Textile structures for limiting the effects of maritime and fluvial disasters

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ABSTRACT – REZUMAT

Textile structures for limiting the effects of maritime and fluvial disasters

Water is essential for the lives of humans, animals and plants, while representing an indispensable resource for the economy, and its management goes beyond national borders. Water pollution with oil residues affects both surface water and groundwater; its consequences on the organoleptic properties of water, aquatic fauna and flora are particularly damaging for all ecosystems and their biodiversity.
Mechanical recovery of the pollutant provides, according to the international norms, the limitation of the polluted surface and the concentration of the pollutant in order to recover and store the water-hydrocarbon mixture, with limits related to the agitation of the marine/fluvial environment and distance from the intervention base to the polluted area. The choice of blocking/storage systems must take into account several factors, such as type and amount of pollutant recovered, the flow of recovery units, area of use, hydro-weather conditions in the field, mode of transport and mode of location in terrain.
This study presents the constructive solutions for the dams made of textile materials, used in case of disasters in the maritime and fluvial area.
Post-processing of data, performed with the help of IBM multiplatform software suite, highlighted the variation intervals of the structural parameters for 7 composite materials differentiated by: location, mass, raw material, thickness and thermal resistance.
These composites were the basis for computer-aided designs of 14 experimental models (EM), differentiated by the dimensions used, the materials of the floats, the skirt and the area of use (maritime from 4bf to 10 bf or fluvial).

Keywords: *3D simulation, CAD, digitized technology, woven fabrics, design engineering, pattern*

Structuri textile pentru limitarea efectelor dezastrelor maritime și fluviale

Apa este esențială pentru viața oamenilor, a animalelor și a plantelor, reprezentând, în același timp, o resursă indispensabilă pentru economie, iar gestionarea sa depășește frontierele naționale. Poluarea apei cu reziduuri petroliere afectează atât apele de suprafață, cât și pe cele subterane, acest gen de poluare a devenit ubicuitar, iar consecințele ei asupra proprietăților organoleptice ale apei, faunei și florei acvatice sunt deosebit de nocive și durabile.
Recuperarea mecanică a poluantului prevede, conform normelor internaționale, în primul rând limitarea suprafeței poluate și concentrarea poluantului în vederea recuperării și stocării amestecului apa-hidrocarburi, desigur cu limite legate de: starea de agitație a mediului marin/fluvial și distanța de la baza de intervenție la zona poluată. Alegerea sistemelor de blocare/stocare trebuie să țină cont de mai mulți factori, cum ar fi: tipul și cantitatea de poluant recuperate, debitul unităților de recuperare, zona de utilizare, condițiile hidro-meteo din teren, modalitatea de transport și modalitatea de amplasare în teren.
Lucrarea prezintă soluțiile constructive pentru barajele realizate din materiale textile, utilizate în caz de dezastre atât în zona maritimă, cât și în cea fluvială. Postprocesarea datelor, realizată cu ajutorul multiplatformei IBM a evidențiat intervalele de variație ale parametrilor structurali pentru cele 7 variante de materiale compozite diferențiate prin: zona de amplasare, masa, materie primă, grosime și rezistența termică. Aceste materiale compzite au constituit baza proiectării CAD a 14 modele experimentale, diferențiate prin: tipo-dimesiunile utilizate, materialele textile din componența flotorilor, jupei și arealul de utilizare (maritime de la 4bf până la 10 bf sau fluvial).

Cuvinte-cheie: *simulare 3D, CAD, tehnologie digitizată, țesături, inginerie asistată, tipar*

INTRODUCTION

Water pollution with oil residues is a very important problem; it is difficult to prevent and remedy, and it affects both surface water and groundwater. Pollution of the marine environment with hydrocarbons is a worrying phenomenon, which has taken an unprecedented scale since the 1960s. The sources and causes of pollution have multiplied year by year in proportion to the emergence and proliferation of risk factors, especially between the 1970s and the 1980s. Incidents in drilling, extraction, transport, transfer operations, loading/unloading, refining, storage, etc. have generated imminent risks, given the dangerous properties of oil and petroleum products. In addition, marine oil pollution may be caused by acts of war against shore-side oil installations [1, 2]. The choice of separation and storage systems must take into account several factors, such as the type and amount of recovered pollutant, the flow of recovery units, area of use, hydro-meteorological conditions in the field, mode of transport and mode of location/placement.

