

**SYSTEM AND METHOD FOR ENVELOPING FLOATING STRUCTURES IN
DEEP OPEN WATER**

Field of Invention

[0001] The present invention addresses to the development of a solution for enveloping the hull of a vessel or stationary floating structure offshore, far from the support of a pier or dock, reducing the need for diving.

[0002] This invention pertains to the field of enveloping activities for floating marine structures, aiming at the rescue of these structures, which may be in the process of decommissioning, or completing an assembly and commissioning process.

Description of the State of the Art

[0003] Any water surface, from rocks to boat hulls or port pillars, is subject to the deposit of materials, the so-called fouling, which are visibly noticeable when going to a beach, or on a pier, for example. This fouling can be inorganic, formed mainly by the deposit of salts in marine environments, or biological, in which a bacterial film is formed that serves as a base for larger species to settle in these structures.

[0004] Even though it is a natural phenomenon, the presence of fouling causes major disruptions. Firstly, it causes an economic problem, as the deposits increase the vessels' friction with the water, increasing drag when sailing, making maneuvering difficult and increasing fuel consumption. Another important problem is environmental, directly related to the contamination of the seas with substances harmful to marine and human life, not to mention the so-called bioinvasion, which is the insertion of new

species into ecosystems by ships through fouling.

[0005] With vessels traveling to increasingly distant places with different biodiversity, biofouling, in other words, small animals that live in the hulls of vessels are transported to different places. In these places, these exogenous species can find a suitable environment to develop and no impediment to the unbridled growth of their population, putting biodiversity at risk.

[0006] Among the environmental problems, there are also those caused by antifouling agents, which are mostly paints that prevent or minimize fouling, but which in turn have organic and inorganic contaminants in their composition and which, when released from the ships when cleaning their hulls, contaminate the seas with traces of metallic elements and organometallic compounds originating from antifouling paints.

[0007] As an alternative to surface treatment techniques with antifouling paints, some companies present products for encapsulating small vessels. The Australian company Flexitank offers the Flexidock™ product, which promotes the encapsulation of vessels from 20 to 45 feet (6,096 to 13,716 meters) (such as yachts, catamarans). Once the ship is anchored and encapsulated with a PVC or PU blanket, the automatic pumping system is activated and the rest is controlled by the Flexidock™, which allows the boat to float on a layer of air, remaining at sea level. Thus, the vessel becomes dry, protecting the vessel's hull from biofouling.

[0008] Another Australian product, Barnacle Barrier™, also promotes the encapsulation of sport boats

that spend much of their time anchored at piers. It works as follows: a canvas made of flexible composite polymers is inserted into the water, the boat passes over it and a pump connected to the system removes all the encapsulated water, allowing the hull to become completely dry, causing the death of biofouling organisms.

[0009] Document BR102016022468-3A2 discloses a technique for enveloping marine structures to prevent and/or eliminate biofouling. The work provides a method and system for enveloping a floating marine structure, which allows the envelope to be positioned safely under its hull and eliminates the need for several support vessels. Despite describing the enveloping of marine structures, the document has a complex positioning method that depends on the assistance of divers.

[0010] Document AU707725B2 discloses antifouling devices for boat hulls and, more particularly, a floating compartment assembly for protecting against marine growth from the underside of a moored boat. Despite inhibiting the appearance of fouling, its use is only viable in sheltered waters and restricted to smaller structures.

[0011] Document US5279244A discloses an antifouling protector in the form of a flexible envelope complementary to the underwater body of a vessel's hull. Despite inhibiting the appearance of fouling, its use is only viable in sheltered waters and restricted to smaller structures.

[0012] In general, existing enveloping solutions are applicable for small vessels in marinas. In this case, the fabric that makes up the envelope is initially extended and fixed to the bottom of the marina and the boat sails until

it is positioned on the fabric. Then, using different mechanisms, the fabric is lifted, isolating the boat.

[0013] The envelope of this invention is made up of a composite, a multiphase compound that combines two or more non-soluble constituents, which are materials that contain reinforcement, such as fibers and particles, supported by a binder matrix.

[0014] The properties of composites are controlled by the properties of their constituent materials, contents, distributions and geometries of the reinforcements. The anisotropy characteristics of a composite are greatly influenced by the orientation of the reinforcement. These composites are characterized by their good thermal insulation properties, their durability, even in chemically aggressive environments, flexibility, mechanical strength, waterproofing, and by allowing the combination of different materials, enabling the creation of relatively complex composites.

