconnecting the four deformed plates along their lateral edges,
- wherein as part of the tube element the interconnected deformed plates are mutually arranged such that each deformed plate forms a respective circumferential section of the tube element and such that, along the longitudinal direction, a transverse shape of the tube element smoothly transitions from a circular shape, namely where the transverse shapes of the deformed plates are arcuate shapes, to a rectangular shape, namely where the transverse shapes of the deformed plates are rectilinear shapes.
2. Method according to claim 1, wherein the four deformed plates each extend in the longitudinal direction beyond the end of the transition of the transverse shape of the plate at a longitudinal side of said transition where the transverse shape of the plate is a rectilinear shape,
- wherein the interconnected deformed plates are mutually arranged such that the tube element extends in the longitudinal direction beyond the end of the transition of the transverse shape of the tube element at a longitudinal side of said transition where the transverse shape of the tube element is a rectangular shape.

3. Method according to claim 2, wherein the smooth transition of the transverse shape of the tube element matches a constant or smoothly changing transverse shape of the tube element adjacent said transition at a longitudinal side of said transition where the transverse shape of the tube element is a rectangular shape, so as to provide a continuing smoothness along the longitudinal direction across the respective end of said transition, wherein the plates are deformed and mutually arranged so as to provide said matching.

4. Method according to claim 3, wherein, to provide said matching, the plates are deformed and mutually arranged such that, along the transition, the plates bulge outwardly at their interconnected lateral edges, in particular compared to imaginary straight lines interconnecting the circular shape and the rectangular shape at positions corresponding to the respective lateral edges.

5. Method according to any of the preceding claims, wherein, at the side of the transition where the transverse shape of the tube element is a rectangular shape, adjacent ones of the interconnected deformed plates extend at right angles to each other along the circumferential direction of the tube element, in particular to conform to the rectangular shape, wherein, at the side of the transition where the transverse shape of the tube element is a circular shape, adjacent ones of the interconnected deformed plates extend at straight angles to each other along the circumferential direction of the tube element, at least at the interconnected lateral edges, in particular to conform to respective local tangents of the circular shape at the interconnected lateral edges.

6. Method according to claim 5, wherein, along the transition, the angles between the plates at the interconnected lateral edges gradually monotonically change between the right angles and the straight angles.
- 5 7. Method according to any of the preceding claims, wherein longitudinal center lines of the plates remain undeformed by the deformation of the plates.
8. Method according to claim 7, wherein, for each of the plates, a
10 triangular section of the plate remains undeformed by the deformation of the plate, the triangular section being defined by a triangle base and a triangle tip,
wherein the triangle base corresponds to the rectilinear transverse shape of the plate at the side of the transition where the
15 transverse shape of the tube element is a rectangular shape,
wherein the triangle tip corresponds to an intersection of the longitudinal center line with the arcuate transverse shape of the plate at the side of the transition where the transverse shape of the tube element is a circular shape.
- 20 9. Method according to claim 8, wherein, along the transition, the triangular section is the only section of the plate that remains undeformed by the deformation of the plate prior to the interconnection of the deformed plates.
- 25 10. Method according to any of the preceding claims, wherein, when viewed in the longitudinal direction, the circular transverse shape does not extend outside the rectangular transverse shape, wherein preferably the sides of the rectangular transverse shape correspond to respective tangents
30 of the circular transverse shape.

11. Method according to any of the preceding claims, wherein interconnecting the four deformed plates along their lateral edges comprises welding adjacent ones of the lateral edges of adjacent ones of the deformed plates together, at least along the transition.

5

12. Method according to any of the preceding claims, further comprising attaching one or more reinforcement structures to the tube element at an inside of the tube element, in particular where the transverse shape of the tube element is a rectangular shape.

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13. Method according to any of the preceding claims, wherein the deforming of the plate is limited:

- such that the deformed plate as a surface is a developable or single-curved surface; and/or
- 15 - such that the deformed plate is free from any knuckles;
- so as to exclude that the deformed plate would have any radius that is smaller than ten times a local thickness of the plate; and/or
- so as to prevent the occurrence of any deformation of the plate that comprises more than 5% local elongation of the steel plate material of
- 20 the plate.

14. Method according to any of the preceding claims, wherein:

- the tube element is formed to be free from any knuckles with respect to the longitudinal direction; and/or
- 25 - deformed sections of the plate are shaped according to respective conical surfaces each defining an imaginary oblique cone having an apex that is positioned outside a longitudinal range and/or a transverse range of the transition and/or the plate, wherein preferably a base of the imaginary oblique cone corresponds to the end of the transition having the circular
- 30 transverse shape.

15. Tube element formed by the method according to any of the preceding claims, for use as a longitudinal section of a brace for a truss structure of a floatable offshore support structure for a wind turbine.

5 16. Brace for a truss structure of a floatable offshore support structure for a wind turbine, comprising a tube element, preferably according to claim 15, as a longitudinal section of the brace, wherein, along a longitudinal direction of the tube element, a transverse shape of the tube element transitions from a circular shape to a rectangular shape.

