Methods and apparatus for installing underwater devices. The apparatus can include a body having at least one pair of support members extending therefrom. At least one actuator, adapted to move in a linear direction, can be disposed on each support member, and at least one connector can be disposed on each actuator.
FIG. 2
UNDERWATER DEVICE FOR ROV INSTALLABLE TOOLS

BACKGROUND OF THE INVENTION

[0001] Field of the Invention

[0002] Embodiments of the present invention generally relate to apparatus and methods for remotely installing underwater tools on subsea structures.

[0003] 2. Description of the Related Art

[0004] Numerous challenges are encountered in offshore operations, such as oil and gas exploration, production and transportation. One such challenge is minimizing or eliminating the vibration of sub-surface equipment and structures caused by currents and tidal action. Typical marine structures susceptible to damage by currents and tidal action include subsea pipelines, drilling and production lines, import and export risers, tendons for tension leg platforms, and other elongated, sub-surface, components and structures used in offshore operations.

[0005] The flow of water around a rigid body, such as sub-surface equipment and/or structures creates a vortex on the reverse or downstream side of the rigid body. The vortexes depart or shed from the downstream side of the rigid body at a frequency that is proportionate to the fluid velocity past the rigid body. Over a given body shape, higher velocity flows will create a higher rate of vortex shedding than lower velocity flows over the same body. The vortices created by the flow are shed on alternate sides of the rigid body (e.g. the first vortex will shed 90° clockwise from the direction of flow, the second 90° counter-clockwise from the direction of flow). The process of vortex shedding on alternate sides of the body places alternating, 180° opposed, forces (i.e. a vibration) on the sub-surface equipment and/or structures. The frequency of the vibration will vary with the velocity of the water flowing past the sub-surface equipment and/or structures.

[0006] This current induced vibration in marine elements is often referred to as "vortex-induced vibration," or "VIV." When the frequency of shedding the vortices is near the natural frequency of the marine element, harmonic resonance can result in potentially destructive levels of vibration.

[0007] Sub-surface shrouds, fairings, and/or strakes are commonly used on equipment and structures to prevent or minimize vortex-induced vibration. Ordinarily, strakes or other VIV-reduction devices are installed on the surface prior to deployment of sub-surface equipment and/or structures. For existing structures, VIV-reduction devices are frequently deployed using divers for shallow water installations or using remotely operated vehicles ("ROVs") for deep water installations.

[0008] ROVs are usually the preferred way to install devices subsea, especially in deeper waters. In deeper waters, human divers are exposed to potentially dangerous working conditions, which are not a factor with a machine. An ROV is an underwater robot that is usually controlled from the surface by an operator. Typical ROVs are equipped with hydraulic manipulators, a vision system, and a remote control system to allow the operator to maneuver the ROV to a desired location under water to perform its intended task.

[0009] U.S. Pat. Nos. 6,994,492; 6,695,539; 6,928,709; and 7,316,525 each disclose hinged or clam shell underwater devices that are manipulated by a ROV for installing a clam shell, VIV-reduction device underwater. Such hinged or "clam shell" underwater device requires a manipulator or clamp having mating ends that rotate bi-directionally upon a pivot point within a single plane. The mating ends of the clamp engage opposite ends of the clam shell, VIV-reduction device in an open position and then rotate or pivot bi-directionally within a single plane to a closed position thereby closing the VIV-reduction device about a subsea structure to be protected from VIV. Such clam shell design in the deployment tool is inherently complex, requiring tight tolerances on the tooling during manufacturing and assembly. Operationally, adequate space must be provided for the tool's pivoting arms to swing during opening and closing. Also, the force exerted by the clam shell tool design when closing is greatly reduced as there is a long moment arm disadvantage between the operating mechanism and where the clam shell tool closes the VIV device. The existing clam shell designs are also bulky and difficult for an ROV to handle, and in some cases the clam shell tool must be supported by a topside vessel when in operation.

[0010] There is a need therefore, for improved systems and methods for deploying underwater devices about sub-sea structures.

SUMMARY OF THE INVENTION

[0011] Apparatus and methods for installing underwater devices on subsea structures are provided. In at least one specific embodiment, the apparatus can include a body, a support member, and a linear actuator. The actuator can be adapted to move in a linear direction and can be disposed on the support member.

[0012] In at least one other specific embodiment, the apparatus can include at least one deployment tool detachably attached to the platform; and one or more underwater devices detachably attached to the one or more deployment tools.

[0013] In at least one specific embodiment, the method for installing underwater devices on subsea structures can include attaching one or more open underwater devices to one or more deployment tools; attaching the one or more deployment tools to a platform; disposing the platform proximate to a subsea structure; removing the one or more deployment tools from the platform using a carrier; closing the one or more open underwater devices held by the one or more deployment tools about the subsea structure using the carrier; releasing the underwater device from the deployment tool wherein the closed underwater device remains attached to the subsea structure; and returning the deployment tool to the platform.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0015] FIG. 1 depicts an isometric view of an illustrative deployment tool for remotely installing an underwater device underwater, according to one or more embodiments described.