[0015] The composite fabric is made up of two phases: the matrix (protective layer), which is continuous and that involves the dispersed phase (fibers). The matrix and fibers work together, but perform different structural tasks. The fibers are responsible for the great tensile strength and stability of the material, they can be positioned parallel or twisted, constituting the threads, which are subsequently woven and form the uniform and fine mesh of the structural fabric. The polymeric covering or matrix consists of different superimposed layers of polymers, on both sides of the fabric. These are the chemical protection of the fibers and surface treatment (sealer or painting) against

ultraviolet radiation (UV), abrasion, weather, fungi and flames, in addition to enabling waterproofing, stability and hot welding.

[0016] Typically, the composite fabric is formed by a weave of some extremely resistant thread (for example polyester or carbon fiber), which is wrapped on both sides by one or more polymeric layers, which can be the same (for example PVC/PVC), or different ones (for example PCV/Alcrin).

[0017] The great technological challenge arises from the great effort that a composite fabric is subjected to when being extended beneath the vessel. All known experiments resulted in the tearing of the tissue, either by effort or by the action of rebounds on the hull or the fouled organisms themselves. Other challenges are the dragging of an area of hundreds of square meters under a hull in the water, the sailing effect caused by the current and, subsequently, the removal of the flexible composite fabric.

[0018] Given the difficulties present in the State of the Art, for enveloping solutions for large floating structures, there is a need to develop a technology capable of presenting effective performance and that is in accordance with current environmental guidelines. The works mentioned in the State of the Art do not have the unique features that will be presented in detail below.

Brief Description of the Invention

[0019] The main objective of the present invention is to cover and isolate the hull of stationary floating structures positioned offshore, with the difference being the use of a composite fabric, with all the artifacts and

systems necessary for enveloping arranged in a compact package, positioned collapsed beneath the floating structure. Another difference is the fact that the envelope is extended by teleoperation and is developed by inflating caissons with a cross section that is not necessarily circular, creating a type of immersed hull, made of composite fabric. Also, by using teleoperation, the envelope is lifted until it is fitted into the floating structure, isolating the same. The envelope is removed by the reverse operation, being sunk again, deflated and compacted. Furthermore, the fact that enveloping is a remotely assisted and teleoperated operation reduces the need for diving.

Brief Description of the Drawings

[0020] The present invention will be described in more detail below, with reference to the attached figures that, in a schematic way and not limiting the inventive scope, represent examples of its embodiment. In the drawings, there are:

- Figure 1 illustrates the folded and compacted envelope system;
- Figure 2 illustrates the expansion of the envelope system;
- Figure 3 illustrates a front view of the installed system;
- Figure 4 illustrates views of the structure of the envelope system;
- Figure 5 illustrates a detail of the main structural element of the envelope system;
- Figure 6 illustrates the gummed envelope in its minimum expansion;

- Figure 7 illustrates the tubular elements with dimensional variation;
- Figure 8 illustrates a detail of the main element of the gummed envelope system;
- Figure 9 illustrates the gummed envelope extended at its maximum expansion;
- Figure 10 illustrates the extended dimensional variation tubular elements;
- Figure 11 illustrates the main element of the extended gummed envelope system.

Detailed Description of the Invention

[0021] The present invention provides a system and a method for enveloping floating structures anchored in open and deep waters, far from the support of any pier or dock, using an envelope composed of flexible composite fabric that can subsequently be removed, performing such operations with reduced need for diving.

[0022] The target applications are floating structures in the process of decommissioning, or that are completing the assembly and commissioning process in locations subject to fouling by undesirable sessile bio-organisms. In addition to these applications, this solution can be useful in emergency, maintenance, or other equivalent situations.

[0023] The composite fabric and all artifacts and systems necessary for enveloping used in this invention are in a compact package, which is positioned collapsed beneath the floating structure. The envelope is extended by teleoperation and develops by inflating caissons, creating a kind of immersed hull, made of composite fabric. Also using

teleoperation, the envelope is lifted until it is fitted into the floating structure, isolating the same, and is then removed using a reverse operation. With this procedure, the composite fabric is not subjected to stresses exceeding specification limits, nor does it touch the hull, as it is unfolded and extended a few meters below the keel. The envelope, when lifted to involve the hull, has fenders that prevent the composite fabric from dragging on the hull, or being punctured or cut by a protrusion. To remove the same, it is then sunk again, deflated and compacted.

[0024] The development of the envelope system disclosed herein was due to the search for better performance in combating and helping to mitigate bio-invasion and biofouling events, providing a more environmentally effective system in relation to other products available on the market, such as TBT paints, Teflon-based paints and biomimetic surfaces. The application of this new solution to fight against fouling organisms is in line with environmental standards, which avoids paying fines, preserving the native ecosystem (originating in the location) and avoiding the reduction of biodiversity.

