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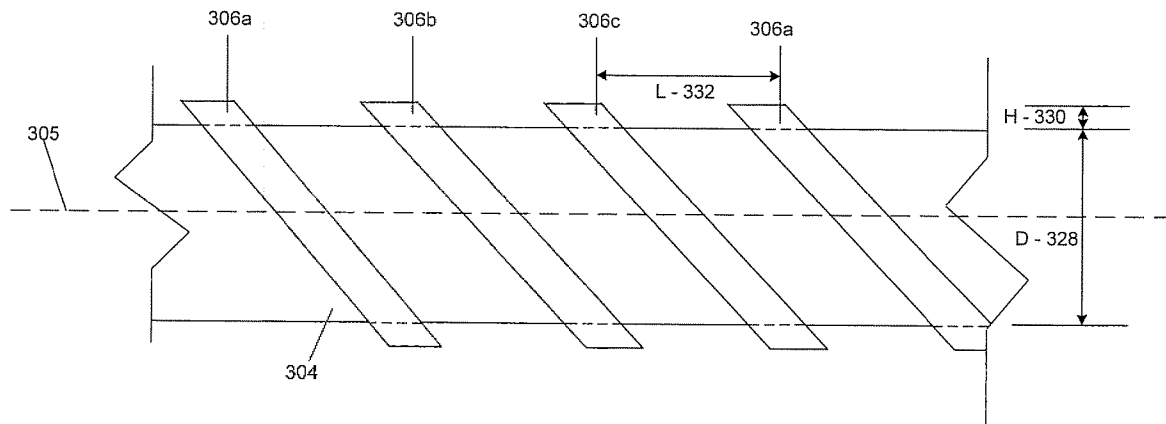
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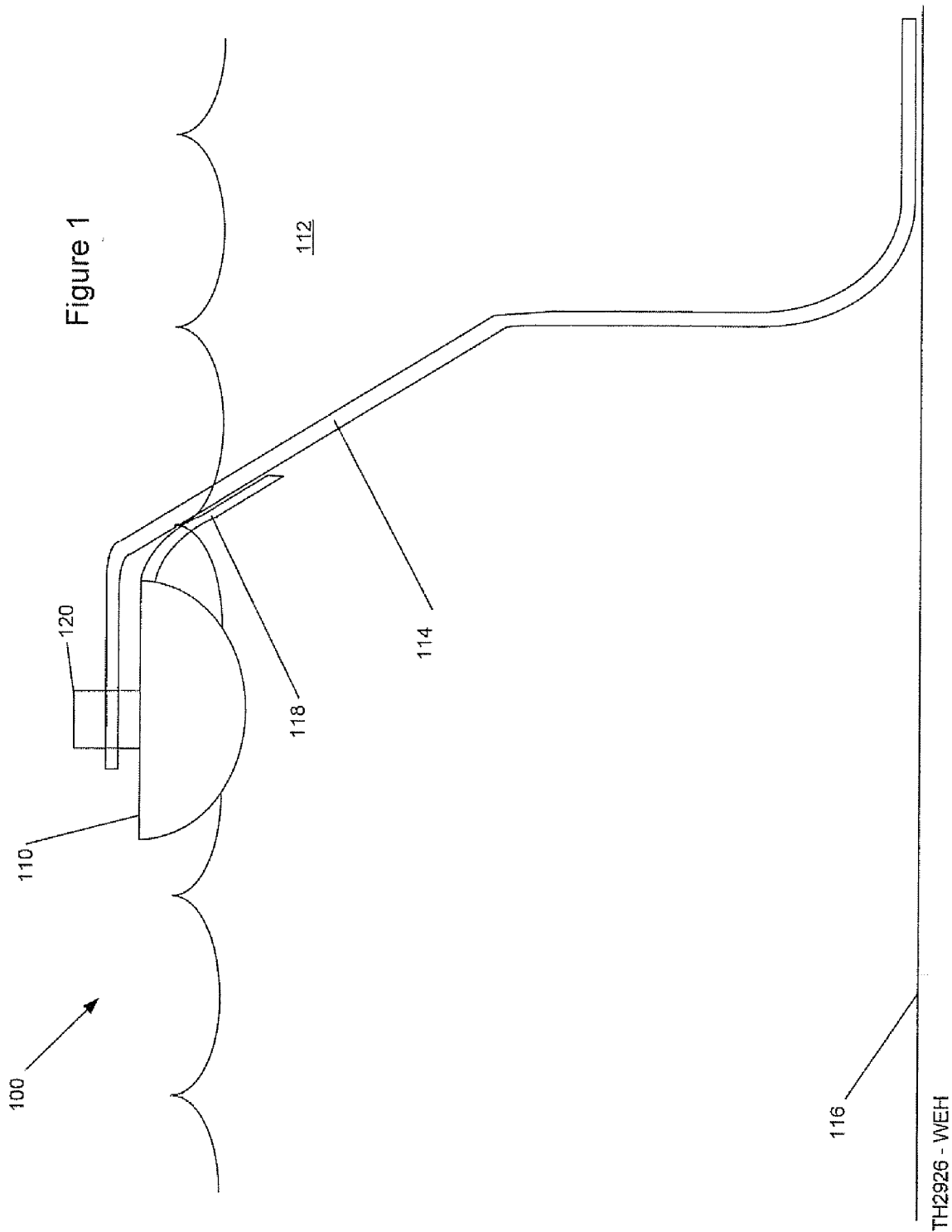
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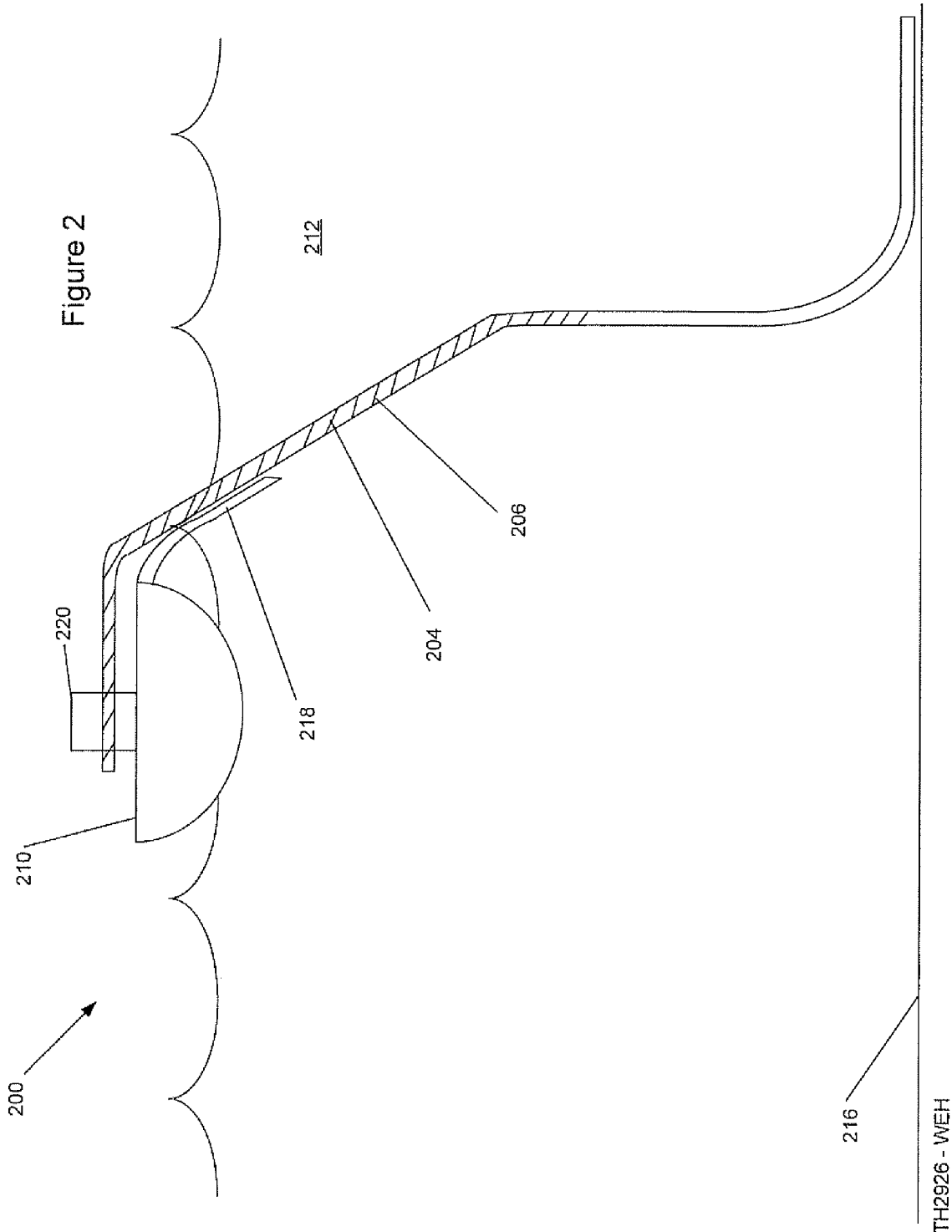
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(57) **ABSTRACT**