[0016] FIG. 2 depicts a reverse isometric view of the deployment tool depicted in FIG. 1, according to one or more embodiments described.
Fig. 3 depicts an elevation view of an illustrative connector according to one or more embodiments described. Fig. 4 depicts an isometric view of an illustrative strake for suppressing vortex-induced vibration caused by fluid flow across a structure according to one or more embodiments described. Fig. 5 depicts a partial cross-sectional view of the strake as depicted in Fig. 4 according to one or more embodiments described. Fig. 6 depicts an elevation view of the connector depicted in Fig. 3 inserted into an illustrative connector lug according to one or more embodiments described. Fig. 7 depicts a plan view of the deployment tool depicted in Fig. 1 holding the strake depicted in Fig. 4 proximate to a subsea structure according to one or more embodiments described. Fig. 8 depicts an isometric view of the deployment tool, the underwater device, and the subsea structure depicted in Fig. 7 according to one or more embodiments described. Fig. 9 depicts a plan view of the deployment tool depicted in Fig. 1 attaching the strake depicted in Fig. 4 to the subsea structure depicted in Fig. 7 according to one or more embodiments described. Fig. 10 depicts an isometric view of the deployment tool, the underwater device, and the subsea structure depicted in Fig. 9 according to one or more embodiments described. Fig. 11 depicts a plan view of the deployment tool depicted in Fig. 1 after attaching the strake depicted in Fig. 4 to the subsea structure depicted in Fig. 7 according to one or more embodiments described. Fig. 12 depicts an isometric view of the deployment tool, the underwater device, and the subsea structure depicted in Fig. 11 according to one or more embodiments described. Fig. 13 depicts an isometric view of an illustrative platform for storing or holding a deployment tool, according to one or more embodiments described. Fig. 14 depicts an isometric view of the platform depicted in Fig. 13 having a deployment tool disposed thereon, according to one or more embodiments described.

DETAILED DESCRIPTION

A detailed description will now be provided. Each of the appended claims defines a separate invention, which for infringement purposes is recognized as including equivalents to the various elements or limitations specified in the claims. Depending on the context, all references below to the "invention" may in some cases refer to certain specific embodiments only. In other cases it will be recognized that references to the "invention" will refer to subject matter recited in one or more, but not necessarily all, of the claims. Each of the inventions will now be described in greater detail below, including specific embodiments, versions and examples, but the inventions are not limited to these embodiments, versions or examples, which are included to enable a person having ordinary skill in the art to make and use the inventions, when the information in this patent is combined with available information and technology.

Figs. 1 and 2 depict isometric views of an illustrative deployment tool 100 for remotely installing an underwater device, according to one or more embodiments. As depicted in Figs. 1 and 2, the deployment tool 100 can include a body 110, support members 120 (four are shown), actuators 170 (four are shown), and connectors 190 (four are shown). The deployment tool 100 is not a clam-shell device. The actuators 170 disposed on the body 110 can be actuated to operate or move in a linear, single coordinate axis.

The body 110 can include one or more structural support beams or members 115 to provide a frame or housing. The structural support members 115 can be arranged in parallel as depicted and any number of cross-beams or support members can be used to add additional strength or support.

Each structural support members 115 can be hollow or solid, depending on the strength and stiffness design requirements. In one or more embodiments, each structural support members 115 can include one or more fins, flutes, ribs, or other similar devices disposed in, on, or thereabout to improve rigidity, strength and/or stiffness. The structural support members 115 can be constructed of a metallic, non-metallic or composite material. In one or more embodiments, the structural support members 115 can be made of one or more non-metallic materials including, but not limited to, engineered plastic, fiberglass, fiber reinforced plastic (FRP), carbon fiber, or any combination thereof. In one or more embodiments, the structural support members 115 can be made of metallic materials including, but not limited to ferrous alloys, non-ferrous alloys, or any combination thereof.

One or more panels 130 can be disposed between any two support members 115. Each panel 130 can be negatively, neutrally, or positively buoyant. In one or more embodiments, the one or more panels 130 can be made of a positively buoyant material to provide a neutrally buoyant deployment tool 100. In one or more embodiments, each panel 130 can include one or more internal chambers (not shown) to contain a fluid capable of changing the buoyancy of the body 110. For example, the buoyancy of a given panel 130 can be adjusted by injecting or releasing a fluid such as a gas or liquid into the one or more internal chambers (not shown).

