



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
24.12.2014 Bulletin 2014/52

(51) Int Cl.:
B63B 35/44 (2006.01)

(21) Application number: **13172949.3**

(22) Date of filing: **20.06.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(54) **Topside module frame and floating hull comprising such a topside module frame**

(57) A topside module frame is provided with at least a bottom process deck and a first elevated process deck. Both process decks have a rectangular perimeter defined by two parallel longitudinal sides and two parallel lateral sides. The vertical loads from the process decks are carried by four main support columns to four module support foots. The process decks are joined to each other by four truss structures: one on each side of the perimeter. Fur-

thermore, each of the four main support columns has a battered section ending in a bottom point located on one of the lateral sides of the bottom process deck. This way, two bottom points are located on one of the lateral sides of the bottom process deck and two other bottom points are located on the other lateral side of the bottom process deck. The module support foots are located vertically below the bottom points.

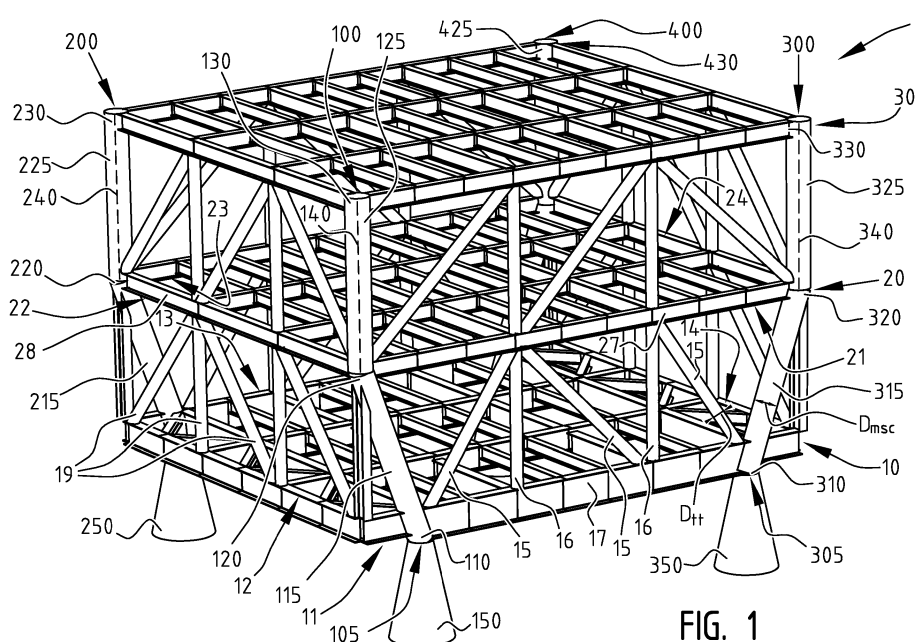


FIG. 1

Description

[0001] In a first aspect, the present invention relates to a topside module frame. In a second aspect, the present invention relates to a floating hull comprising such a topside module frame.

[0002] Topside module frames are employed in the off-shore industry, in particular on ship-shaped offshore installations for hydrocarbon processing. Such structures typically comprise a hull structure including storage tanks, and topsides processing equipment that may be arranged elevated above the main deck on topside module frames.

[0003] In an article "Analysis of hull-topside interaction by experimental approach on floating production unit P-53", which appeared in Applied Ocean Research Vol. 37, pp. 133-144 (2012) the authors Wagner Mespaque et al. describe a floating production unit with topside module frames that are supported on four stools. Figure 23 in this article shows a schematic lateral view of such a module. It comprises two process decks: a bottom process deck and an elevated process deck which is arranged above the bottom process deck. These process decks are connected to each other with a longitudinal truss structure and supported on the four stools by vertically arranged main support columns. The bottom process deck extends beyond the main support columns on both the forward and aft sides. There is no truss structure between the bottom process deck and the elevated process deck in the lateral direction (at least on the forward side) as the process equipment on the bottom process deck extends on both sides of the forward main support columns.

[0004] A drawback of this topside module frame is that it is less suitable for use in heavy metocean conditions because in case of heavy roll (rotation of the hull about its longitudinal axis) the frame strength may be insufficient as a result of the lacking lateral truss structure. Moreover, if a lateral truss structure be provided between the main support columns, the effective floor space on the bottom process deck would be severely smaller than the actual area of the bottom process deck as it would be intersected by a lateral truss structure.

[0005] In accordance with the first aspect of the present invention, there is provided a topside module frame comprising at least two process decks, which at least two process decks comprise a bottom process deck and a first elevated process deck which is arranged above the bottom process deck, wherein each of the bottom process deck and the first elevated process deck both have a rectangular perimeter comprising two parallel longitudinal sides and two parallel lateral sides. One of the longitudinal sides of the bottom process deck and one of the longitudinal sides of the first elevated process deck lie within a first vertical longitudinal side plane and the other of the longitudinal sides of the bottom process deck and the other of the longitudinal sides of the first elevated process deck lie within a second vertical longitudinal side plane, and a first one of the lateral sides of the bottom process deck and a first one of the lateral sides of the first elevated process deck both lie within a first vertical lateral side plane and the other of the lateral sides of the bottom process deck and the other of the lateral sides of the first elevated process deck both lie within a second vertical lateral side plane. The bottom process deck and the first elevated process deck are joined to each other by a first longitudinal truss structure lying within the first vertical longitudinal side plane and by a second longitudinal truss structure lying within the second vertical longitudinal side plane and by a first lateral truss structure lying within the first vertical lateral side plane and by a second lateral truss structure lying within the second vertical lateral side plane. The topside module frame further comprises four main support columns, two of which lying within the first vertical longitudinal side plane and two of which lying within the second vertical longitudinal side plane. Each of the four main support columns comprise a battered section, wherein the first battered section of a first of the main support columns starts in a first elevated point formed by an intersection of the first vertical longitudinal side plane and the first vertical lateral side plane and the first elevated process deck and ends in a first bottom point located on the first one of the longitudinal sides of the bottom process deck between the first vertical lateral side plane and the second vertical lateral side plane, and wherein the second battered section of a second of the main support columns starts in a second elevated point formed by an intersection of the second vertical longitudinal side plane and the first vertical lateral side plane and the first elevated process deck and ends in a second bottom point located on the other one of the longitudinal sides of the bottom process deck between the first vertical lateral side plane and the second vertical lateral side plane, and wherein the third battered section of a third of the main support columns starts in a third elevated point formed by an intersection of the first vertical longitudinal side plane and the second vertical lateral side plane and the first elevated process deck and ends in a third bottom point located on the first one of the longitudinal sides of the bottom process deck between the first bottom point and the second vertical lateral side plane, and wherein the fourth battered section of a fourth of the main support columns starts in a fourth elevated point formed by an intersection of the second vertical longitudinal side plane and the second vertical lateral side plane and the first elevated process deck and ends in a fourth bottom point located on the other one of the longitudinal sides of the bottom process deck between the second bottom point and the second vertical lateral side plane. The topside module frame further comprises a first module support foot located gravitationally vertically below the first bottom point, a second module support foot located gravitationally vertically below the second bottom point, a third module support foot located gravitationally vertically below the third bottom point, and a fourth module support foot located gravitationally vertically below the fourth bottom point.