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17. Brace according to claim 16, wherein the tube element, in particular at a side of the transition where the transverse shape of the tube element is a rectangular shape, forms a connector structure of the brace for connecting the brace to a further part of the floatable offshore support
15 structure, in particular at a longitudinal end of the brace.

18. Brace according to claim 16 or 17, further comprising a cylindrical further tube element as a further longitudinal section of the brace, the cylindrical further tube element being connected to the tube element at a
20 side of the transition where the transverse shape of the tube element is a circular shape,

wherein preferably a circular transverse shape of the cylindrical further tube element matches the circular transverse shape of the tube element.

25

19. Floatable offshore support structure for a wind turbine comprising a brace according to any of claims 16 – 18, wherein the brace forms a truss member as part of a truss structure of the floatable offshore support structure, the truss structure interconnecting two, three, or more
30 column assemblies of the floatable offshore support structure, each column

assembly comprising a respective semi-submersible column, wherein the brace is connected to at least one of the column assemblies, in particular at an end of the brace.

5 20. Floatable offshore support structure according to claim 19, wherein, at the connection with the column assembly, the brace has a rectangular transverse shape, in particular formed by the tube element at a side of the transition where the transverse shape of the tube element is a rectangular shape.

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21. Floatable offshore support structure according to claim 19 or 20, wherein one or more interfaces between the column assembly and the brace are slanted, in particular to provide maneuvering space for maneuvering the end of the brace into position in a substantially downward direction, for
15 assembly of the floatable offshore support structure.

22. Floatable offshore support structure according to any of claims 19 – 21, wherein the column assembly and the brace are configured to help stabilize the brace with respect to the column assembly before and/or during
20 formation of the connection between the column assembly and the brace, in particular by allowing the brace to be at least partly supported on the column assembly.

23. Floatable offshore support structure according to any of claims 19 – 22, wherein, at the connection between the column assembly and the brace, the column has a polygonal, preferably hexagonal, transverse shape, possibly with rounded vertices, wherein the brace is connected to the column assembly at a circumferential position corresponding to a vertex of the polygonal shape of the column.

30

24. Floatable offshore support structure according to any of claims 19 - 23, comprising a damper box, in particular as part of a column assembly as mentioned in any of claims 19 – 23.

5 25. Floatable offshore support structure according to claim 24, wherein the damper box has a top plate and a bottom plate spaced apart from the top plate, wherein the top plate and the bottom plate are mutually interconnected by one or more side plates, wherein the brace is connected to the damper box at the one or more side plates, in particular without
10 overlapping either of the top plate and the bottom plate at an outside of the damper box.

26. Floatable offshore support structure according to claim 24 or 25, wherein, at the connection with the damper box, the brace has a rectangular
15 transverse shape, in particular formed by the tube element at a side of the transition where the transverse shape of the tube element is a rectangular shape.

27. Floatable offshore support structure according to claim 26 as
20 dependent from claim 25, wherein one rectilinear side of the transverse shape of the brace is aligned or at least parallel with one of the top plate and the bottom plate of the damper box, wherein preferably an opposite rectilinear side of the transverse shape of the brace is aligned or at least parallel with the other one of the top plate and the bottom plate of the
25 damper box.

28. Wind turbine provided with a floatable offshore support structure according to any of claims 17 – 27, wherein the wind turbine is supported on the floatable offshore support structure, in particular on the truss structure

and/or spaced apart from any semi-submersible column of the floatable offshore support structure.

29. Offshore wind farm comprising at least one wind turbine
5 according to claim 28.

30. Offshore wind farm according to claim 29, wherein the floatable offshore support structure floatingly supports the wind turbine.

10 31. Method of assembling a floatable offshore support structure according to any of claims 17 – 27, comprising:
- providing at least two, preferably three, column assemblies each comprising a respective semi-submersible column;
- providing at least one brace according to any of claims 14 – 16;
15 - interconnecting the at least two column assemblies by a truss structure, the truss structure comprising the at least one brace, in particular as a respective at least one truss member.

32. Method according to claim 31, wherein the interconnecting of the
20 at least two column assemblies comprises connecting an end of a brace of the at least one brace to one of the column assemblies.

33. Method according to claim 32, wherein the connecting of the end
of the brace to the column assembly comprises, and is preferably performed
25 by, welding of rectilinear plate edges of the end of the brace to rectilinear plate edges formed on the column assembly, wherein preferably the rectilinear plate edges are formed as parts of respective connector structures of the brace and the column assembly.

34. Method according to claim 32 or 33, wherein the end of the brace is cut to size prior to the connecting to the column assembly.

35. Method according to any of claims 32 – 34, wherein the connecting
5 of the end of the brace to the column assembly comprises maneuvering the end of the brace into position at the column assembly in a substantially downward direction,
wherein, to provide maneuvering space for said maneuvering, preferably mutually weldable plate edges or one or more other interfaces
10 between the column assembly and the brace are slanted.

36. Method according to any of claims 32 – 35, wherein an end of a horizontal brace is connected to the column assembly just above an end of a diagonal brace that is already connected to the column assembly.