Each support member 120 can extend laterally from the body 110. The support members ("lataers" or "arms") 120 are preferably normal to the longitudinal centerline of the body 110, but can vary from about 10° to about 90° from the horizontal. Each support members 120 can be permanently or detachably attached to the first side of the body 110 by welding, riveting or any combination thereof. In one or more embodiments, the support members 120 can be detachably attached to the first side of the body 110 by screwing, pinning, bolting, or any combination thereof. In one or more embodiments, the support members 120 can be integral with the body 110.

Each support members 120 can be constructed of one or more metallic, non-metallic, or composite materials. In one or more embodiments, the support members 120 can be made of a metallic material including, but not limited to, ferrous alloys, non-ferrous alloys, or any combination thereof. In one or more embodiments, the support members 120 can be made of a non-metallic material including, but not limited to, engineered plastic, fiberglass, fiber reinforced plastic (FRP), carbon fiber, or any combination thereof. In one or more embodiments, one or more fins, flutes, ribs, or other similar devices can be disposed on, in, or about the support members 120 to improve the rigidity, strength and/or stiffness of the support members 120. In one or more embodiments, a
corrosion resistant coating suitable for use in fresh and/or salt water environments can partially or completely encapsulate the support members 120.

[0036] One or more gussets 125 can be used to support, strengthen, and/or brace the support members 120. In one or more embodiments, the gussets 125 can be permanently attached to the first side of the body 110 and to the support members 120 by welding, riveting or any combination thereof. In one or more embodiments, the gussets 125 can be detachably attached to the first side of the body 110 and to the support members 120 by screwing, pinning, bolting, or any combination thereof. In one or more embodiments, the gussets 125 can be integral with the first side of the body 110 or support members 120.

[0037] The one or more actuators 170 can be disposed on or about each of the support members 120. The actuators 170 can be capable of linear translation and/or displacement through a predetermined range of motion. The actuators 170 can include, but are not limited to one or more electric motors, one or more electromagnetic actuators (e.g. solenoids), one or more pneumatic actuators, one or more hydraulic actuators, one or more mechanical actuators or any combination thereof. In one or more embodiments, the actuators 170 can include, but are not limited to one or more hydraulic cylinders filled with a fluid to achieve a linear displacement. In one or more embodiments, the actuators 170 can incorporate one or more internal springs or similar passive energy storage devices which can permit the actuator to return to a predetermined "fail-safe" position upon loss or removal of hydraulic pressure.

[0038] At least one connector 190 can be disposed on each actuator 170. The connector 190 can permit connect one or more underwater tools or devices (not shown) to the deployment tool 100. In one or more embodiments, the connector 190 can be a resilient or deformable material to engage a complimentary and/or mating receptacles disposed about the one or more underwater devices. For example, the connector 190 can be a resilient or deformable material adapted to snap-fit or friction fit into one or more complimentary and/or mating receptacles disposed about one or more underwater devices.

[0039] FIG. 3 depicts an elevation view of an illustrative connector 190 according to one or more embodiments. The connector 190 can include a single or multi-piece body 305 having a first end 310 and a second end 315. The first end 310 of the body 305 can include one or more protrusions 330 extending therefrom (two protrusions 330 are depicted in FIG. 3). In one or more embodiments, the second end 315 of the body 305 can provide one or more attachment devices 320, such as one or more holes, adapted to accommodate the actuator 170. In one or more embodiments, the attachment device 320 can be a threaded hole to accommodate a complimentary attachment device on the actuator 170. In one or more embodiments, the attachment device 320 connecting the connector 190 to the actuator 170 can include, but is not limited to threads, adhesives, pins, friction fit, or any combination thereof. In one or more embodiments, the connector 190 can be integrally cast with the actuator 170, for example as an integral casting with a piston disposed within the actuator 170.

[0040] The one or more protrusions 330 can extend radially outward from the first end 310 of the body 305. In one or more embodiments, the protrusions 330 can extend from the first end 310 of the body 305 parallel to the longitudinal axis of the body 305. A first profiled surface 335 and a second profiled surface 340 of the one or more protrusions 330 can have similar or different tapered or angled profiles. The first profiled surface 335 of the one or more protrusions 330 can maintain a constant or variable angle profile with respect to the longitudinal centerline of the body 305. In one or more embodiments, the first profiled surface 335 can be at a constant angle, measured with respect to the longitudinal centerline of the body 305, of from about 10° to about 90°.

[0041] The second profiled surface 340 of the one or more protrusions 330 can maintain a constant or variable slope with respect to the longitudinal centerline of the body 305. In one or more embodiments, the second profiled surface 340 can be equally or unequally divided into a first portion 342 and a second portion 344. In one or more embodiments the first 342 and second 344 portions can be sloped at the same or different angles measured with respect to the longitudinal centerline of the body 305. In one or more embodiments, the first portion 342 can be sloped at an angle of from about 10° to about 90°. In one or more embodiments, the second portion 344 can be sloped at an angle of from about 10° to about 90°. In one or more specific embodiments, the first portion 342 can be sloped at an angle of from about 75° to about 90° and the second portion sloped at an angle of from about 30° to about 75°. In one or more embodiments, the one or more protrusions 330 can be capable of resisting a minimum applied shear force of about 3.6 kN (800 lb); about 4.4 kN (1,000 lb); about 5.3 kN (1,200 lb); or about 6.2 kN (1,400 lb); or more without deformation or severance from the body 305.