[0006] In accordance with the second aspect of the invention, there is provided a floating hull having an elongate shape with a longitudinal direction and a transverse direction, said floating hull comprising a deck and a plurality of

transverse bulk heads vertically arranged inside the hull underneath the deck and parallel to the transverse direction and supporting the deck, and at least four stools comprising a first stool, a second stool, a third stool and a fourth stool, wherein each one of the first to fourth stools is mounted on the deck vertically above at least one transverse bulkhead. The floating hull further comprises a topside module frame comprising first, second, third and fourth module support

foots in accordance with the first aspect of the invention, wherein the first module support foot is located gravitationally vertically above the first stool and rests on the first stool, the second module support foot is located gravitationally vertically above the second stool and rests on the second stool, the third module support foot is located gravitationally vertically above the third stool and rests on the third stool, and the fourth module support foot is located gravitationally vertically above the fourth stool and rests on the fourth stool.

[0007] The invention will be further illustrated hereinafter by way of example only, and with reference to the nonlimiting drawing in which;

Fig. 1 schematically shows a perspective view of a topside module frame according to an embodiment of the invention;

Fig. 2 schematically shows a lateral view of a floating hull according to an embodiment of the invention;

Fig. 3 schematically shows a perspective view of two topside module frames according to the embodiment as shown in Fig. 1, in relative arrangement to each other and to transverse bulk heads of a floating hull;

Fig. 4 schematically shows a perspective view of two topside module frames according to another embodiment of the invention, in relative arrangement to each other and to transverse bulk heads of a floating hull;

Fig. 5 schematically shows a perspective view of two topside module frames according to a first comparative design not according to the invention, in relative arrangement to each other and to transverse bulk heads of a floating hull;

Fig. 6 schematically shows a perspective view of two topside module frames according to a second comparative design not according to the invention, in relative arrangement to each other and to transverse bulk heads of a floating hull; and

Fig. 7 shows a graphical representation of deck deflection (on horizontal axis) versus vertical load (on vertical axis) for the embodiments of Figs. 4, 5, and 6 size to provide similar collapse strengths.

[0008] For the purpose of this description, a single reference number will be assigned to a line as well as a stream carried in that line. Same reference numbers refer to similar components. The person skilled in the art will readily understand that, while the invention is illustrated making reference to one or more a specific combinations of features and measures, many of those features and measures are functionally independent from other features and measures such that they can be equally or similarly applied independently in other embodiments or combinations.

[0009] The topside module frame proposed herein comprises at least two process decks: a bottom process deck and a first elevated process deck. The first elevated process deck is arranged above the bottom process deck. Both process decks have a rectangular perimeter comprising two parallel longitudinal sides and two parallel lateral sides. The vertical loads from the process decks are transferred to, and carried by, four main support columns to four module support

foots. **[0010]** The entire module frame may be positioned on the main deck of a floating hull structure, typically on four stools, whereby each of the module support foots rests on one stool that is located gravitationally vertically below the module support foot that rests on it.

[0011] The bottom process deck and the first elevated process deck are joined to each other by four truss structures:

- a first longitudinal truss structure that lies within a first vertical longitudinal side plane, together with one of the longitudinal sides of the bottom process deck and one of the longitudinal sides of the first elevated process deck;
- a second longitudinal truss structure that lies within a second vertical longitudinal side plane, together with the other the two longitudinal sides of the bottom process deck and the other one of the tow longitudinal sides of the first elevated process deck;
- a first lateral truss structure that lies within a first vertical lateral side plane together with one of the lateral sides of the bottom process deck and one of the lateral sides of the first elevated process deck; and
- a second lateral truss structure lying within a second vertical lateral side plane together with the other of the two lateral sides of the bottom process deck and the other of the two lateral sides of the first elevated process deck.

[0012] The lateral truss structures in addition to longitudinal truss structures enhance the lateral strength of the topside module frame which extends the amount of roll that can be tolerated when the topside module frame is used on a floating hull structure. As all the truss structures (both the longitudinal and the lateral truss structures) are arranged in side planes, the useable area on each process deck, notably of the bottom process deck, is maximized.

[0013] Furthermore, each of the four main support columns comprises a battered section. Each of the battered sections starts in an elevated point formed by an intersection of one of the vertical longitudinal side planes, one of the vertical lateral side planes and the first elevated process deck, and ends in a bottom point located on one of the longitudinal sides of the bottom process deck between the first and second vertical lateral side planes. This way, two bottom points

are located on one of the longitudinal sides of the bottom process deck and two other bottom points are located on the other longitudinal side of the bottom process deck. The module support feet are located gravitationally vertically below the bottom points.

[0014] Herewith it is achieved that both the longitudinal trusses and the lateral trusses can directly transfer load to the battered sections of the main support columns (via the elevated points). This is because each of the elevated points lies within one of the vertical longitudinal side planes and one of the vertical lateral side planes. At the same time, the module support feet are located within the boundaries of the vertical lateral side planes. This allows for two topside module frames to be positioned longitudinally side by side on normal stools (i.e. one lateral side plane of one module facing one lateral side plane of the neighboring module) in as close proximity from each other as desired, whereby no special adaption of e.g. the stools is necessary as the stools of the adjacent neighboring modules do not have to be in the same proximity from each other as the lateral side planes.

[0015] Thus, the combination of the lateral truss structures in the lateral side planes and the battered sections of the main support columns provides topside module frames with enhanced lateral strength without suffering from additional constraints in useable process deck space and constraints in inter-modular spacing in the longitudinal direction. In other words, the proposed solution offers topside module frames with improved lateral strength while maintaining maximum availability of process deck space and imposing no additional inter-module spacing between neighboring module frames in the longitudinal direction.

[0016] Figure 1 shows a perspective view of one embodiment of the topside module frame 1 as proposed herein. A bottom process deck 10 is horizontally arranged, and a first elevated process deck 20 is horizontally arranged above the bottom process deck 10. In the embodiment as shown, a second elevated process deck 30 is provided, which is a useful option but not a requirement of the invention. The bottom process deck 10 and the first elevated process deck 20 each have a rectangular perimeter.

[0017] The rectangular perimeter of the bottom process deck 10 is formed by a first longitudinal side 11 and a second longitudinal side 13 that is parallel to the first longitudinal side 11. These longitudinal sides are connected to each other by a first lateral side 12 and a second lateral side 14. Likewise, the rectangular perimeter of the first elevated process deck 20 is formed by a first elevated longitudinal side 21 and a second elevated longitudinal side 23 that is parallel to the first elevated longitudinal side 21. These elevated longitudinal sides are connected to each other by a first elevated lateral side 22 and a second elevated lateral side 24. One of the longitudinal sides of the bottom process deck 10, for instance the first longitudinal side 11, and one of the longitudinal sides of the first elevated process deck 20, in this case the first elevated longitudinal side 21, lie within a first vertical longitudinal side plane. The other of the longitudinal sides of the bottom process deck 10, in this case the second longitudinal side 13, and the other of the longitudinal sides of the first elevated process deck 20, hence the second elevated longitudinal side 23, lie within a second vertical longitudinal side plane. Likewise, a first one of the lateral sides of the bottom process deck 10, for instance the first lateral side 12, and a first one of the lateral sides of the first elevated process deck 20, in this case the first elevated lateral side 22, both lie within a first vertical lateral side plane. The other of the lateral sides of the bottom process deck 10, here represented by the second lateral side 14, and the other of the lateral sides of the first elevated process deck 20, here represented by the second elevated lateral side 24, both lie within a second vertical lateral side plane.