The floating element is in the form of a continuous "curtain" and consists of:

- the freeboard that follows the shape of the wave;
- the skirt that does not allow the pollutant to move in the water and is fixed under the floating element;
- auxiliary systems for fixing the floating elements to each other, maintaining the floating element and the extended skirt in a horizontal position (ballast and chaining), coupling elements.

To describe the phenomena that arise when the fluid is isolated from a floating structure that delimits a mixture (e.g., water and hydrocarbons in open space) and to be able to clearly predict the efficiency of the gravitational storage-separation system, it is necessary to take into account the theories regarding the type of wave, the shape of the seabed and the dimensions of the floating superstructure [3].

Starting from the fundamental theory of system construction, the theories of Fluid Mechanics were studied, which allowed the determination of potential equations for small-amplitude waves and the equilibrium equations for the trochoidal waves (unde multi-direction Gerstner wave with solutions for the Stokes waves).

These led to the conclusion that, for the realization of water-hydrocarbon mixture separation-storage systems, textile structures with a mass of 180 m^2 – 400 g/m^2, thicknesses of 0.2–0.5 mm and thermal resistance of 0.071 m^2K/W (for the balance heat flow in summer or in the situation when it passes from the inside to the outside, during winter) must be used [4, 5].

The structural analysis performed was based on the theories of continuous media mechanics. In other words, the textile structure was considered a continuous, impermeable environment that fills a certain area of space, so that in each of its geometric points, there is a material point of the environment. The woven textiles under analysis contain cotton, polyester (PES), polyamide (PA) and polyamide 6.6 (PA6.6) yarns, with tenacity values of min. 0.60 N/tex and max. 12.4 N/tex, loop resistance of min. 100 N, knot strength of min. 80 N.

The calculation and simulation were performed using the finite element method (FEM), establishing the values of the constituent elements for mesh and the real exploitation conditions of the marine environment (the state of agitation of the sea at 4bf, 6bf, 7bf and 10bf, which implies a wind speed of 11–55 kt (20–102 km/h), wave height from 1.5 m to 12 m and distributed pressures starting with 1500 N/m^2 and increasing up to 12000 N/m^2, respectively).

Thus, by using the solver included in the IBM multi-platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM) and computer-aided engineering (CAE), the visualization of the phenomena that take place on the composite structure (displacement under dynamic pressure, Von Mises stress – nodal values and translational displacement vector) was possible, so the dimensions of the floating elements and of the skirts could be determined, which constitute modular experimental models of the whole directing-storage-separation of water-hydrocarbon mixtures system architecture [5, 6].

MATERIALS AND METHOD

Textile structures used for the development of the experimental models

The results obtained following the use CAD/CAM/CAE techniques allowed the design and development of composite structures for the realization of the experimental models (EM) (table 1).

Constructive solutions for the experimental models of floating elements

The constructive solutions for the floating elements, the dimensions of the patterns that will be modelled and simulated using a specialized program – Optitex Pattern Making PDS software (EFI Optitex) – from INCDTP, as well as the developing technology of the 14 experimental models**,** are presented below.

EM01 and EM02 - use: marine environment and fluvial area

- Float construction shape: straight circular cylinder;
- Float dimensions: bases – circles with a diameter of 300 mm, length of 900 mm;
- Float material type: C4 and C5;
- Float colour: EM01 (C4) and EM02 (C5);
- Skirt construction shape: rectangle, dimensions 900 mm × 800 mm;
- Skirt material type: C2;
- Skirt colour: EM01 (C2) and EM02 (C2);
- Float closure mode: 20 mm wide Velcro tape placed at 180° from the skirt;
- Assembly method: the joint of the circles of a straight circular cylinder with the rectangle is a French seam, finished on the outside with a 2 mm pin stitch. When joining the skirt with the floating cylinder, the grosgrain is added in order to increase the resistance of the seam.

  The rectangular skirt has the sides finished by 10 mm double folding edge and the lower edge has a channel with a height of 30 mm for the insertion of the chain/ballast. On the diameter of the cylinder bases are applied on one side the Velcro - loop and on the other side the Velcro hook that allows the cylinders to be fastened, in order to be able to lock the cylinders between them and capture the oil fractions.