There is disclosed a system comprising a structural element, at least one helical strake about the structural element, and at least one ramp to provide a transition from the structural element to the helical strake.

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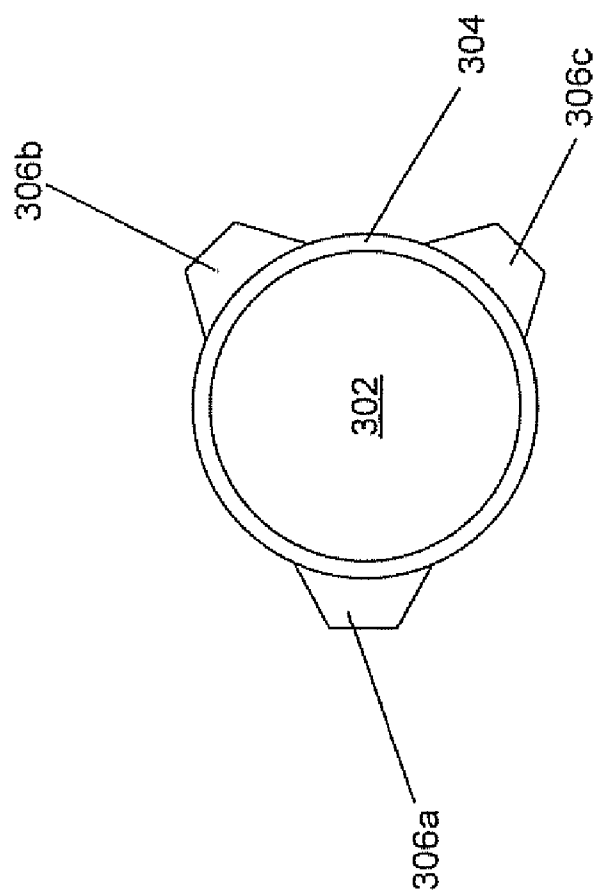