[0042] The one or more connectors 190 can be made of one or more metallic, non-metallic, or composite materials. In one or more embodiments, the one or more connectors 190 can be made of a metallic material including, but not limited to ferrous alloys, non-ferrous alloys, or any combination thereof. In one or more embodiments, the one or more connectors 190 can be made of a non-metallic material including, but not limited to engineered plastic, fiberglass, fiber reinforced plastic (FRP), carbon fiber, or any combination thereof.

[0043] Referring again to FIGS. 1 and 2, the body 110 can further include one or more handles 180 disposed thereon. The one or more handles 180 can provide a point of attachment and can permit movement of the deployment tool 100 using one or more carriers, such as a diver and/or a remotely operated vehicle ("ROV"). In one or more embodiments, the one or more handles 180 can be attached to or otherwise disposed on the one or more structural support members 115 of the body 110. In one or more embodiments, the one or more handles 180 can be permanently attached to the body 110 by welding, riveting or any combination thereof. In one or more embodiments, the one or more handles 180 can be detachably attached to the body 110 by screwing, pinning, bolting, or any combination thereof. In one or more embodiments, the handle 205 can be integral with the body 110.

[0044] The body 110 can also include one or more handles 180 and one or more hydraulic interfaces 185 disposed thereon. The one or more hydraulic interfaces 185 can be used to permit manual operation or ROV manipulation or cycling of the one or more actuators 170. In one or more embodiments, the hydraulic interface 185 can be a no leak, hot-stab type connector permitting leak-free or near leak-free connection of an external hydraulic supply, pump, and/or system to the deployment tool 100. In one or more embodiments, the hydraulic interface 185 can be used to permit the use of a hydraulic system external to the
deployment tool 100, for example an ROV-based hydraulic system. One or more hydraulic lines can be routed from the hydraulic interface 185 to the one or more actuators 170 disposed on each of the support members 120 to provide fluid communication thereto.

[0045] The deployment tool 100 can be used to deploy one or more underwater devices or tools including, but not limited to one or more underwater vortex induced vibration reduction devices, underwater inspection devices, underwater leak detection devices, underwater leak repair devices, underwater pipeline repair devices, underwater maintenance devices, underwater test devices, underwater diagnostic devices, underwater monitoring devices, underwater measurement devices, or any combination thereof. In one or more embodiments, the one or more vortex induced vibration devices can include strakes, strouts, fairings and similar devices intended to minimize and/or prevent vortex induced vibration. Representative strakes, strouts, and fairings are disclosed in U.S. Pat. No. 6,561,734; U.S. Pat. No. 6,702,026; U.S. Pat. No. 6,685,394; U.S. Pat. No. 7,017,666; U.S. Pat. No. 7,070,361; U.S. Pat. No. 6,571,878; U.S. Pat. No. 5,984,584; U.S. Pat. No. 6,067,922; U.S. Pat. No. 6,223,672; U.S. Pat. No. 6,610,278; U.S. Pat. No. 6,401,646; and US 2008/0050181. For clarity and ease of description, the deployment tool 100 will be further described with reference to a strake 400 as depicted in FIG. 4.

[0046] FIG. 4 depicts an isometric view of an illustrative strake 400 for suppressing vortex induced vibration caused by fluid flow across a structure according to one or more embodiments. In one or more embodiments, the strake 400 can include a housing 410, one or more fins 420, one or more alignment stubs 450, and one or more pairs of connector lugs 500. The housing 410 can have a split-body or hinged-body configuration. In the split-body configuration, the housing 410 can have two or more discrete pieces which can be joined, fastened or otherwise attached together thereby permitting installation of the strake 400 about an elongated sub-sea structure (not shown). In the hinged-body configuration, the housing 410 can have a longitudinal split allowing the body to pivotably open and close thereby permitting installation of the strake 400 about an elongated sub-sea structure (not shown). The illustrative strake 400 depicted in FIG. 4 is a hinged-body configuration. In one or more embodiments, all or a portion of the strake 400 can be constructed of a flexible material, such as polyolefin including polyethylene like linear low density polyethylene (LLDPE), for example. The density of such materials can advantageously assist in making the strake 400 neutrally buoyant.