[0018] The bottom process deck 10 may comprise multiple longitudinal beams and multiple lateral beams and optionally angled beams. Amongst the multiple longitudinal beams is at least a first bottom beam 17, which defines said first longitudinal side 11 of the bottom process deck 10, and a third bottom beam, which defines said second longitudinal side 13 of the bottom process deck 10. Amongst the multiple lateral beams is at least a second bottom beam 28, which defines the first lateral side 12 of the bottom process deck 10, and a fourth bottom beam, which defines said second lateral side 14 of the bottom process deck 10. Likewise, the first and optional second elevated process decks 20, 30, may comprise multiple longitudinal beams and multiple lateral beams and optionally angled beams. Amongst the multiple longitudinal beams of the first elevated process deck 20 is at least a first elevated beam 27 that defines said first elevated longitudinal side 21 of the first elevated process deck 20, and a third elevated beam that defines said second elevated longitudinal side 23 of the first elevated process deck 20. Amongst the multiple lateral beams of the first elevated process deck 20 is at least a third elevated beam 28 that defines said first elevated lateral side 22 of the first elevated process deck 20, and a fourth elevated beam that defines said second elevated lateral side 24 of the first elevated process deck 20.

[0019] The bottom process deck 10 and the first elevated process deck 20 are joined to each other by a first longitudinal truss structure, lying within the first vertical longitudinal side plane, and by a second longitudinal truss structure lying within the second vertical longitudinal side plane, and by a first lateral truss structure lying within the first vertical lateral side plane, and by a second lateral truss structure lying within the second vertical lateral side plane.

[0020] The first longitudinal truss structure may comprise:

- the first bottom beam 17;
- the first elevated beam 27;
- a plurality of first compression members 15; and

- a plurality of first tension members 16.

[0021] The first compression members 15 extend from the first bottom beam 17 to the first elevated beam 27 and are connected to the first bottom beam 17 and the first elevated beam 27. The first tension members 16 also extend from the first bottom beam 17 and the first elevated beam 27 and are connected to the first bottom beam 17 and the first elevated beam 27.

[0022] Similarly, the first lateral truss structure comprises compression and tension members 19 between the second bottom beam 18 and the second elevated beam 28, and the second longitudinal and second lateral truss structures also comprise similar compression and tension members. Additional truss structures, according to similar designs, may similarly be provided to join the first elevated process deck 20 with the second elevated process deck 30.

[0023] In addition, the topside module frame further comprises four main support columns: a first main support column 100, a second main support column 200, a third main support column 300, and a fourth main support column 400. The first main support column 100 and the third main support column 300 both lie within the first vertical longitudinal side plane defined by the first longitudinal side 11 and the first elevated longitudinal side 21. The second main support column 200 and the fourth main support column 400 both lie within the second vertical longitudinal side plane, as defined by the second longitudinal side 13 and the second elevated longitudinal side 23.

[0024] Each of the four main support columns comprise a battered section. The first main support column 100 has a first battered section 115; the second main support column 200 has a second battered section 215; the third main support column 300 has a third battered section 315; and the fourth main support column 400 has a fourth battered section (not visible in Figure 1). The first battered section 115 starts in a first elevated point 120 that is formed by an intersection of the first vertical longitudinal side plane and the first vertical lateral side plane and the first elevated process deck 20. The first battered section 115 ends in a first bottom point 110 located on the first longitudinal side 11 of the bottom process deck 10, between the first vertical lateral side plane and the second vertical lateral side plane. The second battered section 215 starts in a second elevated point 220, formed by an intersection of the second vertical longitudinal side plane and the first vertical lateral side plane and the first elevated process deck 20. The second battered section 215 ends in a second bottom point located on the second longitudinal side 13 of the bottom process deck 10, between the first vertical lateral side plane and the second vertical lateral side plane. The third battered section 315 starts in a third elevated point 320 formed by an intersection of the first vertical longitudinal side plane and the second vertical lateral side plane and the first elevated process deck 20, and ends in a third bottom point 310 that is located on the first longitudinal side of the bottom process deck 10 between the first bottom point 110 and the second vertical lateral side plane. Finally, the fourth battered section (not visible in Figure 1), of the fourth main support column 400, starts in a fourth elevated point formed by an intersection of the second vertical longitudinal side plane and the second vertical lateral side plane and the first elevated process deck and ends in a fourth bottom point located on the second longitudinal side 13 of the bottom process deck 10, between the second bottom point and the second vertical lateral side plane.

[0025] The topside module frame 1 further comprises a first module support foot 105 located gravitationally vertically below the first bottom point 110, a second module support foot located gravitationally vertically below the second bottom point, a third module support foot 305 located gravitationally vertically below the third bottom point 310, and a fourth module support foot located gravitationally vertically below the fourth bottom point.

[0026] The optional second elevated process deck 30 is arranged vertically displaced from the first elevated process deck 20, and above the bottom process deck 10. The second elevated process deck 30 preferably also has a rectangular perimeter having four corner points, of which a first corner point 130 lies in a first vertical line 140 that is formed by an intersection of the first vertical longitudinal side plane and the first vertical lateral side plane. A second corner point 230 of said four corner points lies in a second vertical line 240 formed by an intersection of the second vertical longitudinal side plane and the first vertical lateral side plane. A third corner point 330 of said four corner points lies in a third vertical line 340 formed by an intersection of the first vertical longitudinal side plane and the second vertical lateral side plane, while and a fourth corner point 440 of said four corner points lies in a fourth vertical line formed by an intersection of the second vertical longitudinal side plane and the second vertical lateral side plane.

[0027] The optional second elevated process deck 30 may be arranged below or above the first elevated process deck 20. In the embodiment of Figure 1, it is shown above the first elevated process deck 20. The second elevated process deck 30 and the first elevated process deck 20 are joined to each other by a third longitudinal truss structure 25, which lies within the first vertical longitudinal side plane; and by a fourth longitudinal truss structure that lies within the second vertical longitudinal side plane. The second elevated process deck 30 and the first elevated process deck 20 are also joined to each other by a third lateral truss structure 26, which lies within the first vertical lateral side plane, and by a fourth lateral truss structure lying within the second vertical lateral side plane. In such embodiments, the first main support column 100 may have a first vertical section 125 that is joined to the first battered section 115 in the first elevated point 120.

[0028] The first vertical section 125 extends vertically to the first corner point 130, along the first vertical line 140. Likewise, the second main support column may have a second vertical section 225, joined to the second battered section

215 in the second elevated point 220 and extending vertically to the second corner point 230. The third main support column may have a third vertical section 325 that is joined to the third battered section 315 in the third elevated point 320 and that extends vertically to the third corner point 330. Finally, the fourth main support column 400 may have a fourth vertical section 425 joined to the fourth battered section in the fourth elevated point, and extending vertically to the fourth corner point 430.

[0029] In use, the topside module frame 1 may be positioned on four stools. When this is the case, the first module support foot 105 rests on a first stool 150 that is located gravitationally vertically below the first module support foot 105. Similarly, the second module support foot 205 rests on a second stool 250, located gravitationally vertically below the second module support foot 105; the third module support foot 305 rests on a third stool 350 located gravitationally vertically below the third module support foot 305; and the fourth module support foot (not visible in Figure 1) rests on a fourth stool (not visible in Figure 1) located gravitationally vertically below the fourth module support foot. The stools may be fixed stools and/or sliding stools as known in the art, and usually a mix of fixed and sliding stools is recommended to support each topside module frame.

[0030] The stools have been indicated very schematically in the figures as the details of their construction do not form part of the present invention. For a more detailed explanation of known stool designs, both of fixed and sliding stools, reference is made to the article "Analysis of hull-topside interaction by experimental approach on floating production unit P-53", by Wagner Mespaque et al., Applied Ocean Research Vol. 37, pp. 133-144 (2012).