Figure 3a

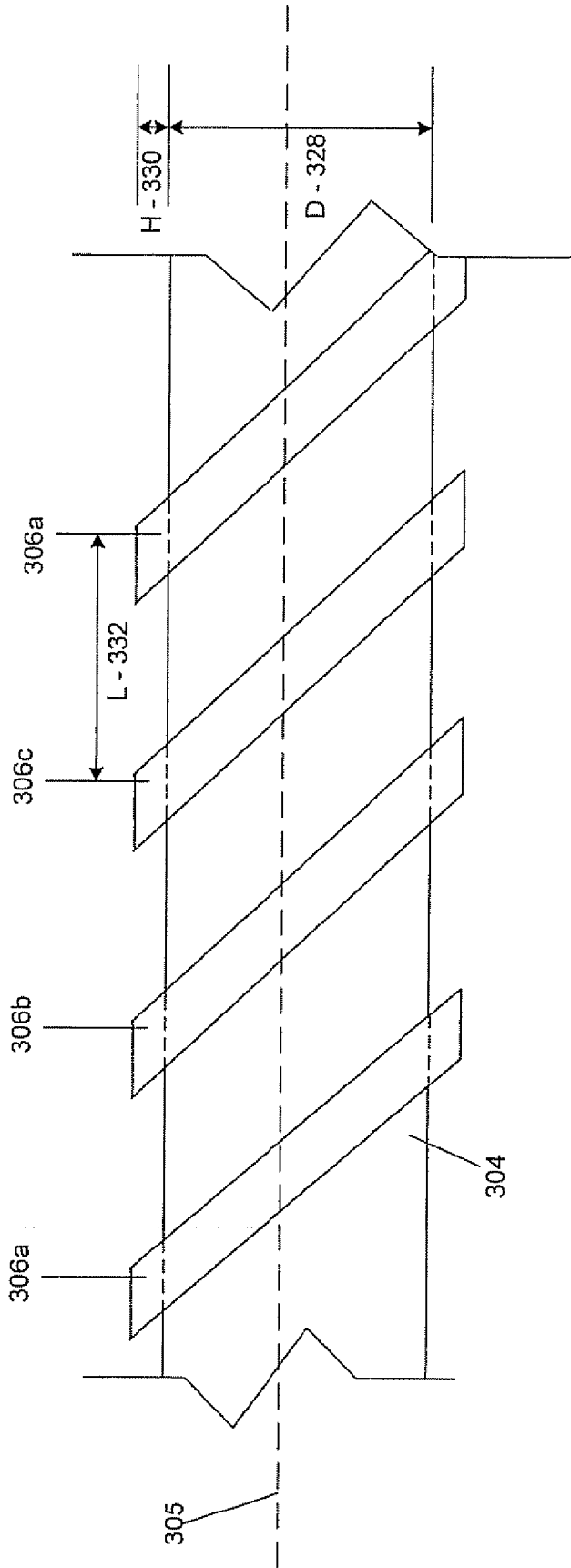


Figure 3b

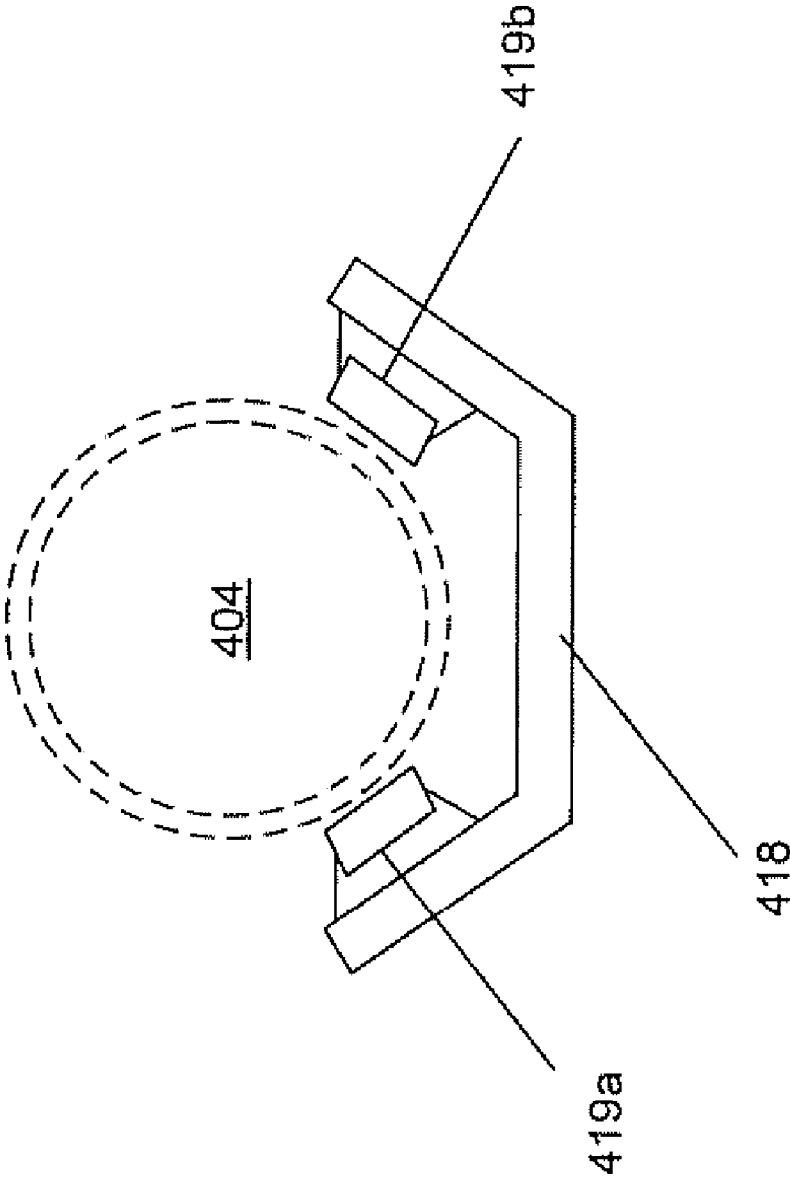


Figure 4a

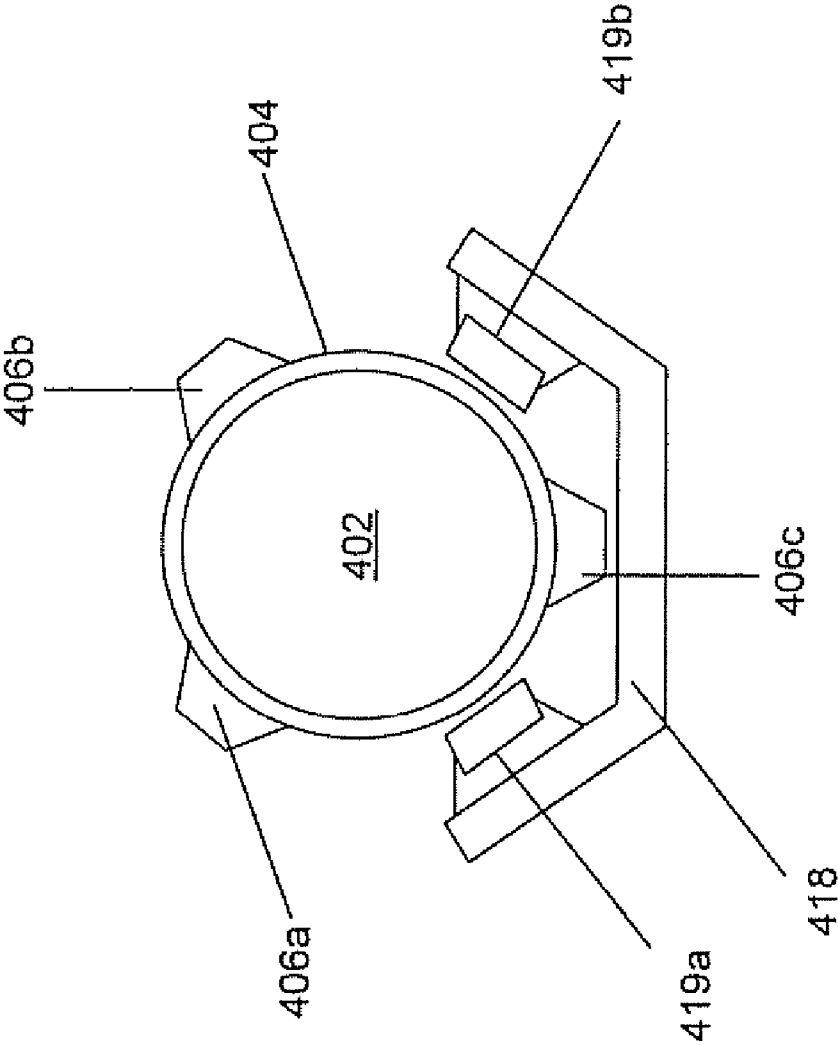


Figure 4b

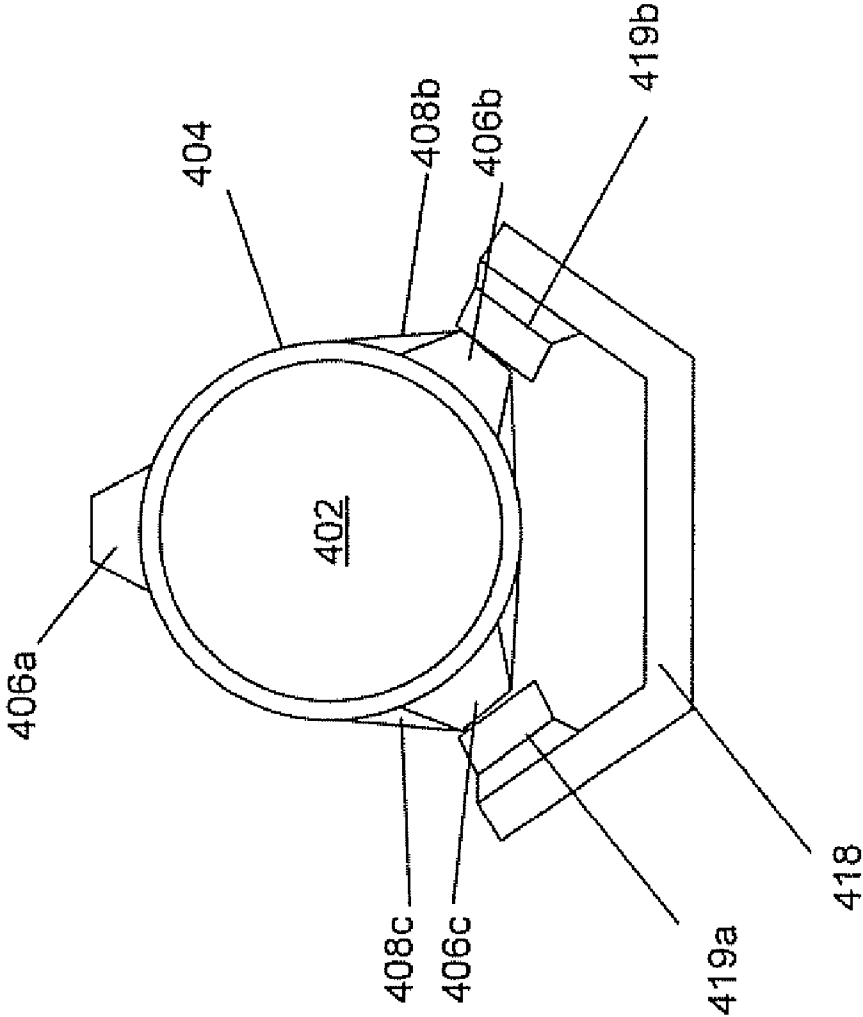


Figure 4c

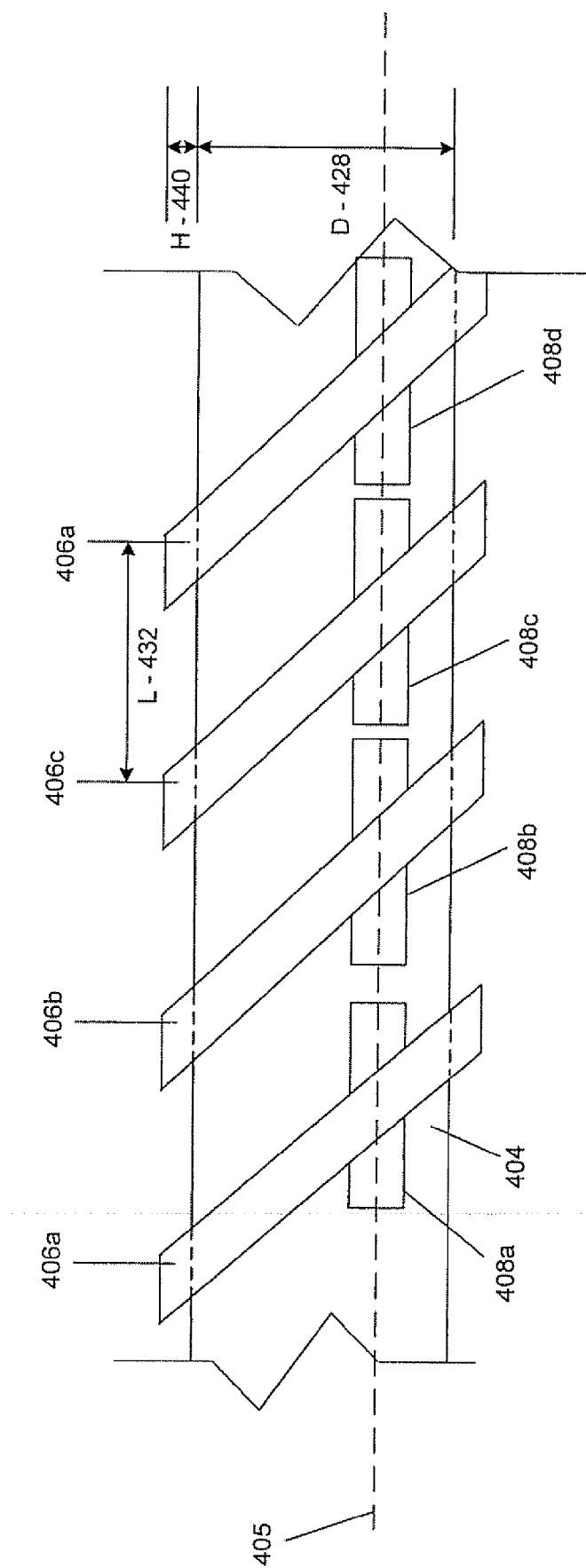


Figure 4d

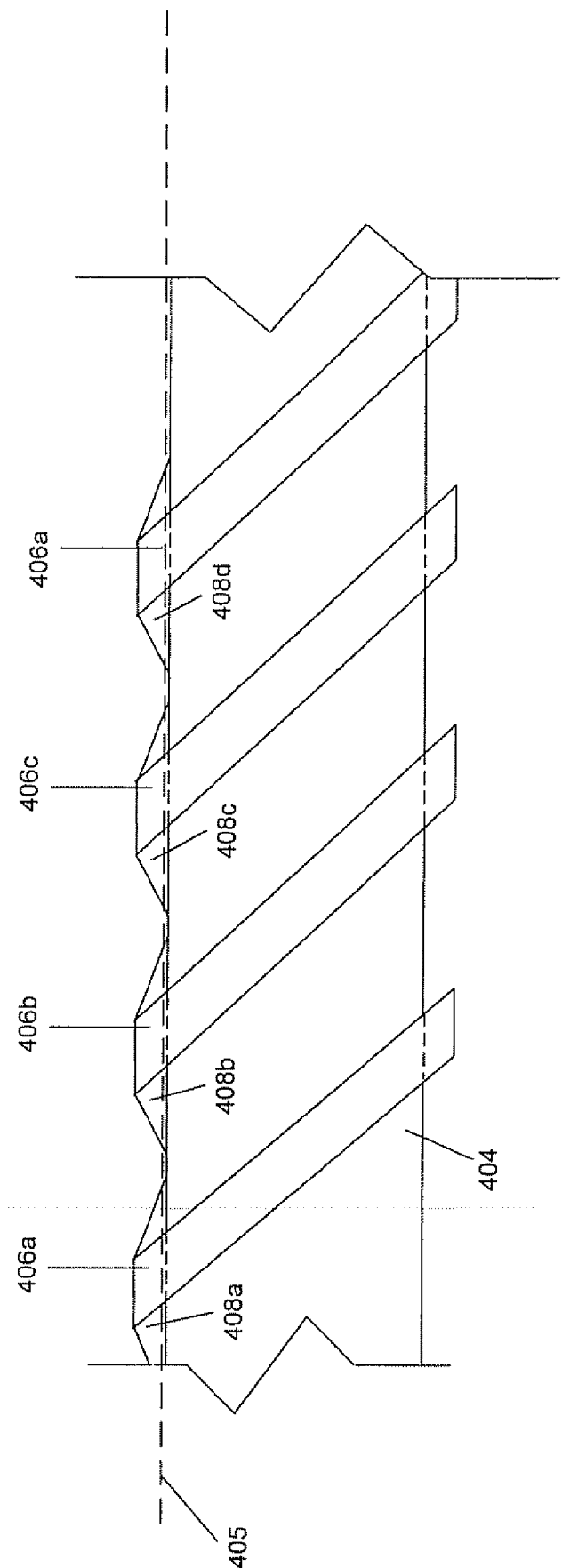


Figure 4e

STRAKE SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application 60/713,981 filed on Sep. 2, 2005, herein incorporated by reference in its entirety.

FIELD OF INVENTION

[0002] The present disclosure relates to strake systems and methods.

BACKGROUND

[0003] Structural elements can be installed at sea from a floating vessel using a J-lay configuration where the structural element is held vertically on the vessel and dropped vertically into the water and then when it reaches the bottom of the body of water, it lays horizontal, or alternatively structural elements can be