[0047] In one or more embodiments, the housing 410 can be cylindrically shaped, having an inner and an outer diameter. In one or more embodiments, the inner diameter can accommodate an elongated sub-sea structure, for example a riser, a tendon, or a pipeline. In one or more embodiments, the longitudinal axes of the housing 410 and the sub-sea structure can be coaxially aligned. In a hinged-body configuration, the housing 410 can extend from a first locking edge 432 to a second locking edge 434. When in a closed position, the first locking edge 432 of the housing 410 can abut the second locking edge 434 of the housing 410, thereby permitting the attachment of the housing 410 to a sub-sea structure.

[0048] The use of a flexible material for the housing 410 can enable the housing 410 to flexibly open, and close about, the sub-sea structure upon which the housing 410 is disposed. In one or more specific embodiments, the housing 410 can be a unitarily formed cylindrical structure. One or more fins 420 can be formed or helically attached about the circumference of the outer surface 416 forming the housing 410. The number of fins 420 most effective for reducing eddy formation is determined by the outer diameter of the housing 410. In one or more embodiments, the fins 420 can extend over the entire length of the housing 410 or any section/portion thereof. The number of fins 420 disposed on the housing 410 can range from 1 to 200, or from 1 to 150, or from 1 to 100, or from 5 to 60. The one or more fins 420 can be helically arranged or disposed in any pattern about the body 305. The fins 420 can have a projection from the surface 416 of the body 410 from about 0.05D to about 0.5D. The fins 420 can have a height ranging from a low of about 0.05D, about 0.1D, or about 0.15D to a high of about 0.2D, 0.25D, or 0.3D or more. As used herein “D” refers to the inner diameter 415 of the housing 410.

[0049] Each fin 420 can be integrally formed with the housing 410 or each fin 420 can be a separate component that is affixed, attached, or otherwise disposed on the outer surface of the housing 410. For example, the fins 420 can and the housing 410 can be integrally formed by injection molding, insert molding, or rotomolding techniques. If two or more materials are desired, 2K or 3K injection or insert molding techniques can be used. The fins 420 can be attached to the housing 410 using any suitable method, including, but not limited to epoxy or other adhesives, thermal fusion or bonding, fasteners, rivets, screws, nuts and bolts, welding, or any combination thereof. In one or more embodiments, the housing 410 can have one or more fins 420 that are integrally formed therewith and one or more fins 420 that are affixed, attached, or otherwise disposed thereon.

[0050] In one or more embodiments, one or more alignment stubs 450 can project outwardly from the exterior surface of the housing 410. In one or more embodiments, the alignment stubs 450 can serve as engagement members for an ROV (not shown). In one or more embodiments, the alignment stub 450 and the housing 410 can be integrally formed such that the alignment stub 450 is an extension of the housing 410. The physical shape and projection of the alignment stub 450 can be determined based upon the physical characteristics of the carrier, ROV, or deployment tool 100 used to deploy the strake 400. In one or more embodiments, the top surface of the alignment stub 450 can be rounded or tapered to aid in the engagement of alignment stub 450 by the ROV or deployment tool. In one or more embodiments, the alignment stub 450 can be centrally located on the housing 450. Locating the alignment stub 450 at a central point both longitudinally and laterally on the housing 410 can permit even distribution of the weight of the strake 400 on the ROV and/or deployment tool 100, increasing the stability of the ROV and/or deployment tool 100 while holding the strake 400.

[0051] FIG. 5 depicts a partial cross sectional view of an illustrative strake 400 as depicted in FIG. 4, according to one or more embodiments. In one or more embodiments, the two or more connector lugs 500 can be disposed on opposite sides of the longitudinal split on the exterior of the housing 410. In one or more embodiments, opposing pairs of complimentary connector lugs 500 can be disposed proximate the first 432 and the second 434 locking edges of the housing 410. In one or more embodiments, the one or more connector lugs have two side walls 510 extending perpendicularly from a housing 565 disposed parallel to the first 432 and second 434 locking edges. In one or more embodiments, the side walls 510 can be
parallel and spaced apart from each other as depicted in FIGS. 5 and 6. In one or more embodiments, one or more slots or apertures 515 can be disposed in either or both side walls 510 to permit the detachable attachment of the one or more connector lugs 500 to one or more connectors 190.

[0052] In one or more embodiments, each of the opposing connector lugs 500 can include one male (projecting) connector 550 disposed perpendicular to the first locking edge 432 and one female (receiving) 560 connector disposed perpendicular to the second locking edge 434. In one or more embodiments, the male connector 550 and female connector 560 can be as described in US 2008/005181.