[0031] The topside module frame described herein may be used on floating hydrocarbon fluid processing units, particularly on ship-shaped floating hulls. A floating hydrocarbon fluid processing unit is a hydrocarbon processing plant on floating hull, which plant receives a hydrocarbon fluid such as oil and/or natural gas in a starting condition, processes the hydrocarbon fluid whereby changing the hydrocarbon fluid into one or more hydrocarbon products, and discharges the one or more hydrocarbon products. Example of a floating hydrocarbon fluid processing unit include a so-called floating production, storage, and offloading unit (FPSO); a floating liquefied natural gas unit (FLNG) on which a natural gas is cryogenically cooled and liquefied; and a floating regasification unit (FRU) or a floating storage and regasification unit (FSRU). Such regasification units can be used to re-vaporize liquefied natural gas by adding heat to it, thereby changing the condition from liquid to a vapour. An example is described in US pre-grant patent application publication No. 2006/0156744.

[0032] Figure 2 schematically illustrates how the topside module frames may be applied on a floating hull, such as the floating hull of a floating hydrocarbon fluid processing unit. A floating hull 500 is shown in lateral side view. It generally may have an elongate shape with a longitudinal direction indicated by arrow 510, and a transverse direction perpendicular to the arrow 510 and in the lateral view direction. The floating hull 500 typically comprises a main deck 520, and a plurality of transverse bulk heads 530. Each of the transverse bulk heads 530 is vertically arranged inside the hull 500, underneath the main deck 520 and parallel to the transverse direction. The transverse bulk heads 530 mechanically support the main deck 520.

[0033] Stools (visible are the first stool 150 and the third stool 350) are each mounted on the main deck 520, vertically above at least one transverse bulkhead 530. Each topside module frame 1 rests on at least four of such stools. Preferably, each one of the first to fourth stools is mounted vertically above exclusively two transverse bulkheads 530. One or more pieces of process equipment 550 can be mounted on at least one of the process decks of the topside module frames 1. Preferably such process equipment 550 is mounted on at least the bottom process deck 10. The process equipment can be used in all kinds of methods of processing a hydrocarbon fluid containing process stream.

[0034] Figure 3 schematically shows an enlarged perspective view of two topside module frames 1, 1a according to the embodiment as shown in Fig. 1, and in relative arrangement to each other and to the transverse bulk heads 530 of the floating hull 500 as described above with reference to Fig. 2. Each of the first to fourth stools are mounted on the deck of the floating hull, but the deck has been omitted from the drawing in Figure 3 to show the relation between the topside module frames 1 and the transverse bulk heads 530. The transverse bulk heads 530 are vertically arranged inside the hull underneath the deck and parallel to the transverse direction. Each one of the first to fourth stools is mounted vertically above at least one transverse bulkhead. In the embodiment as shown, each one of the first to fourth stools is mounted vertically above exactly two transverse bulkheads. The same two bulk heads above which the first stool 150 is mounted both extend also underneath the second stool 250. Likewise, the same two bulk heads above which the third stool 350 is mounted both extend underneath the fourth stool (not visible in Figure 3).

[0035] A similar but different embodiment is schematically shown in Figure 4. The difference is that the battered sections of the main support columns have a smaller batter angle (angle with respect to the vertical direction). Comparing the embodiments of Figures 3 and 4, and assuming equal topside module frame longitudinal dimension and equal interspacing between adjacent neighboring transverse bulk heads, there are four transverse bulk heads between the first stool 150 and third stool 350 in the embodiment of Figure 3 while there are six in the embodiment of Figure 4.

[0036] Figure 5 shows a first comparative design, wherein the main support columns 100-400 are vertically arranged from the four corner points, i.e. in the four intersections of the vertical lateral side planes and the vertical longitudinal side planes, with no battered sections. This comparative design has the same useable process deck space as the

embodiments of Figs. 1, 3, and 4, but when two topside module frames 1,1a are placed longitudinally adjacent to each other on a floating hull, observing the same inter-modular longitudinal spacing of the vertical lateral side planes, a combined stool 50 is needed. Such combined stool is different from standard stools and thus less preferred. Alternatively, when standard stools are maintained the consequence would be that fewer topside module frames can be positioned in a selected longitudinal distance as a larger longitudinal inter-modular spacing would be required compared to the embodiments of Figs. 1, 3, 5.

[0037] Figure 6 shows a second comparative design, which has in common with the first comparative design that the main support columns 100-400 are vertically arranged but in this case the main support columns together with the lateral trusses in between the main support columns, are arranged between the two vertical lateral side planes. Thus, the process deck space on the bottom process deck in the longitudinal direction extends beyond the lateral trusses as indicated by a in Fig. 6. This way, the topside module frame does not benefit from the battered sections, but successive topside module frames can still be positioned next to each other in longitudinal alignment with the same inter-modular spacing as in the embodiments with battered sections as shown in Figs. 1, 2, 4 without the need for special, combined, stools. However, in this second comparative embodiment, the useable process deck space is smaller in the longitudinal direction if there are lateral truss structures between the main support columns 100 and 200 (respectively 300 and 400), or such lateral truss structures between the main support columns must be omitted in order to achieve the same useable process deck area.

[0038] Furthermore, while the second main support column 200 and fourth main support column 400 of the four main support columns are disposed within the second vertical longitudinal side plane, the first main support column 100 and the third main support column 300 are in a plane between the first and second vertical longitudinal side planes, retracted by an amount b from the first vertical longitudinal side plane as indicated in Fig. 6. This further reduces the useable process deck space.

[0039] Table 1 provides a comparative overview of the various designs described above in terms of useable process deck area (particularly on the bottom process deck), both in absolute units m^2 and relative to the useable area of the comparative design as shown in Fig. 6, and in terms of relative steel weight necessary to achieve approximately the same collapse strength as the embodiment of Fig. 6. A typical interspacing of 4 m between successive neighbouring transverse bulk heads 530 has been assumed. The length of each topside module frame was assumed to be 32 m and the width 27 m. An inter-modular longitudinal spacing between the first and second vertical lateral side planes of two adjacent neighbouring topside module frames of 4 m (indicated at c in Fig. 6) has been assumed for each of the cases.

[0040] In the comparative design of Fig. 6, the first and second main support columns and the third and fourth main support columns are retracted by 4 m from the first, respectively second, vertical lateral side plane (i.e. $a = 4$ m). The first and third main support columns are retracted by 3 m from the first vertical longitudinal side plane (i.e. $b = 3$ m). This leaves a useable process deck area of $24 \times 24 m^2$.

Table 1

Embodiment as represented in:	Invention	Useable deck area (m^2)	Useable deck area relative to Fig. 6	Steel weight relative to Fig. 6.
Fig. 3	Yes	864	1.50	1.27
Fig. 4	Yes	864	1.50	1.23
Fig. 5	No	864	1.50	1.22
Fig. 6	No	576	1.00	1.00

[0041] It can be concluded that 50 % more useable process deck area can be obtained compared to the comparative design of Fig. 6, whereas only 23 % to 27 % more steel is required. Compared to the comparative design of Fig. 5, which has the same useable process deck area as the embodiments according to the invention, only between about 0.5 % and about 4.0 % more steel is needed to achieve approximately the same collapse strength as the comparative design of Fig. 5.