installed in a S-lay configuration where the structural element is held horizontally on the vessel, drops to vertical through the body of water, and then rests on the bottom of the body of water in a horizontal configuration. Other configurations for installing a structural element from a vessel in a body of water are also known.

[0004] Referring now to FIG. 1, system 100 for installing structural element 114 on bottom 116 of body of water 112 is illustrated. System 100 includes vessel 110 with tensioner 120 and stinger 118. Tensioner 120 holds structural element 114 in a horizontal configuration as it enters water, and then structural element 114 rolls down stinger 118, then drops to a vertical configuration, and then back to a horizontal configuration as it lays on bottom 116. Tensioner 120 and vessel 110 have a sufficient capacity to support structural element 114 as it is being installed.

[0005] Currents in body of water 112 may cause vortexes to shed from the sides of structural element 114. When these types of structural elements, such as a cylinder, experience a current in a flowing fluid environment, it is possible for the structural element to experience vortex-induced vibrations (VIV). These vibrations may be caused by oscillating dynamic forces on the surface which can cause substantial vibrations of the structural element, especially if the forcing frequency is at or near a structural natural frequency. The vibrations may be larger in the transverse (to flow) direction; however, in-line vibrations can also cause stresses, which may sometimes be larger than those in the transverse direction.

[0006] The magnitude of the stresses on a structural element is generally a function of and increases with the velocity of the water current passing these structural elements and the length of the structural element.