EM03 and EM04 - use: marine environment and fluvial area

- Float construction shape: straight circular cylinder;
- Float dimensions: bases – circular surfaces with a diameter of 600 mm, length of 1200 mm;
- Float material type: C1;
- Float colour: EM03 and EM04 (C1);
- Skirt construction shape: rectangle, dimensions 1200 mm × 1100 mm;

Table 1

COMPOSITE STRUCTURES DESIGN DATA AND CHARACTERISTICS		
Composite structure	**Design data/Identification EM**	
C1	Fibrous composition	100% cotton
	Width	140 cm
	Weave	Basket weave
	Finishing type	polyurethane (PU) film coating
	Colour	Khaki
C2	Fibrous composition	45%/55% PES/PA
	Width	150 cm
	Weave	Rep weave
	Finishing type	PU impregnation
	Colour	Orange
C3	Fibrous composition	45%/55% PA6.6/PES
	Width	150 cm
	Weave	Rep weave
	Finishing type	PU impregnation
	Colour	Purple
C4	Fibrous composition	100% PA6.6
	Width	150 cm
	Weave	Plain weave
	Finishing type	PU film coating
	Colour	White
C5	Fibrous composition	100% PES
	Width	150 cm
	Weave	Plain weave
	Finishing type	PU film coating
	Colour	Green
C6	Fibrous composition	100% PES
	Width	140 cm
	Weave	Basket weave
	Finishing type	PU film coating
	Colour	Grey
C7	Fibrous composition	100%PES
	Width	150 cm
	Weave	Rep weave
	Finishing type	PU film coating
	Colour	Turquoise

- Skirt material type: C1 and C2;
- Skirt colour: EM03 (C2) and EM04 (C1);
- Float closure mode: 20 mm wide Velcro tape placed at 180° from the skirt;
- Assembly method: the joint of the circles of a straight circular cylinder with the rectangle is a French seam, finished on the outside with a 2 mm pin stitch. When joining the skirt with the floating cylinder, the grosgrain is added in order to increase the resistance of the seam. The rectangular skirt has the sides finished by 10 mm double folding and the lower edge has a channel with a height of 30 mm for the insertion of the chain/ballast. On the diameter of the cylinder bases are applied on one side the Velcro - loop and on the other side the Velcro hook that allows the cylinders to be fastened, in order to be able to lock the cylinders between them and capture the oil fractions.

EM05 and EM06 - use: marine environment and fluvial area

- Float construction shape: straight circular cylinder;
- Float dimensions: bases – circular surfaces with a diameter of 300 mm, length of 900 mm;
- Float material type: C3 and C6;
- Float colour: EM05 (C3) and EM06 (C6);
- Skirt construction shape: rectangle, dimensions 900 mm × 800 mm;
- Skirt material type: C3;

- Skirt colour: EM05, EM06 (C3);
- Assembly method: the joint of the circles of a straight circular cylinder with the rectangle is a French seam, finished on the outside with a 2 mm pin stitch. When joining the skirt with the floating cylinder, the grosgrain is added in order to increase the resistance of the seam. The rectangular skirt has the sides finished by 10 mm double folding edge and the lower edge has a channel with a height of 30 mm for the insertion of the chain/ballast. On the diameter of the cylinder, bases are applied 250 mm wide grosgrain tapes that allow the cylinders to be fastened, in order to be able to lock the cylinders between them and capture the oil fractions.

EM07 and EM08 - use: marine environment and fluvial area

- Float construction shape: straight circular cylinder;
- Float dimensions: bases – circular surfaces with a diameter of 600 mm, length of 1200 mm;
- Float material type: C1 and C5;
- Float colour: EM07 (C1) and EM08 (C5);
- Skirt construction shape: rectangle, dimensions 1200 mm × 1100 mm;
- Skirt material type: C2 and C1;
- Skirt colour: EM07 (C2) and EM08 (C1);
- Assembly method: the joint of the cylinder (skirt with float) is made through a French seam and on the outside the fixing seam at a 2 mm distance from the edge. When joining the skirt with the float, the grosgrain was added in order to increase the resistance of the seam. The skirt has the sides finished by a double folding of the edge and fixing by sewing, and the lower edge has a channel with a height of 30 mm for the insertion of the chain/ballast. On the diameter of the cylinder, bases are applied 250 mm wide grosgrain tapes that allow the cylinders to be fastened, in order to be able to lock the cylinders between them and capture the oil fraction.

