Innovative solutions based on CAD of the protective barrier systems architecture for maritime disasters

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Abstract. Pollution of the waters of the planetary ocean is due both to the evacuation of waste water from industrial units along the sea, as well as to the operational or accidental losses that have occurred in the process of oil marine exploitation and the uncontrolled evacuation of the sentries of ships in traffic or stationary. Nowadays, in order to limit the effects of pollution, inflatable and non-inflatable systems based on composite structures are used in all riverside countries of the seas and oceans. The textile material covered with elastomeric mixture made up of special ingredients has proved to be a very successful material for marine environment applications. For establishing the design principles of a composite material, as part of a barrier protection system made of floating surface elements, used in dynamic conditions (for accidental pollution), in open water (offshore), a specialized software that enables the definition of the calculation parameters, accomplishment of the effective calculations, processing, visualization and the export of the numerical data was used.

1. Introduction

Stopping the current decline in the quality of environmental factors and applying ecological reconstruction measures is a priority for surface waters. Pollution of the waters of the planetary ocean is due both to the evacuation of waste water from industrial units along the sea, as well as to the operational or accidental losses that have occurred in the process of oil marine exploitation and the uncontrolled evacuation of the sentries of ships in traffic or stationary. The celerity of action in the occurrence of serious pollution cases is vitally important. Awareness of the human factor can ensure the maintenance of that fragile and unstable balance between human society and the environment [1]. In this activity must be attracted both indigenous specialists, from the companies that produce depollution equipment, and from other countries in order to present the latest realization in the field, as the efficiency of the intervention depends a lot on the use of advanced equipment and technologies [2]. It is also necessary to permanently update the river and maritime intervention plans, in case of pollution of the aquatic environment.

For the construction of ecological systems intended to limit the effects of pollution, textile materials covered with flexible polymers having high mechanical strengths, and resistance both to the action of chemicals and to the perforation and abrasion are required [3]. The selection and usage of a textile material for the reinforcement are conditioned by the level of performances of the mechanical and chemical characteristics represented by the resistance to traction, compression, shear or torsion, thermo-mechanical resistance, thermal stability, chemical inertia. Considering the strains to which the woven supports are subjected during the process for the composite
system accomplishment, following basic properties are required: very good mechanical strengths, flexibility; resistance to accelerated aging. The combination between a textile material and a polymer, leads to a composite structure with new properties and improved functionality that maintain the performances of the basic components. The softness of the textile material is related to the very small diameter of the elemental fibers and the flexibility of the polymer is given by its physico-chemical nature. The new structure that represents the result of the combination between these two materials could be placed into the large class of the composites that enable the capitalization of two characteristics of polymers reinforced with textiles, related to the fluid tightness and to the capacity of the polymer that represents the continuous medium to ideally supports the deformations of the textile support that is discontinuous in nature. Nowadays, in order to limit the effects of pollution, inflatable and non-inflatable systems based on textile composite structures are used in all riverside countries of the seas and oceans [4]. The textile material covered with elastomeric mixture made up of special ingredients has proved to be a very successful material for marine environment applications. The protective-barrier systems, so called “anti-oil dams”, aim to limit/seal of a polluted surface and are currently used for maintaining of the petroleum film in a delimited area in order to prevent the uncontrolled spread and movement of hydrocarbons on the water surface; facilitating the operations for hydrocarbon recovery and for hydrocarbon film guidance to the recovery units [5].

Floating anti-oil dams are presented as a continuous "curtain", consisting of:

a) Free board that follows the wave ensuring the buoyancy of the system.
b) Skirt that does not allow the pollutant to move in the water, below the dam.
c) Ballast chain intended to keep the dam upright (to maintain the skirt in the extended position).
d) Basic segment that represents a dam portion of a certain length.
e) Metal system for fast coupling.
f) Auxiliary system for fixing and towing the entire dam consisting of anchors, fixing cables etc.

2. Material and methods

For establishing the design principles of a composite material, as part of a barrier protection system made of floating surface elements, used in dynamic conditions (for accidental pollution), in open water (offshore), a specialized software that enables the definition of the calculation parameters, accomplishment of the effective calculations, processing, visualization and the export of the numerical data was used. During the pre-processing stage, the following specific structural parameters were defined: units system, referential system, geometry of the structure, type of material from the structure of the composite material, structure discretisation element type, analysis type and outline conditions. On the processing and post processing stages, the visualisation of the phenomena taking places at the composite structure level was possible via the included solver that also enabled the evaluation of the structural parameters variation intervals.

The structural analysis was performed based on the theories of the mechanics of continuous medium for two cases, considering the wind force at 6 and 8 bf. It was considered that the composite structure is a continuous, impermeable medium that fills a certain area of space, so that in every geometric point there is a material point of the environment [6].

Under these conditions, the geometry of the floating element was discretized into a series of finite elements having the elementary mass, where the continuity property imposed the existence of the mass density. It must be emphasized from the beginning that the structural analysis was based upon the real exploitation conditions, so that the entire configuration should have been considered as being elastic [6]. The contour idealization was made possible by the sketcher module within the multi-platform software suite. The result was a 2D element shape (figure 1, figure 2) that represented the starting point for the 3D model to be subjected to structural analysis.