[0042] The corresponding collapse behaviour of the designs as shown in Figs. 4, 5, 6 is graphically represented in Figure 7. In the graphical representation, deck deflection is plotted on the horizontal axis (normalized) versus vertical load on the vertical axis (normalized to collapse load). Lines 74 and 75 show that the designs of Figs. 4 respectively 5 are more elastic than the design of Fig. 6, which is represented by line 76. This is attributable to the fact that the span between the vertical sections of the main support columns is larger than in the comparative design of Fig. 6 (32 m instead of 24 m). The yield load, which is the load where the deflection as function of load starts to become nonlinear, is approximately the same for each of the embodiments (approximately 75% of the collapse load).

[0043] In any of the embodiments and/or designs described herein, the topside module frames may be made out of

conventional materials, notably steel, and welded together in any suitable conventional way.

[0044] Each of the first to the fourth of the main support columns may be made of one or more main support tubes, each having an outer cross sectional diameter D_{msc} that is larger than a selected size D . The compression members 15 are made out of truss tubes each having an outer cross sectional diameter D_{tt} that is smaller than said selected size D .

[0045] The person skilled in the art will understand that invention and the specific embodiments disclosed herein may be applied in a wide variety of situations, particularly off-shore on ship-shaped structures. Examples include floating oil and/or gas processing facilities, including floating production storage and offloading (FPSO) structures, floating liquefied natural gas plants (FLNG) plants (which may or may connect directly to sub-sea wells or which may be fed from other facilities), floating storage and regas units (FSRU) which comprise LNG storage and regasification equipment.

[0046] The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the appended claims.

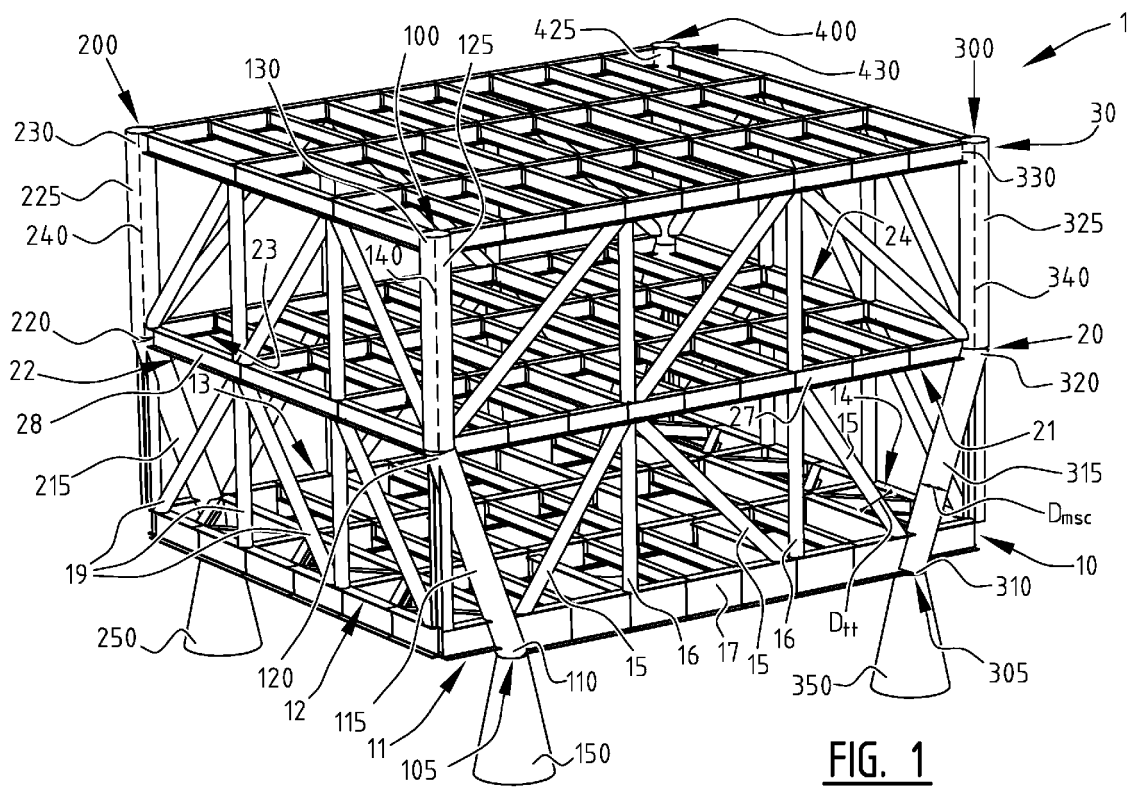
Claims

1. A topside module frame comprising at least two process decks, which at least two process decks comprise a bottom process deck and a first elevated process deck which is arranged above the bottom process deck, wherein each of the bottom process deck and the first elevated process deck both have a rectangular perimeter comprising two parallel longitudinal sides and two parallel lateral sides, wherein one of the longitudinal sides of the bottom process deck and one of the longitudinal sides of the first elevated process deck lie within a first vertical longitudinal side plane and the other of the longitudinal sides of the bottom process deck and the other of the longitudinal sides of the first elevated process deck lie within a second vertical longitudinal side plane, and wherein a first one of the lateral sides of the bottom process deck and a first one of the lateral sides of the first elevated process deck both lie within a first vertical lateral side plane and the other of the lateral sides of the bottom process deck and the other of the lateral sides of the first elevated process deck both lie within a second vertical lateral side plane, and wherein the bottom process deck and the first elevated process deck are joined to each other by a first longitudinal truss structure lying within the first vertical longitudinal side plane and by a second longitudinal truss structure lying within the second vertical longitudinal side plane and by a first lateral truss structure lying within the first vertical lateral side plane and by a second lateral truss structure lying within the second vertical lateral side plane, wherein the topside module frame further comprises four main support columns, two of which lying within the first vertical longitudinal side plane and two of which lying within the second vertical longitudinal side plane, wherein each of the four main support columns comprise a battered section, wherein the first battered section of a first of the main support columns starts in a first elevated point formed by an intersection of the first vertical longitudinal side plane and the first vertical lateral side plane and the first elevated process deck and ends in a first bottom point located on the first one of the longitudinal sides of the bottom process deck between the first vertical lateral side plane and the second vertical lateral side plane, and wherein the second battered section of a second of the main support columns starts in a second elevated point formed by an intersection of the second vertical longitudinal side plane and the first vertical lateral side plane and the first elevated process deck and ends in a second bottom point located on the other one of the longitudinal sides of the bottom process deck between the first vertical lateral side plane and the second vertical lateral side plane, and wherein the third battered section of a third of the main support columns starts in a third elevated point formed by an intersection of the first vertical longitudinal side plane and the second vertical lateral side plane and the first elevated process deck and ends in a third bottom point located on the first one of the longitudinal sides of the bottom process deck between the first bottom point and the second vertical lateral side plane, and wherein the fourth battered section of a fourth of the main support columns starts in a fourth elevated point formed by an intersection of the second vertical longitudinal side plane and the second vertical lateral side plane and the first elevated process deck and ends in a fourth bottom point located on the other one of the longitudinal sides of the bottom process deck between the second bottom point and the second vertical lateral side plane, and wherein the topside module frame further comprises a first module support foot located gravitationally vertically below the first bottom point, a second module support foot located gravitationally vertically below the second bottom point, a third module support foot located gravitationally vertically below the third bottom point, and a fourth module support foot located gravitationally vertically below the fourth bottom point.
2. The topside module frame according to claim 1, further comprising a second elevated process deck which is arranged vertically displaced from the first elevated process deck and above the bottom process deck, which second elevated process deck has a rectangular perimeter having four corner points, of which a first of said corner points lies in a first vertical line formed by an intersection of the first vertical longitudinal side plane and the first vertical lateral side plane, a second of said corner points lies in a second vertical line formed by an intersection of the second vertical

longitudinal side plane and the first vertical lateral side plane, a third of said corner points lies in a third vertical line formed by an intersection of the first vertical longitudinal side plane and the second vertical lateral side plane, and a fourth of said corner points lies in a fourth vertical line formed by an intersection of the second vertical longitudinal side plane and the second vertical lateral side plane.