EM09, EM10 and EM11 - use: marine and fluvial harbours

- Float construction shape: frustum
- Float dimensions: large base with a diameter of 530 mm, small base with a diameter of 100 mm;
- Float material type: C3, C4 and C7;
- Float colour: EM09 (C3), EM10 (C7) and EM11 (C4);
- Skirt construction shape: rectangle, placed on the diameter of the large base, dimensions of 530 mm × 510 mm;
- Skirt material type: C3, C4 and C7;
- Skirt colour: EM09 (C3), EM10 (C7) and EM11 (C4);
- Assembly method: the large base of the circle of the frustum cone is assembled through a French seam followed on the outside by a 2 mm pin stitch. The small base of the frustum consists of 2 overlapped circles, stitched together, and on the diameter of the small circle was applied 50/60 mm grosgrain tape. To cover and reinforce the edge of the small circle of the frustum 25 mm einfas tape /grosgrain tape was added. A loop of 100 mm folded length grosgrain tape with the 20 mm width was added over the wide grosgrain tape. Through this loop, a cable tape will be inserted to hold the frustums between them in order to achieve the system of blocking and capturing the oil fractions. On the side of the cone trunk, a waterproof zipper with a length of 360 mm was stitched.

EM12, EM13 and EM14 - use: marine environment and fluvial area

- Constructive shape of the float: straight circular cylinder;
- Float 1 dimension: bases – circular surfaces with a diameter of 300 mm, length of 1200 mm;
- Float 1 material type: C2 and C3;
- Float 1 colour: EM12 (C3), EM13 (C3) and EM14 (C2);
- Float 2 and 3 dimensions – submerged elements: bases – circular surfaces with a diameter of 300 mm, length of 1200 mm;
- Float 2 and 3 material type: C2, C4 and C3;
- Float 2 and 3 colours: EM12 (C2), EM13 (C4) and EM14 (C3);
- Constructive skirt shape: rectangle, dimensions of 1000 mm × 1200 mm;
- Skirt material type: C1, C6
- Skirt colour: EM12 (C6), EM (C6) and EM14 (C1);
- Assembly method: the 20 mm wide grosgrain tape was applied along the cylinder length of the submerged elements, and the submerged elements were stitched together to reinforce the stitching.
  2 overlapping tapes of 300 mm length each (grosgrain) were applied on the film-coated side of the float and on the film-coated side of the submerged elements. 20 mm length of each end of the grosgrain tape is reinforced. To increase the resistance of the seams, 20 mm of reinforcing grosgrain tape is applied on the inside of the float and on the submerged elements. When joining each skirt with each float, the 20 mm wide grosgrain tape was added in order to increase the resistance of the seam. The skirt has the sides finished by a double folding edge and the lower edge has a channel with a height of 30 mm for the insertion of the chain/ballast. On the diameter of the floating cylinder, the grosgrain tapes were added, which allow the cylinders to be attached to each other to achieve the system of blocking and capturing oil fractions. 1070 mm length waterproof zippers were applied on each base of the cylinder.

RESULTS

CAD design of the experimental models

Using the modules included in the program, the changes made to the patterns were transferred to the virtual model. In addition, using Optitex 3D, the following data was obtained:

- the visualization in the virtual 3D mode of the experimental models created as 2D patterns;
- the analysis of how the changes made on 3D models affect 2D patterns;

