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Experimental Data Management for the Panel Joints of the Naval Emergency Shuttle

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ABSTRACT

One of the most conspicuous forms of damage to the aquatic environment is oil pollution. In marine transport, the risks leading to disasters are associated to the sea and its hazards; related to the state of the ship and to the competency of the crew members; related to the transport of hazardous chemical products or nuclear wastes. The naval emergency shuttle is a floating unit accomplished from textile-reinforced composite material and is used for vertical temporary storage and horizontal transport of water petroleum hydrocarbon compound recovered. Advanced techniques and certified methods have been used in order to evaluate the mechanical, chemical, structural characteristics, including advanced technics of the raw materials. Colectia de date obtinute, a fost gestionata cu ajutorul unui software specializat. Concluziile obtinute in urma analizei statistice au permis stabilirea intervalelor de valori pentru caracteristicile tehnnico-operationale ale naval emergency shuttle.

Keywords: Physic-chemical characteristics information, Database, Descriptive statistics, Statistical parameters, Naval shuttle

INTRODUCTION

Spilled oil can represent also an extremely valuable raw material resource, which, through efficient processing, can be reintroduced into the economic value chain. (Baker JM et al. 2001, Saleem S. et al. 2022, Zhou, 2022). For this purpose, oil fractions can be collected by various means and transported from the spill site to areas arranged specially where specific treatments for reprocessing could be applied. (Luo H., 2018, Sang Q., 2014, Wang J., et al. 2014). A sequence of generic stages, in response to oil spills, includes the phases of their segregation and collection by various means, transport and reprocessing treatments - Figure 1 (Mahrabian S. et al. 2018, Afsharpoor, A et al. 2010).

The naval emergency shuttle (NES) is a floating, collapsible and towable unit fabricated from textile-reinforced composite material, used for vertical temporary storage and horizontal transport of water – petroleum hydrocarbon (raw oil) compound recovered in the event of disasters from brackish sea

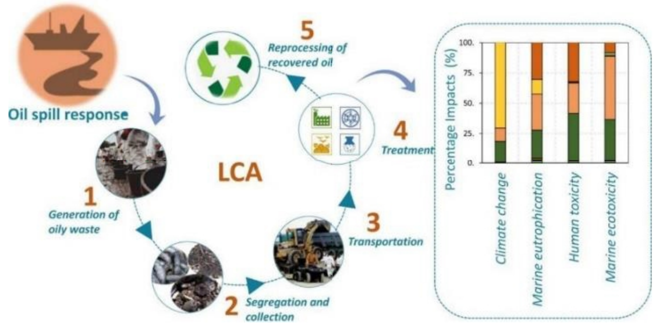

Figure 1: Schema managementului deseurilor petroliere (Saleem S. et al., 2022).

habitat. The proposed NES will be made of composite materials with textile matrix covered with hypalon - for the main module of the shuttle and four floating elements made of composite material covered with PVC.

For the digital and experimental design of NES, the experimental plan was focused on the determination of the main characteristics of the: i) threads (100%PA6.6 – 600dtex x 3 and 300dtex x 3; 100%PES 250 × 3 dtex), ii) composite materials (45%/55% p-aramid / PA6.6 covered with PVC and 50%/50% p-aramid/PES covered with hypalon) and iii) types of joints that will be used in its construction.

The composite materials were joined using different techniques and seams (301-LSa-1, 301-SSd2-4, 301-SSa-1) and were tested for assessing the maximum strength and elongation at maximum force and tearing force (wing shaped) composite specimen material).

The obtained database that included the values for: breaking, loop and knot resistances evaluated for 3 types of threads used to join the panels; strength, breaking elongation and tear force for the joined panels was managed with the help of a specialised software.

MATERIALS AND METHODS

The variants of threads used to join the panels and the panels fabricated from composite materials were subjected to a complex experimental program in the accredited laboratories. The obtained database, with 1800 values for threads and 1200 values for the combined flexible panels, was analysed through descriptive statistics analysis.

Summaries for the characteristics of the 3 types of yarns (9 independent variables, respectively breaking resistance, knot resistance and loop resistance for each type of yarn), as well as for the characteristics of the two flexible composite materials combined with 4 types of seams and used to make the floating and hull element (12 independent variables) are presented in Table 1 and Table 2.

For all the considered distributions (9 for threads and 12 for panels made of composite materials) were calculated the: i) values corresponding to the division into equal groups, ii) parameters related to the data scattering and iii) asymmetries and the vaulting of the distributions were calculated.