[0007] There are generally two kinds of current-induced stresses in flowing fluid environments. The first kind of stress is caused by vortex-induced alternating forces that vibrate the structural element ("vortex-induced vibrations") in a direction perpendicular to the direction of the current. When fluid flows past the structural element, vortices may be alternately shed from each side of the structural element. This produces a fluctuating force on the structural element transverse to the current. If the frequency of this harmonic load is near the resonant frequency of the structural element,

large vibrations transverse to the current can occur. These vibrations can, depending on the stiffness and the strength of the structural element and any welds, lead to unacceptably short fatigue lives. In fact, stresses caused by high current conditions in marine environments have been known to cause structural elements such as risers to break apart and fall to the ocean floor.

[0008] The second type of stress is caused by drag forces which push the structural element in the direction of the current due to the structural element's resistance to fluid flow. The drag forces may be amplified by vortex induced vibrations of the structural element. For instance, a riser pipe that is vibrating due to vortex shedding will disrupt the flow of water around it more than a stationary riser. This may result in more energy transfer from the current to the riser, and hence more drag.

[0009] Some devices used to reduce vibrations caused by vortex shedding from sub-sea structural elements operate by modifying the boundary layer of the flow around the structural element to prevent the correlation of vortex shedding along the length of the structural element. Examples of such devices include sleeve-like devices such as helical strake elements, shrouds, fairings and substantially cylindrical sleeves. Currently available strake elements and fairings cover an entire circumference of a cylindrical element or may be clamshell shaped to be installed about the circumference.

[0010] Some VIV and drag reduction devices can be installed on risers and similar structural elements before those structural elements may be deployed underwater. Alternatively, VIV and drag reduction devices can be installed on structural elements after those structural elements may be deployed underwater.

[0011] When installing a structural element in an S-lay configuration, the structural element may travel over a stinger and encounter one or more rollers on the stinger. A pre-installed strake may be damaged if it passes over the stinger. One alternative is to install the strakes on the structural element after it passes over the rollers and the stinger. Another alternative is to protect the strakes as they are passed over the rollers and the stinger.

[0012] U.S. Pat. No. 6,896,447 discloses a vortex induced vibration suppressor and method. The apparatus includes a body that is a flexible member of a polymeric (e.g., polyurethane) construction. A plurality of helical vanes on the body extend longitudinally along and helically about the body. Each vane has one or more openings extending transversely there through. A longitudinal slot enables the body to be spread apart for placing the body upon a riser, pipe or pipeline. Tensile members that encircle the body and pass through the vane openings enable the body to be secured to the pipe, pipeline or riser. U.S. Pat. No. 6,896,447 is herein incorporated by reference in its entirety.

[0013] There is a need in the art for an improved apparatus and method for suppressing vibration. There is another need in the art of apparatus for and new and improved methods of installing strake elements for suppressing vibration in a flowing fluid environment. There is another need in the art of apparatus for and new and improved methods of installing strake elements for suppressing vibration in a flowing fluid environment on a structural element before the structural

element is installed over a ramp or roller. There is another need in the art of apparatus for and new and improved methods of installing stake elements for suppressing vibration in a flowing fluid environment on a structural element before the structural element is installed in the flowing fluid environment which does not require intervention or adjustment of the stake elements once the structural element is in the flowing fluid environment.

[0014] These and other needs of the present disclosure will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

SUMMARY OF THE INVENTION

[0015] One aspect of the invention provides a system comprising a structural element, at least one helical stake about the structural element, and at least one ramp to provide a transition from the structural element to the helical stake.

[0016] Another aspect of the invention provides a method of installing a structural element in a body of water comprising attaching at least one helical stake about the structural element, attaching at least one ramp to the structural element and/or the at least one helical stake, the at least one ramp to provide a transition from the structural element to the helical stake, and moving the structural element, the ramp, and the stake over a roller, so that the at least one ramp provides a transition from the structural element to the helical stake where the roller interfaces with the structural element, the ramp, and the stake.

[0017] Advantages of the invention include one or more of the following:

[0018] improved apparatuses and methods for suppressing vibration;

[0019] improved methods of installing stake elements for suppressing vibration in a flowing fluid environment;

[0020] improved methods of installing stake elements for suppressing vibration in a flowing fluid environment on a structural element before the structural element is installed over a ramp or roller; and

[0021] improved methods of installing stake elements for suppressing vibration in a flowing fluid environment on a structural element before the structural element is installed in the flowing fluid environment which does not require intervention or adjustment of the stake elements once the structural element is in the flowing fluid environment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1 illustrates a system for installing a structural element in a body of water in an S-lay configuration.

[0023] FIG. 2 illustrates a system for installing a structural element in a body of water in an S-lay configuration.

[0024] FIGS. 3a and 3b illustrate a structural element with stakes.

[0025] FIGS. 4a-4c illustrate a structural element with stakes and ramps traveling over a stinger.

[0026] FIGS. 4d and 4e illustrate a structural element with stakes and ramps.

DETAILED DESCRIPTION OF THE INVENTION

[0027] In one embodiment, there is disclosed a system comprising a structural element, at least one helical stake about the structural element, and at least one ramp to provide a transition from the structural element to the helical stake. In some embodiments, the structural element is selected from the group consisting of a shell, a collar, an oil flowline, a pipeline, a drilling riser, a production riser, a steel tubular, import and export risers, subsea pipelines, tendons for tension leg platforms, legs for traditional fixed and for compliant platforms, space-frame members for platforms, cables, umbilicals, mooring elements for deepwater platforms, hull structures for tension leg platforms and for spar type structures, and column structures for tension leg platforms and for spar type structures. In some embodiments, the structural element comprises a plurality of sections welded to each other. In some embodiments, the structural element comprises a plurality of sections threaded to each other. In some embodiments, the at least one helical stake about the structural element comprises at least three helical stakes about the structural element. In some embodiments, the at least one ramp comprises a plurality of ramps aligned along a longitudinal axis of the structural element, the ramps adapted to interface with a stinger and/or a roller. In some embodiments, the at least one ramp comprises a first set of ramps and a second set of ramps, the first set and the second set aligned along a longitudinal axis of the structural element, the first set adapted to interface with a first roller, and the second set adapted to interface with a second roller azimuthally spaced apart from the first roller. In some embodiments, a first end of the at least one helical stake is attached to a first collar, and a second end of the at least one helical stake is attached to a second collar, the first collar and the second collar attached about the structural element.