- 5 3. The topside module frame according to claim 2, wherein the second elevated process deck is arranged above the first elevated process deck, and wherein the second elevated process deck and the first elevated process deck are joined to each other by a third longitudinal truss structure lying within the first vertical longitudinal side plane and by a fourth longitudinal truss structure lying within the second vertical longitudinal side plane and by a third lateral truss structure lying within the first vertical lateral side plane and by a fourth lateral truss structure lying within the second vertical lateral side plane, and wherein the first of the main support columns has a first vertical section joined to the first battered section in the first elevated point and extends vertically to the first corner point and wherein the second of the main support columns has a second vertical section joined to the second battered section in the second elevated point and extends vertically to the second corner point, and wherein the third of the main support columns has a third vertical section joined to the third battered section in the third elevated point and extends vertically to the third corner point, and wherein the fourth of the main support columns has a fourth vertical section joined to the fourth battered section in the fourth elevated point and extends vertically to the fourth corner point.
- 10 4. The topside module frame according to any one of the preceding claims, wherein each of the first to the fourth of the main support columns are made of one or more main support tubes each having an outer cross sectional diameter larger than a selected size D, and wherein the first longitudinal truss structure comprises a first bottom beam that forms said one of the longitudinal sides of the bottom process deck and a first elevated beam that forms said one of the longitudinal sides of the first elevated process deck, a plurality of first tension members extending between the first bottom beam and the first elevated beam and connected to the first bottom beam and the first elevated beam, and a plurality of first compression members extending between the first bottom beam and the first elevated beam and connected to the first bottom beam and the first elevated beam, which first compression members are made out of truss tubes each having an outer cross sectional diameter smaller than said selected size D.
- 20 5. The topside module frame according to claim 4, wherein the first lateral truss structure comprises a second bottom beam that forms one of the lateral sides of the bottom process deck and a second elevated beam that forms one of the lateral sides of the first elevated process deck, a plurality of second tension members extending between the second bottom beam and the second elevated beam and connected to the second bottom beam and the second elevated beam, and a plurality of second compression members extending between the second bottom beam and the second elevated beam and connected to the second bottom beam and the second elevated beam, which second compression members are made out of truss tubes each having an outer cross sectional diameter smaller than said selected size D.
- 30 6. The topside module frame according to any one of the preceding claims, wherein the first module support foot rests on a first stool located gravitationally vertically below the first module support foot, the second module support foot rests on a second stool located gravitationally vertically below the second module support foot, the third module support foot rests on a third stool located gravitationally vertically below the third module support foot, and the fourth module support foot rests on a fourth stool located gravitationally vertically below the fourth module support foot, wherein each of the first to fourth stools are mounted on a deck of a floating hull, said floating hull having an elongate shape with a longitudinal direction and a transverse direction, said floating hull comprising a plurality of transverse bulk heads vertically arranged inside the hull underneath the deck and parallel to the transverse direction and supporting the deck, wherein each one of the first to fourth stools is mounted vertically above at least one transverse bulkhead.
- 45 7. The topside module frame according to claim 6, wherein each one of the first to fourth stools is mounted vertically above exclusively two transverse bulkheads.
- 50 8. The topside module frame according to claim 6 or 7, wherein at least one of the transverse bulkheads, preferably two of the transverse bulkheads, extends underneath both of the first and second stools.
- 55 9. The topside module frame according to any one of the preceding claims, further comprising one or more pieces of process equipment mounted on at least one of the process decks, preferably on at least the bottom process deck, for use in a method of processing of a hydrocarbon containing process stream.

10. Floating hull having an elongate shape with a longitudinal direction and a transverse direction, said floating hull comprising a deck and a plurality of transverse bulk heads vertically arranged inside the hull underneath the deck and parallel to the transverse direction and supporting the deck, and at least four stools comprising a first stool, a second stool, a third stool and a fourth stool, wherein each one of the first to fourth stools is mounted on the deck vertically above at least one transverse bulkhead, the floating hull further comprising a topside module frame comprising first, second, third and fourth module support feet as described in any one of claims 1 to 5, wherein the first module support foot is located gravitationally vertically above the first stool and rests on the first stool, the second module support foot is located gravitationally vertically above the second stool and rests on the second stool, the third module support foot is located gravitationally vertically above the third stool and rests on the third stool, and the fourth module support foot is located gravitationally vertically above the fourth stool and rests on the fourth stool.
11. The floating hull according to claim 10, wherein each one of the first to fourth stools is mounted vertically above exclusively two transverse bulkheads.
12. The floating hull according to claim 10 or 11, wherein at least one of the transverse bulkheads, preferably two of the transverse bulkheads, extends underneath both of the first and second stools.
13. The floating hull according to any one of the claims 10 to 12, further comprising one or more pieces of process equipment mounted on at least one of the process decks, preferably on at least the bottom process deck, for use in a method of processing of a hydrocarbon containing process stream.