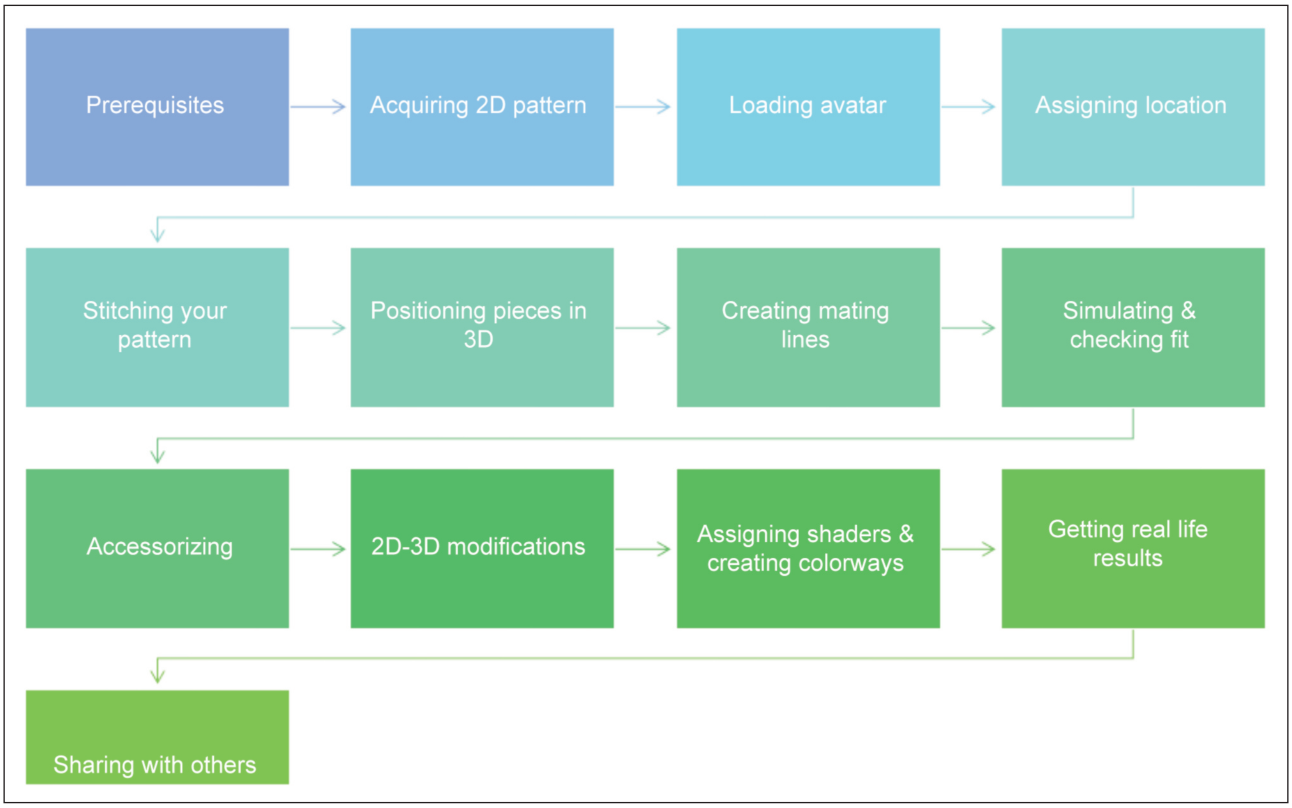


Fig. 1. Workflow for transforming into 3D samples of EM01–EM014

- the direct transition from concept to virtual 3D model with all aspects related to the fully defined product (material properties and their behaviour) [7].

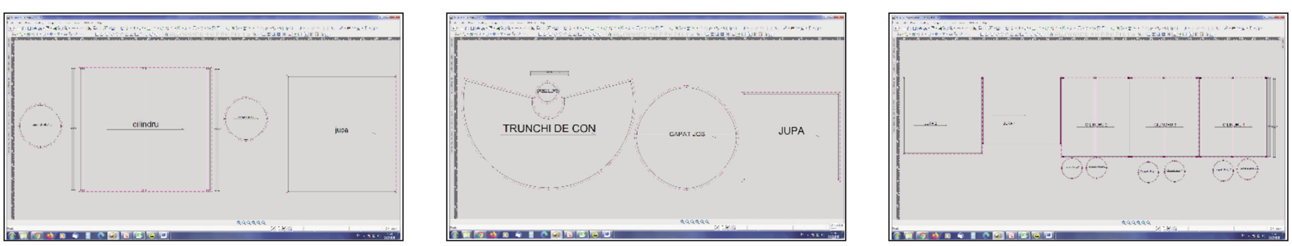
The workflow for taking over 2D models and transforming them into 3D samples is shown in figure 1.