[0028] In one embodiment, there is disclosed a method of installing a structural element in a body of water comprising attaching at least one helical stake about the structural element, attaching at least one ramp to the structural element and/or the at least one helical stake, the at least one ramp to provide a transition from the structural element to the helical stake, and moving the structural element, the ramp, and the stake over a roller, so that the at least one ramp provides a transition from the structural element to the helical stake where the roller interfaces with the structural element, the ramp, and the stake. In some embodiments, the structural element is selected from the group consisting of a shell, a collar, an oil flowline, a pipeline, a drilling riser, a production riser, a steel tubular, import and export risers, subsea pipelines, tendons for tension leg platforms, legs for traditional fixed and for compliant platforms, space-frame members for platforms, cables, umbilicals, mooring elements for deepwater platforms, hull structures for tension leg platforms and for spar type structures, and column structures for tension leg platforms and for spar type structures. In some embodiments, the structural element comprises a plurality of sections welded to each other. In some embodiments, the structural element comprises a plurality of sections threaded to each other. In some embodiments, the structural element comprises attaching at least three helical stakes about the structural element. In some embodiments, the at least one ramp comprises a plurality of ramps aligned along a longitudinal axis of the structural element, where the roller interfaces with the structural element. In some embodiments, the at least one ramp comprises a first set of ramps and a second set of ramps, the first set and the second set

aligned along a longitudinal axis of the structural element, the first set adapted to interface with a first roller, and the second set adapted to interface with a second roller azimuthally spaced apart from the first roller. In some embodiments, the first roller is azimuthally spaced apart from the second roller by 90 to 150 degrees measured as an arc angle of the structural element.

[0029] Referring now to FIG. 2, in one embodiment of the invention, system 200 is illustrated. System 200 includes vessel 210 in body of water 212, installing structural element 204 in body of water 212 and resting a portion of structural element 204 on bottom 216. Vessel 210 may include tensioner 220 to keep tension on structural element 204 so that it does not sink in water 212. Strakes 206 are attached to structural element 204 to dampen any vortex induced vibration of structural element 204.

[0030] Referring now to FIGS. 3a-3b, in some embodiments of the invention, structural element 304 is illustrated. Structural element 304 encloses passage 302. Strake elements 306a, 306b, and 306c may be mounted about the circumference of structural element 304. Strake elements 306a-306c serve to inhibit vortex induced vibration when structural element 304 is in a flowing fluid stream.

[0031] Structural element 304 has outside diameter D 328. Strake elements 306a-306c have height H 330. Adjacent strake elements may be spaced apart by a pitch L 332. In some embodiments of the invention, outside diameter D 328 may be from about 2 to 60 cm. In some embodiments of the invention, height H 330 may be from about 5% to about 50% of outside diameter D 328. In some embodiments of the invention, height H 330 may be from about 1 to about 15 cm. In some embodiments of the invention, pitch L 332 may be from about 1 D to about 10 D. In some embodiments of the invention, pitch L 332 may be from about 10 to about 500 cm.

[0032] In some embodiments of the invention, there may be about 1 to about 10 helical strake starts about a circumference of structural element 304. In some embodiments of the invention, there may be about 2 to about 6 helical strake starts about a circumference of structural element 304. In some embodiments of the invention, there may be about 3 helical strake starts about a circumference of structural element 304.

[0033] In some embodiments of the invention, strakes 306a-306c may be made of a polymer, such as a thermoplastic polymer or a thermosetting polymer, for example polypropylene, polyethylene, other polyolefins, or co-polymers of olefins. In some embodiments of the invention, strakes 306a-306c may be made of a composite, such as fiberglass or carbon fiber composite. In some embodiments of the invention, strakes 306a-306c may be made of a metal, such as steel or aluminum.

[0034] In some embodiments of the invention, strakes 306a-306c may be attached to a collar, pipe, shell, or other support apparatus. The support apparatus and strakes 306a-306c may then be installed about structural element 304.

[0035] Referring now to FIGS. 4a-4c, in some embodiments of the invention, stinger 418 and structural element 404 are illustrated. Stinger 418 includes roller 419a and roller 419b which are adapted to transport structural element 404. Structural element 404 is able to roll down stinger 418 while resting on rollers 419a and 419b. In some embodiments of the invention, rollers 419a and 419b may be

azimuthally spaced from about 90 to about 150 degrees apart, measured as an arc-angle of structural element 404.

[0036] Referring now to FIG. 4b, structural element 404 is shown in cross-section moving along stinger 418. Structural element 404 encloses passage 402 and has attached to its exterior strakes 406a, 406b, and 406c. Stinger has rollers 419a and 419b, which interface with an exterior of structural element 404 to support structural element 404 and allow structural element to roll along stinger 418.

[0037] Referring now to FIG. 4c, in some embodiments of the invention, structural element 404 of FIG. 4b has moved further along so that strake 406b is interfacing with roller 419b, and strake 406c is interfacing with roller 419a. Ramps 408b are provided adjacent strake 406b, and ramps 408c are provided adjacent strake 406c. Ramps 408b and 408c are adapted to interface with rollers 419a and 419b to lift structural element 404 and provide a smooth transition from the outside surface of structural element 404 to the height of strakes 406b and 406c, so that the strakes are not damaged when they encounter the rollers.

[0038] Referring now to FIG. 4d, in some embodiments of the invention, a side view of structural element 404 is illustrated. Line 405 indicates where roller 419b encounters structural element 404. Ramps 408a, 408b, 408c, and 408d are provided along line 405, to provide a smooth transition of lifting and lowering structural element when it encounters roller 419b, so that strakes 406a, 406b, and 406c are not damaged. Similar ramps may be provided on the opposite side of structural element 404 where roller 419a encounters structural element 404.

[0039] Referring now to FIG. 4e, in some embodiments of the invention, a different side view of the structural element 404 illustrated in FIG. 4d is shown. In this view, line 405 where roller 419b encounters the structural element is at the top, so that the tapering of ramps 408a, 408b, 408c, and 408d may be seen. The ramps provide a smooth transition from the outside surface of structural element 404 to the height of each of the strakes, and then back to the outside surface of the structural element 404 to the roller 419b, so that the strakes are not damaged when they encounter the roller.