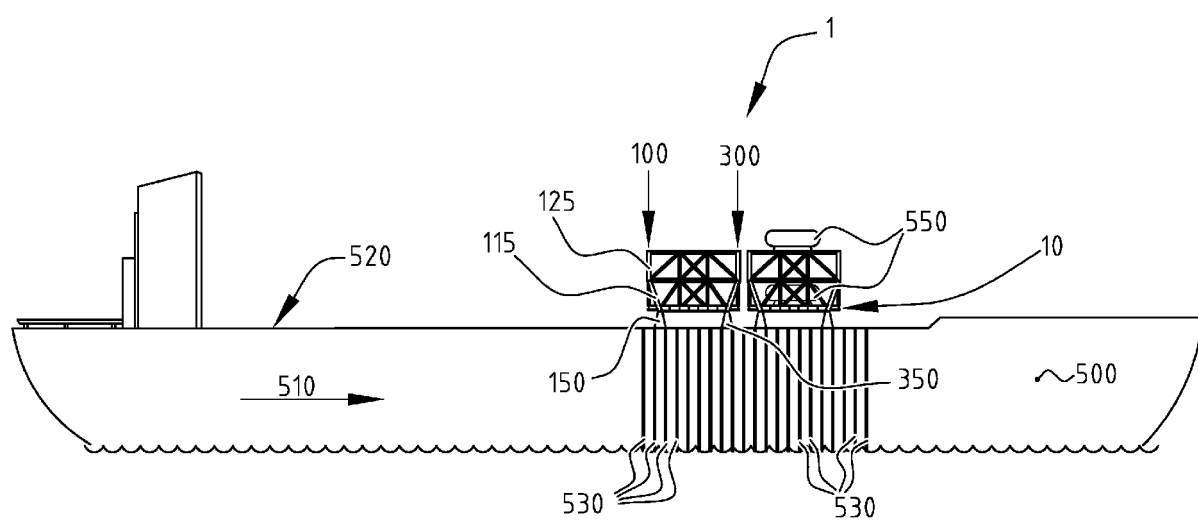
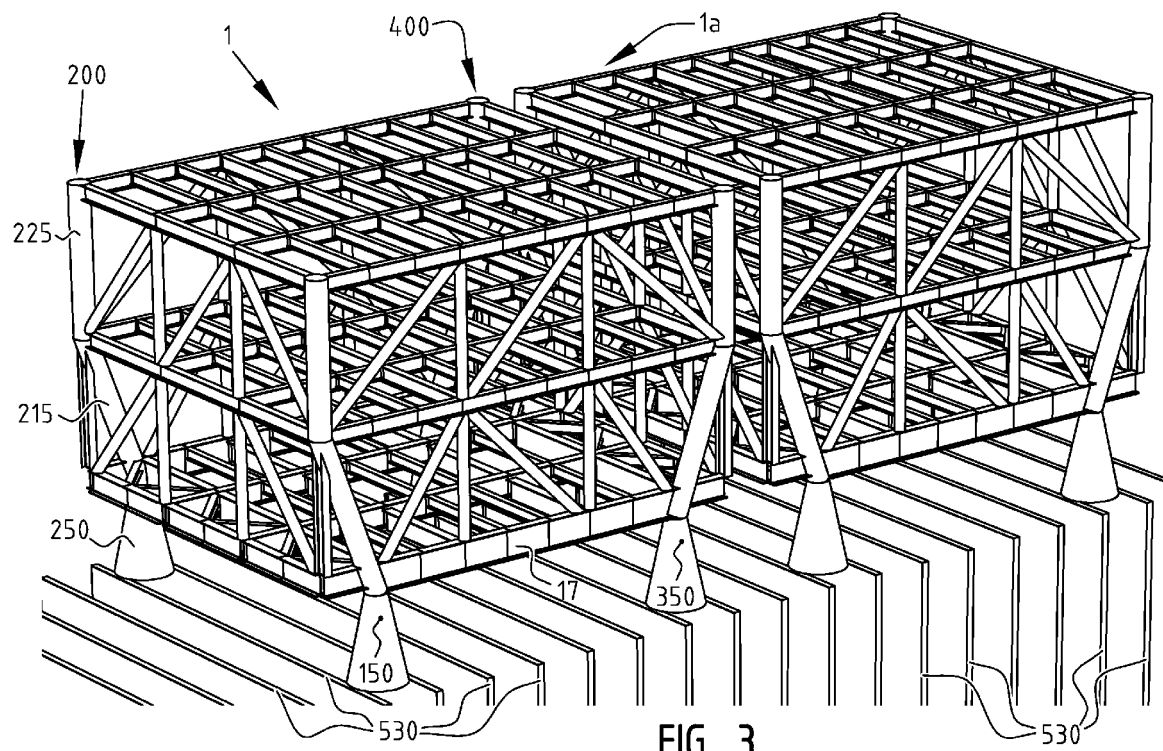