The following input data were considered: - predefined profile: rectangle, circle; - dimensional constraints: length: 1500 mm/diameter: 500 mm.
The obtained geometry was evaluated based on the constraints analyses, and it was demonstrated that it is well defined, having: an implicit closed profile and Iso-Constrained diagnostic for construction and constrains (lines, points, circles, offset, radius).

**Figure 1.** Sketch of the floating structure.

**Figure 2.** Sketch of the skirt structure.

The Part Design module enabled both to obtain the 3D image of the model (figure 3) and the visualisation of the system sizing (figure 4).

**Figure 3.** 3D model - Multi-view edges.

**Figure 4.** Floating element with the metal system for fast coupling.

Generative Structural Analysis module highlighted the behaviour of the composite structure virtual model as a component of the analysed system, under the static and dynamic conditions. The calculation and simulation were performed by using FEM, and by establishing the values of the constituent elements of the discretization network, respectively:

- for discretization [7] (mesh): finite element size: 5 mm; maximum tolerance between the real and the discretized model: 0.1 mm; minimum finite element size: 0.01 mm; element type: linear (4 nodes, 1 Gauss point, 3 degrees of freedom).
- constraints: for each face of the geometry [8].

Considering the Beaufort wind force scale 6, the simulation was performed under the following conditions: wind speed: 22 - 27 knots (10.8 – 13.8 m/s); state of the sea: large waves being to form and the white foam crests are extensive everywhere; at the ground level: large branches in motion; - distributed pressure: 2800 N/m²; force distributed on vertical surfaces: 2000 N; force distributed on the horizontal surface: 1500 N (figure 5).

The obtained results for distribution of the displacement vectors were between [0; 12.8] mm and could be visualised in the figure 6.

Using the input data presented above, with the help of the program solver it was determined the deformation of the structure under the effect of dynamic pressure (figure 7).

The stress state for composite structure was predicted using the Von Mises criterion [9]: the theoretical value that allows the comparison between the general tri-dimensional stress with the uniaxial stress yield limit. From the mathematical point of view, the limit can be achieved when the second invariant of the stress tensor reaches a point at the value of a tangential force. For this situation, the obtained nodal values were [1.94e-009; 1.22e+006] N_m².

Estimated local error: [9.77e-038; 1.73e-005]J.
The second case analysed through simulation was related to the Beaufort wind force scale of 8. The conditions were: wind speed: 34 - 40 knots (17.2 – 20.7 m/s); state of the sea: moderately high waves of greater length, foam is blown in well-marked streaks along the direction of the wind; at the ground level: twigs break off trees; distributed pressure: 7800N/m2; force distributed on vertical surfaces: 7000 N; force distributed on the horizontal surface: 5500 N. Following the same algorithm as it has been already detailed above, the calculation and simulation were performed with the help of FEM, thus determining: deformation of the structure under the effect of dynamic pressure (figure 8), the Von Mises nodal values (figure 9) and the estimated local errors (figure 9).

In order to determine the values of the density in the warp and the weft of the textile structures intended for the floating element of the barrier protection system, the linearization of the solution for small amplitude waves (6bf) that implicitly leads to neglecting the slope of the free surface and the membrane vibration (boundary conditions) were considered [10].
3. Results and discussion
Under these conditions, for the floating element of the barrier protection system the resistance surface is 1500 square meters and the shock force (depending on the Beaufort scale with the highest value, up to the destruction of the system) is 10,000 N.

The safety coefficients that influence the composite structure have the following values: the safety coefficient: 1.40; the dynamic loading coefficient: 1.40; the asymmetric loading coefficient: 2.80; fatigue: 2.60; the environmental factors: 3.30. In these conditions the required static breaking force becomes $F_s \approx 461.3$ daN/5cm.

For the fabric thicknesses calculation, it was considered that:
- After the warping process, the value of the breaking force decreases with 3%, so the value of the yarn breaking force subjected to this operation that must be taken into account is of 80 N.
- The participation yarn breaking resistance coefficient in the fabric breaking resistance should be 1.8.

In these conditions the fabric density is: 12 - 15 threads/cm and the value selected for both system is 14 threads/10 cm.

As a permanent ecological system for the control and limitation of pollution, the accomplishment of the composite structure should take into consideration additional factors represented by the action of the solar radiation and the chemical products, the impact and the shocks created by the combined action of the waves, the winds and the sea currents. The experiments will be performed under real conditions of use in Military Harbor 0 of Constanta Port, in an area polluted by the Naval Shipyard.

4. Conclusion
The structural analysis performed for two different conditions of sea agitation, was based on the theories of the mechanics of continuous medium. The values resulting from the structural analysis allowed the definition of the main design parameters of the composite material used in the realization of the floating elements - as part of the entire protective-barrier systems.

The experiments will be performed under real conditions in an area polluted by the Naval Shipyard.

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