[0025] This invention was initially developed with a focus on eliminating biofouling organisms. However, the proposed system has several other applications, allowing remote/teleoperated robotic devices to be manipulated in the space between the hull and the envelope. These devices are used in inspection, scraping, repair or painting operations. The envelope of this invention can also be used to contain leaks that need to be completely isolated, preventing them from spreading beneath conventional barriers. The invention

allows an FPSO that is enveloped to be moved with the help of tugboats, without the need for a heavy lift. The invention also presents a solution for the construction of an envelope with variable dimensions, as well as for the construction of an envelope that can be assembled in sessions. The shape of the envelope described in this invention, when unfolded and inflated, takes on the shape of a hull; however, with the possibilities of dimensional variation, its application in a semi-submersible unit is possible.

[0026] There follows below a detailed description of a preferred embodiment of the present invention, which is exemplary and in no way limiting. Nevertheless, it will be clear to a technician skilled on the subject, from reading this description, possible additional embodiments of the present invention, still comprised by the essential and optional features.

[0027] In Figure 1, the system launched under the vessel to be enveloped, floating structure (1), is represented, with the envelope (2) folded and compacted. This system is fixed by using positioning cables (10) to the moorings (11) of the floating structure (1). When the compressors located on the support vessel (3) are activated, the flexible composite fabric caissons are inflated.

[0028] In the method of this invention, according to Figure 1, the entire compacted enveloping system (2) is transported to the location where the floating structure (1) is located by a support vessel (3), or other means transport prepared for the service.

[0029] The support vessel (3) is provided with an electrical power unit (4), monitoring and control equipment,

compressed air, and water pumping. The envelope system (2) contains, in addition to the envelope itself made of flexible waterproof composite fabric, positioning and attitude sensors (6), traction and pressure sensors (7), a set of hydraulic and pneumatic connections and valves (8), tensioning straps (9), which ensure balanced lifting during water and air filling, and positioning cables (10). There is also an umbilical (5) that connects the envelope to the equipment located on the support boat (3), to command and control the unfolding of the package into the envelope.

[0030] In Figure 2, the expansion of the envelope system (2) is demonstrated, exemplifying the beginning of the opening process and development of the envelope structure to be applied to the floating structure (1), initially connected to the support vessel (3).

[0031] Figure 3 presents a front perspective view of the arrangement, representing the enveloped floating structure (1), the envelope system (2), and the support vessel (3). In this view, the floating structure (1) is already enveloped and the envelope (2) is already structured and installed.

[0032] Figure 4 represents views of the structure of the model of the simple envelope system (2), formed by the union of the caissons (12), thus constituting a channel (13). Also shown are the front closure (14) and rear closure (15) of the structure, which are made with waterproof flexible composite fabric curtains.

[0033] A single caisson (12) is represented in Figure 5 in perspective of a single U-shaped structural element, with floating fenders (16) at the top of each of the two

legs (17) of the caisson. Item (19) corresponds to the horizontal section of the caisson.

[0034] The floating fenders (16) prevent the composite fabric from coming into contact with the hull. The channel (13) formed by the union of the caissons (12) is exactly the space where the envelope will contain the vessel or floating structure (1). The floating structure (1), fenders (16), and caissons (12) assembly forms an integrated whole, capable of resisting waves and tides.

[0035] Figure 6 and the following present, in detail, the gummed envelope system, which allows a variation in longitudinal and transverse dimensions. The gummed envelope is made up of internal closing membranes, which correspond to sections of another type of fabric that closes the space between the caissons, since the caissons can be moved apart by inflating spacer tubes.

[0036] Figure 6 presents the configuration at minimum expansion of the gummed envelope (20). Elements called flexible tubular units with spacer tubes (18) are united to form the gummed envelope. Also shown are the front closure (14) and rear closure (15) of the structure.

[0037] Figure 7 illustrates the detail of the elements called flexible tubular units with spacer tubes (18), also representing the gummed envelope with minimal expansion (20) and the front closure curtains (14).

[0038] Figure 8 shows the detail of the U-shaped caisson with the two legs (17), the fenders (16) at the top of each of the two legs (17), spacer tubes (18), longitudinal spacer tubes (21), and transverse spacer tubes (22). Item (19) corresponds to the horizontal section of the caisson,

and item (23) corresponds to the vertical section of the gummed caisson.

[0039] Figure 9 illustrates the maximum expansion of the gummed envelope (24), with the front closure (14) and the rear closure (15) of the structure and the spacer tubes (18).