FIG. 2



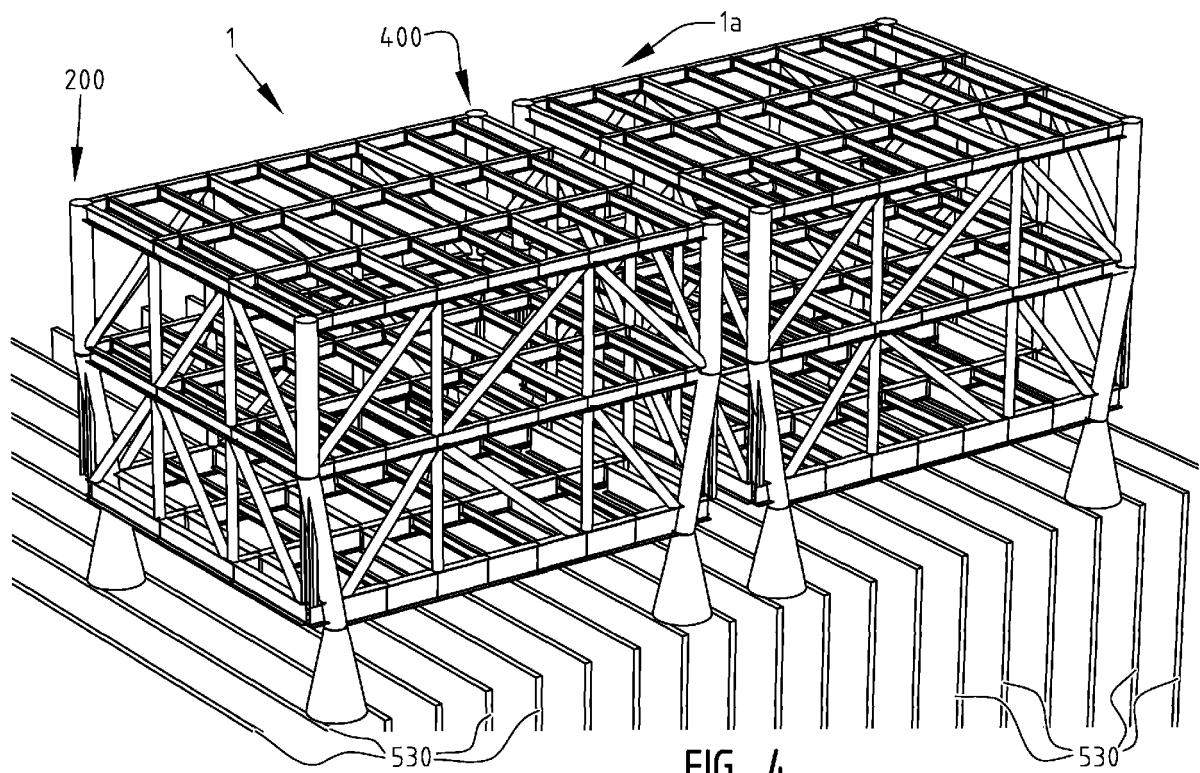


FIG. 4

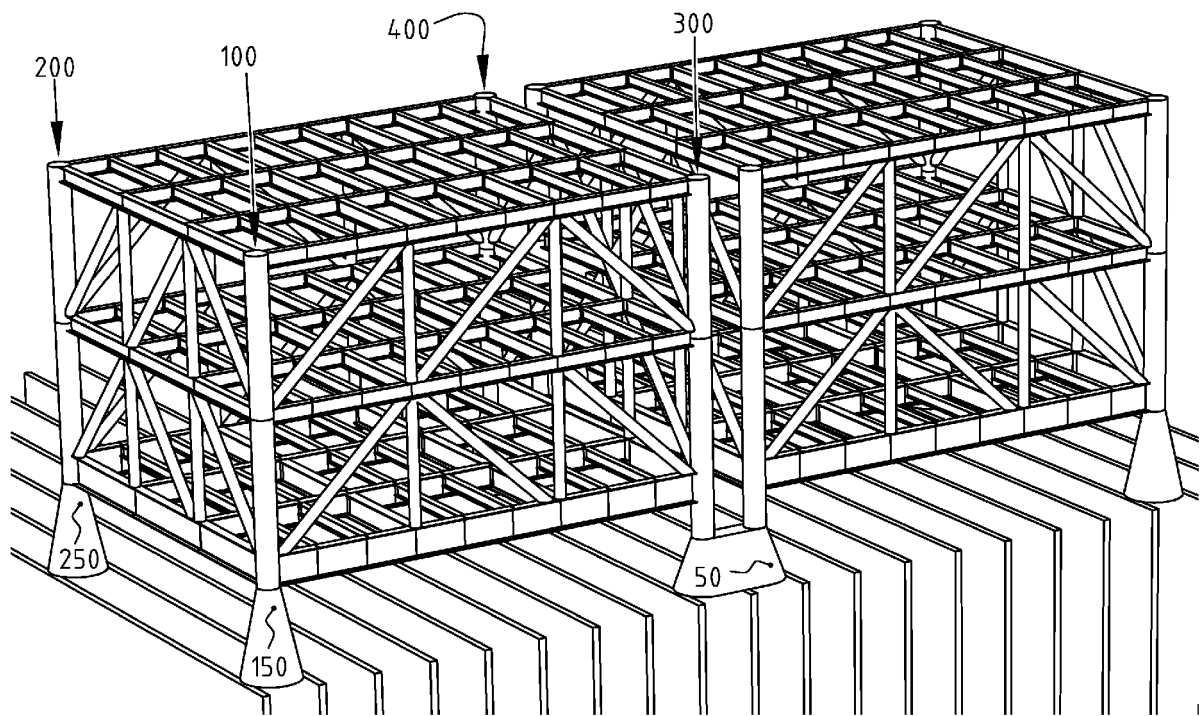


FIG. 5

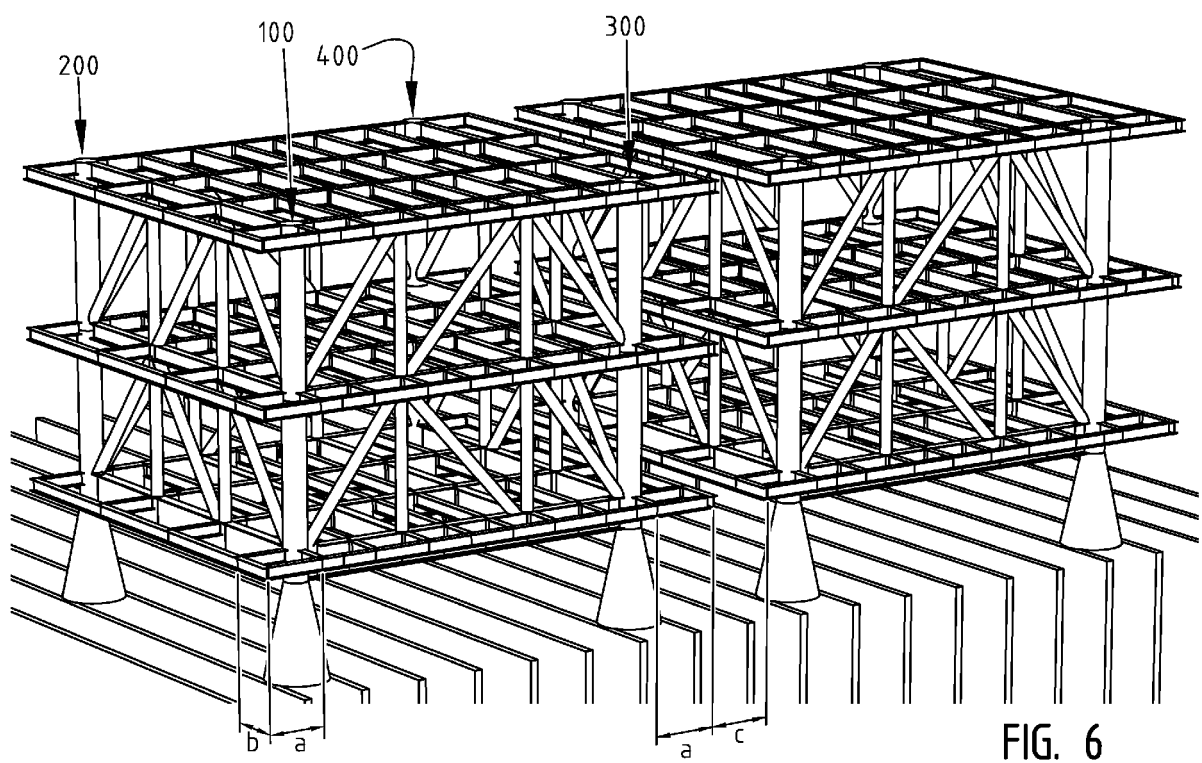


FIG. 6

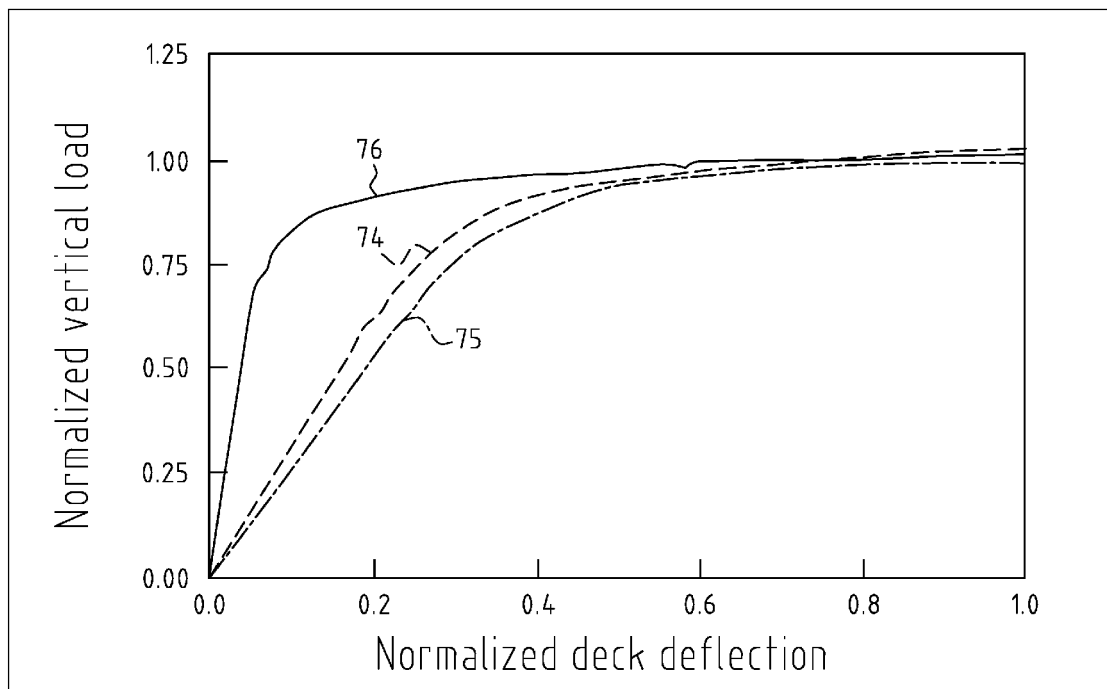


FIG. 7



EUROPEAN SEARCH REPORT

 Application Number
 EP 13 17 2949

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2013/036915 A2 (HORTON WISON DEEPWATER INC [US]; MAHER IV JAMES V [US]; FINN LYLE DAVI) 14 March 2013 (2013-03-14) * paragraphs [0026] - [0032]; figures 1, 2 *	1,10	INV. B63B35/44
A	US 2012/093587 A1 (FINN LYLE DAVID [US] ET AL) 19 April 2012 (2012-04-19) * paragraphs [0027] - [0033]; figures 1, 2 *	1,10	
A	US 2013/000540 A1 (RIJKEN ORIOL R [US] ET AL) 3 January 2013 (2013-01-03) * paragraphs [0060] - [0074]; figures 1-3 *	1,10	
			TECHNICAL FIELDS SEARCHED (IPC)
			B63B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 November 2013	Examiner Brumer, Alexandre
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19-11-2013

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