[0053] As depicted in FIG. 5, the male connector 550 can be inserted into the opposing female connector 560. Inserting the male connector 550 into the opposing female connector 560 can hold the first locking edge 432 and the second locking edge 434 together, thereby locking the strake 400 in a closed position. In one or more embodiments, inserting the male connector 560 into the opposing female connector 550 can provide a separation-resistant connection between the male 560 and female 550 connectors. Although two male connector assemblies 550 and two female connector assemblies 560 are depicted on the strake 400 as depicted in FIG. 4, any number of similarly opposing male 550 and female 560 connector assemblies can be disposed on the strake 400. In one or more embodiments, the one or more male connectors 550 can be withdrawn or otherwise removed from the one or more female connectors 560, thereby permitting subsequent detachment of the strake 400 from a sub-sea structure. The separation of the one or more male connectors 550 from the one or more female connectors 560 without can permit the removal of the strake 400 from the sub-sea structure without causing damage to either the strake 400 or the sub-sea structure. In one or more embodiments, the force required to separate the male connector 550 from the female connector 560 can be about 3.6 kN (800 lb.) or more; about 4.4 kN (1,000 lb.) or more; about 5.3 kN (1,200 lb.) or more; or about 6.2 kN (1,400 lb.) or more.

[0054] FIG. 6 depicts an elevation view of the illustrative connector 190 inserted into an illustrative connector lug 500 according to one or more embodiments. For clarity, the male connector 550 and the female connector 560 are omitted from FIG. 6. The insertion of the one or more connectors 190 into the one or more connector lugs 500 disposed on or about the strake 400 can detachably attach the strake 400 to the deployment tool 100. In one or more embodiments, the attachment of the strake 400 to the deployment tool 100 can be performed by surface and/or ship-borne personnel and/or automated machines.

[0055] In one or more embodiments, the protrusions 300 on the connector 190 can be press-fitted into slots or apertures 515 in the parallel arms 510 of the connector lug 500. The sloped first profiled surface 335 of the protrusions 300 can assist in spreading the parallel arms 510 of the connector lug 500 a sufficient distance to permit the insertion of the protrusions 300 into the slots or apertures 515 in the parallel arms 510. After press-fitting the connectors 190 into the connecting lugs 500, the actuators 170 can be retracted to open the strake 400. The first portion 342 of the second sloped surface 340 of the one or more protrusions can have a sufficiently steep slope to prevent the disengagement of the connector 190 from the slots or apertures 515 in the parallel arms 510 of the connector lugs 500 when the actuators 170 are retracted.

[0056] FIG. 7 depicts a plan view of the deployment tool 100 depicted in FIG. 1 holding an open strake 400 proximate to an illustrative sub-sea structure 700 according to one or more embodiments. FIG. 8 depicts an isometric view of the deployment tool 100, strake 400, and sub-sea structure 700 depicted in FIG. 7 according to one or more embodiments. The strake 400 can be attached to the deployment tool 100 at the fabrication yard or on the vessel by ship-borne personnel. Referring to FIGS. 7 and 8, the strake 400 can be detachably attached to the deployment tool 100 by inserting the connectors 190 on the deployment tool 100 into the corresponding connector lugs 500 on the strake 400. In one or more embodiments, after attaching the connector lugs 500 to the connectors 190, the actuators 170 can be partially or completely retracted to open the strake 400. Opening the strake 400 can permit the placement of the strake 400 proximate the sub-sea structure 700 using the deployment tool 100 as depicted in FIGS. 7 and 8.

[0057] FIG. 9 depicts a plan view of the deployment tool 100 depicted in FIG. 1 attaching the strake 400 depicted in FIG. 4 to the sub-sea structure 700 according to one or more embodiments. FIG. 10 depicts an isometric view of the deployment tool 100, strake 400, and sub-sea structure 700 depicted in FIG. 9, according to one or more embodiments. Referring to FIGS. 9 and 10, after positioning the strake 400 proximate to the sub-sea structure 700, the one or more actuators 170 can be extended using the hydraulic interface 185. Extending the one or more actuators 170 can close the strake 400 thereby inserting the male connectors 550 into the opposing female connectors 560, attaching the strake 400 to the sub-sea structure 700.

[0058] FIG. 11 depicts a plan view of the deployment tool 100 depicted in FIG. 1 after attaching the strake 400 depicted in FIG. 4 to the sub-sea structure 700 according to one or more embodiments. FIG. 12 depicts an isometric view of the deployment tool 100, the strake 400, and the sub-sea structure 700 depicted in FIG. 11, according to one or more embodiments. Referring to FIGS. 11 and 12, the one or more actuators 170 on the deployment tool 100 can be partially or completely retracted using the hydraulic interface 185 after inserting the male connectors 550 into the opposing female connectors 560 and attaching the strake 400 to the sub-sea structure 700. Retracting the actuators 170 can cause the connectors 190 to withdraw from the connector lugs 500 thereby detaching the strake 400 from the deployment tool 100.

[0059] In one or more embodiments, the second portion 344 of the second profiled surface 340 of the protrusion 330 can assist in the separation of the one or more connectors 190 from the one or more lugs 400. As the actuator 170 is retracted, the second profiled surface 340 can contact the parallel arms 510 of the connector lug 500, causing the arms 510 to ride up the first portion 342 of the profiled surface 340 of the one or more protrusions 330. When the parallel arms 510 reach the less steeply sloped second portion 344 of the second profiled surface 340 of the protrusion 330, the connector 190 can detach from the one or more connector lugs 500. In one or more embodiments, the force required to separate the one or more connectors 190 from the one or more connector lugs 500 can be about 0.9 kN (200 lb.) or less; about 1.8 kN (400 lb.) or less; or about 2.7 kN (600 lb.) or less.