[0040] In the detail of Figure 10, the flexible tubular units with the spacer tubes (18) are united in order to constitute the gummed envelope at its maximum expansion (24). The front closure (14) of the structure and the internal closing membranes (25) are also represented.

[0041] Figure 11 represents the two legs (17) of the U-shaped caisson, the fenders (16) at the top of each of the two legs (17), spacer tubes (18), longitudinal spacer tubes (21), and transverse spacer tubes (22). Item (19) corresponds to the horizontal section of the caisson and item (23) corresponds to the vertical section of the gummed caisson.

[0042] The caissons (12) are inflated with seawater. The fenders (16) with air, pumps and compressors are on the support boat (3) and, therefore, there are pipelines (5) and valves (8) that transfer the fluids to the respective caissons (12) and the respective fenders (16), controlled by computer-sequenced valves.

[0043] The caissons (12) and the tubular structures responsible for the dimensional variation (longitudinal spacer tubes (21) and transverse spacer tubes (22)) are inflated with seawater. In this way, the assembly has a density slightly greater than that of seawater. The fenders (16) are inflated with compressed air, creating a "float" at the top. In this way, the assembly rises and floats, with

the fenders above the water surface.

[0044] The envelope models represented in their minimum (20) and maximum (24) expanded configurations comprise a flexible tubular structure (12), made of waterproof and resistant composite fabric, coating membranes (25) and front (14) and rear (15) closure membranes, fluid pipelines (5), valves and connections (8), and their control actuator systems (6 and 7). This watertight tubular structure is inflated with water and the fenders (16) with compressed air, in a controlled volume and pressure manner, to guarantee its buoyancy and stability.

[0045] The development of this new technology increases the operational safety of the various vessels that support the operation and support oil production. Furthermore, the fact that enveloping is a remotely assisted and teleoperated operation eliminates the need for diving. It also ends up introducing a new dimension in the reliability of floating oil production systems, providing alternatives for solving biofouling and other risk situations.

CLAIMS

1. A SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS, characterized in that it comprises simple envelopes (2) and gummed envelopes (20 and 24), at least one caisson (12), formed by a single structural element, with a front closure (14) and a rear closure (15).

2. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 1, characterized in that the caisson (12) has at least one floating fender (16) at the top of each of the vertical sections (23).

3. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 1 or 2, characterized in that the caisson (12) comprises a pipeline with a circular cross section, not being restricted to this model.

4. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to any of the previous claims, characterized in that the union of the caissons (12) is carried out together in the simple envelope (2) and by flexible tubular units with spacer tubes (18, 21 and 22) in the gummed envelope (20 and 24).

5. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 4, characterized in that the union of the caissons (12) is carried out by coating membranes (25) and by front (14) and rear (15) closures, with waterproof composite fabric curtains.

6. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 4, characterized in that the union of the caissons (12) forms a channel (13).

7. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 1, characterized in

that the simple (2) and gummed (20 and 24) envelopes are made of composite fabric.

8. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 7, characterized in that the composite fabric of the simple (2) and gummed (20 and 24) envelopes is composed of at least two phases, a continuous polymeric matrix phase with special additives and a braided fiber phase.

9. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claims 7 and 8, characterized in that the composite fabric of the simple (2) and gummed (20 and 24) envelopes enables chemical protection, waterproofing, heat stability, and repair.

10. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 1, characterized in that simple (2) and gummed (20 and 24) envelopes can be emptied, folded and compacted.

11. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 1, characterized in that the envelope is instrumented, provided with control valves (8), tensioning straps (9) and floating fenders (16).

12. THE SYSTEM FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 1, characterized in that the envelope is assembled in sessions.

13. A METHOD FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS, using the system as defined in claim 1, characterized in that it comprises the following steps:

a) transporting the entire envelope system (2) to the location where the floating structure (1) is located by a support vessel (3);

b) positioning the envelope in its compacted and empty mode (2) beneath the floating structure (1);

c) fixing the envelope in its compacted and empty mode (2) to the moorings (11) of the floating structure (1);

d) activating the compressors to inflate the caissons (12) and the flexible tubular units in the first simple envelope model (2), or in the second gummed envelope model (20 and 24).

14. THE METHOD FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 13, characterized in that, in step d), through the use of pumps, the injection of seawater occurs in a controlled manner in volume and pressure.

15. THE METHOD FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 13, characterized in that the activation of the envelope (2) is carried out in a remotely assisted and teleoperated manner.

16. THE METHOD FOR ENVELOPING FLOATING STRUCTURES IN OPEN AND DEEP WATERS according to claim 13, characterized in that it uses, but is not restricted to, a support vessel (3) provided with a dedicated unit (4) of electrical energy, monitoring and control, compressed air, and water pumping.