[0040] In some embodiments of the invention, strakes 406a-406c may be attached to a collar, pipe, shell, or other support apparatus. The support apparatus and strakes 406a-406c may then be installed about structural element 404. The ramps provide a smooth transition from the outside surface of the support apparatus to the height of each of the strakes, and then back to the outside surface of the support apparatus to the roller 419b, so that the strakes are not damaged when they encounter the roller.

[0041] In some embodiments of the invention, clamshell type strake elements may be mounted around a structural element according to the method disclosed in U.S. Pat. No. 6,695,539, which is herein incorporated by reference in its entirety.

[0042] In some embodiments of the invention, strake elements may be installed about a structural element according to the method disclosed in U.S. Pat. No. 6,561,734, which is herein incorporated by reference in its entirety.

[0043] In some embodiments of the invention, strake elements may be installed about a structural element according to the method disclosed in United States Patent Application Publication No. 2003/0213113, which is herein incorporated by reference in its entirety.

[0044] In some embodiments of the invention, the outside diameter of a structural element to which strake elements can be attached may be from about 10 to about 50 cm. In some embodiments of the invention, the height of strake elements may be from about 5% to about 50% of the structural element's outside diameter. In some embodiments of the invention, the height of strake elements may be from about 5 to about 20 cm.

[0045] In some embodiments of the invention, the structural element may be cylindrical, or have an elliptical, oval, or polygonal cross-section, for example a square, pentagon, hexagon, or octagon.

[0046] In some embodiments, portions of structural element 204 may be lowered onto bottom 216 of water 212. In some embodiments, water 212 has a depth of at least about 1000 meters, at least about 2000 meters, at least about 3000 meters, or at least about 4000 meters. In some embodiments, water 212 has a depth up to about 10,000 meters.

[0047] In some embodiments of the invention, structural element 204 may be a pipeline, a crude oil flowline, a mooring line, a riser, a tubular, or any other structural element installed in a body of water. In some embodiments, structural element 204 may have a diameter from about 0.1 to about 5 meters, and a length from about 10 to about 200 kilometers (km). In some embodiments, structural element 204 may have a length to diameter ratio from about 100 to about 100,000. In some embodiments, structural element 204 may be composed from about 50 to about 30,000 tubular sections, each with a diameter from about 10 cm to about 60 cm and a length from about 5 m to about 50 m, and a wall thickness from about 0.5 cm to about 5 cm.

[0048] Those of skill in the art will appreciate that many modifications and variations are possible in terms of the disclosed embodiments, configurations, materials and methods without departing from their spirit and scope. Accordingly, the scope of the claims appended hereafter and their functional equivalents should not be limited by particular embodiments described and illustrated herein, as these are merely exemplary in nature.

1. A system comprising:

a structural element;

at least one helical strake about the structural element; and

at least one ramp to provide a transition from the structural element to the helical strake.

2. The system of claim 1, wherein the structural element is selected from the group consisting of a shell, a collar, an oil flowline, a pipeline, a drilling riser, a production riser, a steel tubular, import and export risers, subsea pipelines, tendons for tension leg platforms, legs for traditional fixed and for compliant platforms, space-frame members for platforms, cables, umbilicals, mooring elements for deepwater platforms, hull structures for tension leg platforms and for spar type structures, and column structures for tension leg platforms and for spar type structures.

3. The system of claim 1, wherein the structural element comprises a plurality of sections welded to each other.

4. The system of claim 1, wherein the structural element comprises a plurality of sections threaded to each other.

5. The system of claim 1, wherein the at least one helical strake about the structural element comprises at least three helical strakes about the structural element.

6. The system of claim 1, wherein the at least one ramp comprises a plurality of ramps aligned along a longitudinal axis of the structural element, the ramps adapted to interface with a stinger and/or a roller.

7. The system of claim 1, wherein the at least one ramp comprises a first set of ramps and a second set of ramps, the first set and the second set aligned along a longitudinal axis of the structural element, the first set adapted to interface with a first roller, and the second set adapted to interface with a second roller azimuthally spaced apart from the first roller.

8. The system of claim 1, wherein a first end of the at least one helical strake is attached to a first collar, and a second end of the at least one helical strake is attached to a second collar, the first collar and the second collar attached about the structural element.

9. A method of installing a structural element in a body of water comprising:

attaching at least one helical strake about the structural element;

attaching at least one ramp to the structural element and/or the at least one helical strake, the at least one ramp to provide a transition from the structural element to the helical strake; and

moving the structural element, the ramp, and the strake over a roller, so that the at least one ramp provides a transition from the structural element to the helical strake where the roller interfaces with the structural element, the ramp, and the strake.

10. The method of claim 9, wherein the structural element is selected from the group consisting of a shell, a collar, an oil flowline, a pipeline, a drilling riser, a production riser, a steel tubular, import and export risers, subsea pipelines, tendons for tension leg platforms, legs for traditional fixed and for compliant platforms, space-frame members for platforms, cables, umbilicals, mooring elements for deepwater platforms, hull structures for tension leg platforms and for spar type structures, and column structures for tension leg platforms and for spar type structures.

11. The method of claim 9, wherein the structural element comprises a plurality of sections welded to each other.

12. The method of claim 9, wherein the structural element comprises a plurality of sections threaded to each other.

13. The method of claim 9, wherein attaching at least one helical strake about the structural element comprises attaching at least three helical strakes about the structural element.

14. The method of claim 9, wherein the at least one ramp comprises a plurality of ramps aligned along a longitudinal axis of the structural element, where the roller interfaces with the structural element.

15. The method of claim 9, wherein the at least one ramp comprises a first set of ramps and a second set of ramps, the first set and the second set aligned along a longitudinal axis of the structural element, the first set adapted to interface with a first roller, and the second set adapted to interface with a second roller azimuthally spaced apart from the first roller.

16. The method of claim 9, wherein the first roller is azimuthally spaced apart from the second roller by 90 to 150 degrees measured as an arc angle of the structural element.