[0060] FIG. 13 depicts an isometric view of an illustrative platform 800 for storing or holding a deployment tool 100, according to one or more embodiments. The platform or rack
The second frame 880 can include one or more hanger arms 882 disposed thereon. Each hanger arm 882 can be extendable and retractable. Each hanger arm 882 can also include one or more attachment devices 885 for holding or otherwise engaging the deployment tool 100. Each attachment device 885 can include one or more rods, hooks, or similar devices complimentary to the one or more attachment devices 135 disposed on each deployment tool 100. For example, the equipment attachment device 885 can be a hook, and the complimentary attachment device 135 on each deployment tool 100 can be an aperture into which the hook can be securely inserted.

The second frame support 880 can also include one or more lifting lugs 890 disposed thereon. The lifting lug 890 can be connected to a crane, winch or similar equipment to permit the positioning of the platform 800. In one or more embodiments, the lifting lug 890 can be integral with, or attached to the second frame support 880 via welding, screwing, pinning or any other permanent or temporary means of attachment. In one or more embodiments, the lifting lug 890 can include a member having a plurality of holes for the insertion of the one or more cables, chains or similar devices connecting the platform 800 to a crane, winch or similar equipment.

The one or more support members 840 can be disposed in any order, arrangement and/or frequency about the frame 810. The one or more support members 840 can project from the frame 810 at the same angle or at different angles measured with respect to an upper surface 820 of the frame 810. Preferably, the support members 840 project normally, i.e. at 90°, measured with respect to the upper surface 820 of the frame 810. In one or more embodiments, the support members 840 can be extendable, permitting adjustment of the length of the support members 840 from the frame 810. Each support member 840 can be temporarily joined or affixed at a desired length using one or more connectors (not shown) including, but not limited to bolts, screws, pins or any combination thereof.

The first ("lower") frame 820, second ("upper") frame 880, and support members 840 can be made from a metallic, non-metallic or composite material, including but not limited to ferrous alloys, non-ferrous alloys, aluminum, engineered plastics, fiberglass, carbon fiber, fiber reinforced plastic (FRP), or any combination thereof. In one or more embodiments, one or more ribs or channels or other structural strengtheners can be incorporated in, on, or about the one or more first ("lower") frames 820, second ("upper") frames 880, and support members 840. In one or more embodiments, one or more corrosion resistant coatings can partially or completely encapsulate the one or more first ("lower") frames 820, second ("upper") frames 880, and support members 840.

FIG. 14 depicts an isometric view of the platform 800 depicted in FIG. 13 having a deployment tool 100 disposed thereon, according to one or more embodiments. As depicted, the deployment tool 100 can be hung or otherwise attached to the platform 800 via the attachment device 885 disposed on the one or more hanger arms 882. Although not shown in FIG. 14, two or more platforms 800 can be connected, either end-to-end or side-to-side, to provide additional capacity for additional deployment tools 100.

In operation, a surface or ship-borne crew can attach one or more underwater devices, i.e. the strakes 400, to one or more deployment tools 100. The deployment tools 100, each having one or more strakes 400 attached thereto can be attached to one or more platforms 800. In one or more embodiments, all or a portion of the deployment tools 100 can be attached to a platform 800 with the actuators 170 retracted and strake 400 in the open position or with the actuators 170 extended and the strake 400 in the closed position. In one or more embodiments, a crane or winch can be attached to the lifting lugs 890 of the platform 800. The crane or winch can position the platform 800 containing the one or more deployment tools 100 proximate the sub-sea structure 700, for example one or more tendons, risers, pipes, or platform legs.

After deploying the platform 800 proximate the sub-sea structure, the one or more deployment tools 100 can be removed from the platform 800 using a carrier to engage the one or more handles 180 and the hydraulic interface 185. As used herein, the term "carrier" can include, but is not limited to one or more divers, one or more remotely operated vehicles, manually operated submersible, robot, robot operated submersible, or any combination thereof. The carrier can maneuver the deployment tool 100 and strake 400 to a location proximate the sub-sea structure 700. After positioning the strake 400 on the sub-sea structure 700, the carrier can extend the one or more actuators 170. Extending the one or more actuators 170 can close the strake 400, to engage the male connector 550 with the opposing female connector 560.

After attaching the strake 400 to the sub-sea structure 700, the carrier can retract the one or more actuators 170. Retracting the one or more actuators 170 can disengage the connector 190 from the lug 500. The empty deployment tool 100 can be returned to the platform 800 by the carrier. The installation procedure can be repeated until all or any number of strakes 400 is installed. The platform 800 can be brought to the surface via the crane or winch and re-used.