Design stages EM01–EM14

I. Construction of the 2D pattern, with the help of the integrated PDS software (figures 2 and 3).

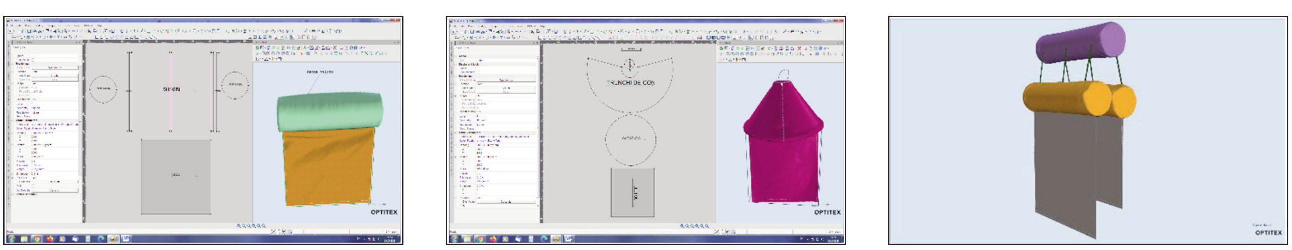
II. Establishing the positions of the parts in the virtual plan, of assembly lines and placement of accessories (zippers, Velcro, carbines, ballast), assembly and placement lines, assigning materials and colours. The obtained elements for all 14 experimental models are shown in figure 4.

III. 3D simulation, verification and correction of possible nonconformities and visualization of the experimental models (through two windows simultaneously: PDS and 3D) (figures 5 and 6).



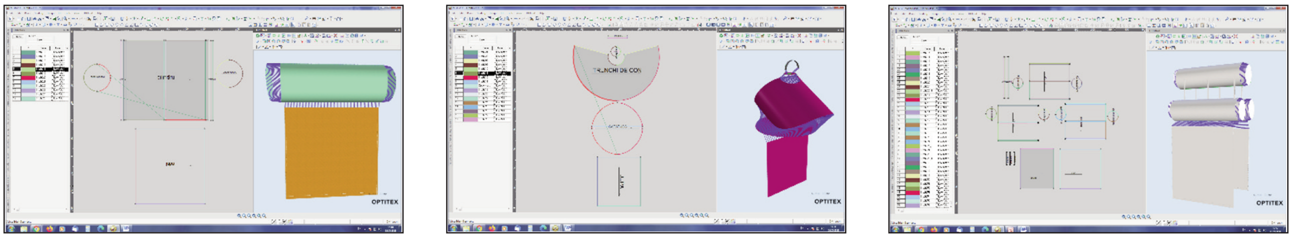
a *b* *c*

Fig. 2. Design of the patterns for: *a* – EM01–EM08; *b* – EM09–EM11; *c* – EM12–EM14



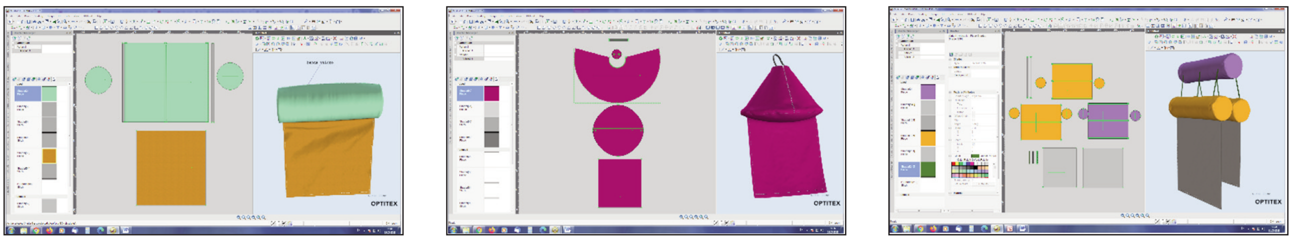
a *b* *c*

Fig. 3. Insertion of the determining parameters values of the materials for:
a – EM01–EM08; *b* – EM09–EM11; *c* – EM12–EM14