In one or more embodiments, any component, part, or device described above including the entire tool 100, the body 105, support members 115, 130, connectors 190, or strake 400 can be at least partially made from a material, including, or having disposed thereon, one or more marine growth inhibitors ("anti fouling agents"). Anti fouling agents can be applied in any suitable form such as a solid or a liquid. The one or more anti fouling agents can be applied as or included within a coating, such as a paint, paste, lacquer, laminate, wax, gel, glue, epoxy, or resin; a solid, such as a foil, bar, rod, particulate powder, or a wire. Illustrative solid anti fouling agents can include copper, zinc, titanium, tin, tantalum, nickel, iron, alloys thereof, oxides thereof, and combinations thereof. Preferred alloys include copper/nickel and copper/beryllium alloys and other alloys known in the art to deter marine life growth. Illustrative, commercially available coatings or paints include, but are not limited to International Paint's Intersleek 900, Intersleek 700, Micron 66, Micron Extra, all available from International Paints; Trinidad, available from Pettit; ABC Release 670 and 671, available from PPG; and/or Flag CopperQuick Antifouling, and Flag Perfor-
mance Extra Antifouling, available from Flag Paint and Finishes. An antifouling system known by the trade name Cuproprotect can also be used.

[0070] Certain embodiments and features have been described using a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges from any lower limit to any upper limit are contemplated unless otherwise indicated. Certain lower limits, upper limits and ranges appear in one or more claims below. All numerical values are “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

[0071] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

[0072] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. An apparatus for installing underwater devices on sub-sea structures, comprising:
   a body having at least one pair of support members extending therefrom;
   at least one actuator disposed on each support member, wherein the actuator is adapted to move in a linear direction; and
   at least one connector disposed on each actuator.

2. The apparatus of claim 1, wherein the connector comprises a body having two spaced apart protrusions defining a void therebetween.

3. The apparatus of claim 2, wherein each protrusion comprises at least two tapered profiles disposed thereon.

4. The apparatus of claim 2, wherein each protrusion comprises a first profiled surface on a first end thereof and a second profiled surface on a second end thereof.

5. The apparatus of claim 2, wherein the connector comprises a threaded hole formed in the body for mounting on the actuator.

6. The apparatus of claim 1, wherein the body comprises at least two spaced apart structural members having a buoyant material disposed therebetween.

7. The apparatus of claim 1, wherein each support member is disposed normal to a first side of the frame.

8. The apparatus of claim 1, wherein the body comprises a first set of support members extending from a first end thereof and a second set of support members extending from a second end thereof.

9. The apparatus of claim 1, wherein the body further comprises a third set of support members extending therefrom, wherein the third set is located between the first and second.

10. A system for remotely installing one or more underwater devices on a sub-sea structure, comprising:
   a platform;
   at least one deployment tool detachably attached to the platform; and
   at least one or more underwater devices detachably attached to the one or more deployment tools.

11. The system of claim 10 further comprising at least one carrier for detaching the one or more deployment tools from the platform, detaching the one or more underwater devices from the deployment tool and returning the one or more deployment tools to the platform.

12. The system of claim 11, wherein the carrier comprises one or more divers, one or more remotely operated vehicles, or any combination thereof.

13. The system of claim 11, wherein the one or more underwater devices remain attached to a sub-sea structure.

14. The system of claim 10, wherein the one or more underwater devices comprise strakes, fairings, or any combination thereof.

15. A method for remotely installing underwater devices on sub-sea structures, comprising:
   detachably attaching one or more open underwater devices to one or more deployment tools;
   detachably attaching the one or more deployment tools to a platform;
   disposing the platform proximate to a sub-sea structure;
   removing the one or more deployment tools from the platform using a carrier;
   disposing the one or more deployment tools proximate to a sub-sea structure using the carrier;
   closing the one or more open underwater devices held by the one or more deployment tools about the sub-sea structure using the carrier;
   releasing the underwater device from the deployment tool wherein the closed underwater device remains attached to the sub-sea structure; and
   returning the deployment tool to the platform.

16. The method of claim 15, wherein the carrier comprises one or more divers, one or more remotely operated vehicles, or any combination thereof.

17. The method of claim 15, wherein the one or more underwater devices comprise strakes, fairings, or any combination thereof.

18. The method of claim 15, wherein the one or more underwater devices are released from the deployment tool using one or more hydraulic actuators, one or more electric actuators, or one or more mechanical actuators.

19. The method of claim 15, wherein the platform is disposed proximate to the sub-sea structure using a surface mounted crane or winch.

20. The method of claim 15 further comprising:
   returning the platform and the one or more deployment tools to the surface after disposing the one or more underwater devices on the sub-sea structure.

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