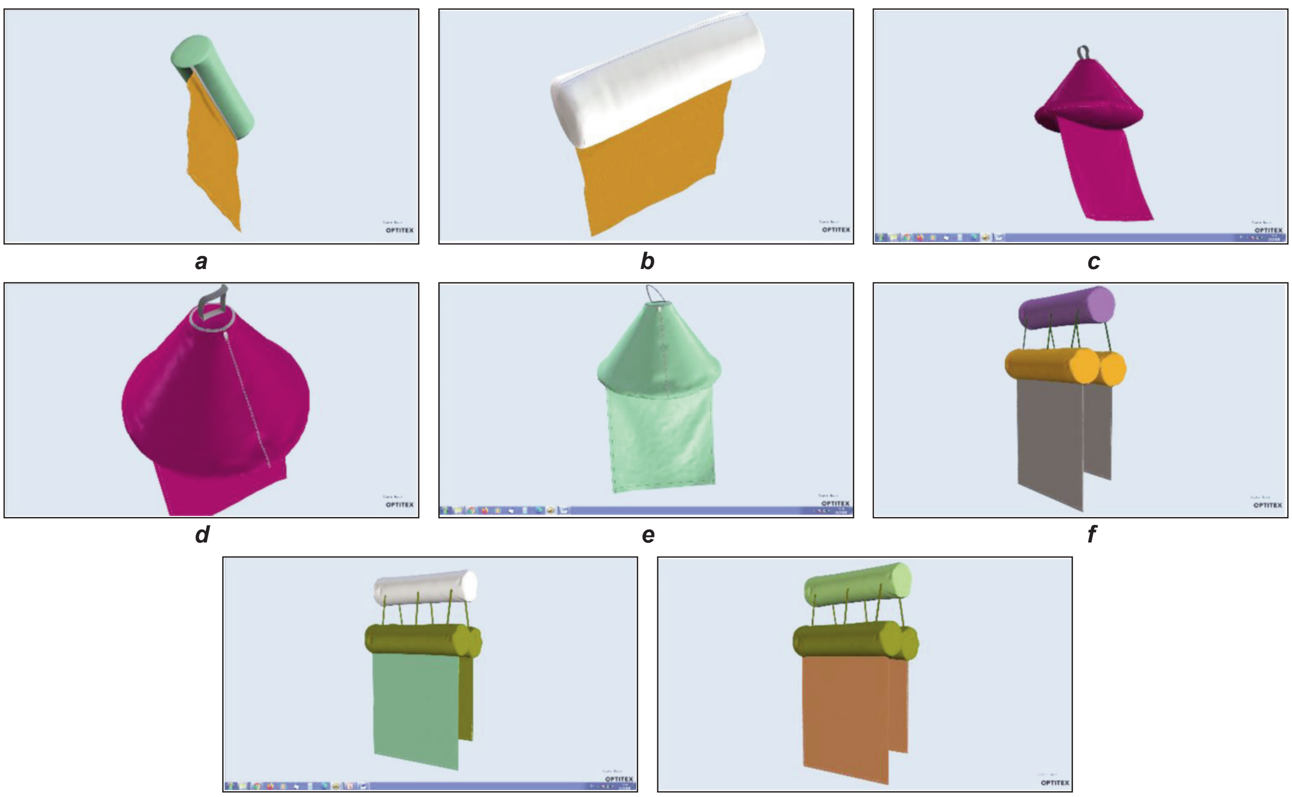
a *b* *c*

Fig. 4. Establishing the assembly seams between the parts of the experimental models:
a – EM01–EM08; *b* – EM09–EM11; *c* – EM12–EM14



a *b* *c*

Fig. 5. 2D print and 3D virtual model of the experimental models: *a* – EM01–EM08; *b* – EM09–EM11; *c* – EM12–EM14



a *b* *c* *d* *e* *f* *g* *h*

Fig. 6. 3D simulation for: *a* and *b* – EM01–EM08; *c, d* and *e* – EM09–EM11; *f, g* and *h* – EM12–EM14

The 14 experimental models were made in the sampling room from Design and Anthropometry Department within INCDTP, using as technological equipment the simple sewing machine, seam 301, the joining of the elements being made with 20 mm grosgrain or, depending on each case, Velcro or zipper. For the structure fastening of EM09 – EM11, a special sea waterproof zipper was used.

CONCLUSIONS

The 14 experimental models that have been designed vary depending on size, material and pattern in order to meet the requirements of the marine and fluvial environment. The EMs meet several requirements imposed by the exploitation in real conditions of use, such as the concentration on a strictly delimited area of oil residues, distance from the intervention base to the polluted area, the state of agitation of the marine environment.

The use of CAD/CAM/CAE techniques allowed the design and development of 7 composite structures identified as C1–C7, which were used to make the experimental models EM01–EM14.

The combination of woven fabrics for different dimensions of floating elements and skirts was made in order to verify the dimensional stability of the composite material, resistance to solar radiation, resistance to large temperature variations and resistance to sea agitation (4bf–10bf).

The CAD design made using the Optitex software allowed the visualization of the patterns created for each experimental model. All 14 experimental models were assembled within the pilot station of INCDTP, using the provided equipment. The developed experimental models will be tested at the berth in the Port of Constanta, Romania and at the embankment in the Port of Galati, Romania.

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