Table 1. Resistance characteristics for the threads used for joining the panels. Summaries.

Yarn Characteristics	Y1 - 100% PA6.6 600dtex x 3	Y2 - 100% PA6.6 300dtex x 3	Y3 - 100% PES 250dtex x 3
Breaking resistance, N			
Mean Statistic	96.22	42.93	54.40
Minimum Statistic	95.75	45.58	633.38
Maximum Statistic	96.88	40.49	46.13
Std. Deviation Statistic	0.22	1.12	4.14
Skewness Statistic	0.672	-0.290	-0.027
Kurtosis Statistic	0.775	-0.199	-0.690
Knot resistance, N			
Mean Statistic	51.95	28.26	31.18
Minimum Statistic	54.64	36.62	38.44
Maximum Statistic	49.02	21.92	23.96
Std. Deviation Statistic	1.07	3.41	3.27
Skewness Statistic	-0.169	0.441	-0.290
Kurtosis Statistic	0.768	0.317	-0.371
Loop resistance, N			
Mean Statistic	143.54	75.11	74.16
Minimum Statistic	150.52	82.31	80.16
Maximum Statistic	135.53	69.50	67.75
Std. Deviation Statistic	2.62	2.80	3.27
Skewness Statistic	-0.030	0.704	-0.223
Kurtosis Statistic	1.57	0.392	-0.918

In addition, the histograms corresponding to each independent variable that characterise the thread variants were drawn (Figure 2) and the level and dispersion indicators were represented simultaneously (Figure 5).

The types of seams used to join the panels are shown in Figure 3 and aspects from the test in Figure 4.

The physical-mechanical characteristics of the tested flexible panels and the values of the fundamental indicators resulting from the statistical analysis are presented in Table 2 and Figure 5.

It was recorded that obtained outliers do not negatively impact the finished structures (floating elements and hull), because their values are higher than the necessary ones for retreiving the shock loads that can be developed in real conditions of usage in the open sea, for a state of sea agitation of 4–6 degrees Beaufort.

RESULTS AND DISCUSSIONS

The statistical analysis carried out for the populations of threads and joined flexible composite materials demonstrated that the coefficient of variability for Y1, Y2, Y3 and composite materials for floating element and hull is below 11%, so the average for each set of values (50 for threads and 100 for the joined panels) is representative, and consequently the populations are homogeneous.

Table 2. Resistance characteristics for jointed composite panels. Summaries.

Composite material Characteristics	45%/55% p-aramid / PA6.6 – Floating element	50%/50% p-aramid/ PES - Hull
Breaking resistance warp / weft, daN		
Mean Statistic	886 / 935	586 / 455
Minimum Statistic	880 / 929	578 / 442
Maximum Statistic	892 / 945	595 / 469
Std. Deviation Statistic	2.36 / 3.06	3.50 / 5.17
Skewness Statistic	-0.005 / 0.156	0.233 / -0.263
Kurtosis Statistic	-0.408 / -0.659	0.063 / 0.409
Percentile		
25	884 / 933	584 / 452
50	886 / 935	586 / 456
75	888 / 937	588 / 459
Elongation at breaking warp / weft, %		
Mean Statistic	15.7 / 12.8	13.0 / 8.7
Minimum Statistic	12.5 / 5.2	6.5 / 2.11
Maximum Statistic	18.9 / 20	19.3 / 14.0
Std. Deviation Statistic	1.26 / 3.03	2.67 / 2.59
Skewness Statistic	0.157 / -0.118	0.007 / -0.093
Kurtosis Statistic	0.079 / -0.118	-0.206 / -0.333
Percentile		
25	14.9 / 10.8	11.2 / 6.8
50	15.5 / 12.9	13.1 / 8.8
75	16.5 / 14.9	15.0 / 10.4
Tear resistance, wing, warp / weft, daN		
Mean Statistic	334 / 236	127 / 106
Minimum Statistic	326 / 229	121 / 101
Maximum Statistic	341 / 242	133 / 109
Std. Deviation Statistic	2.98 / 2.80	2.45 / 1.52
Skewness Statistic	-0.094 / -0.276	-0.181 / -0.162
Kurtosis Statistic	-0.378 / -0.104	-0.192 / 0.227
Percentile		
25	332 / 234	126 / 105
50	334 / 236	127 /106
75	340/ 238	129 / 107

For threads:

- the drawn histograms (9 independent variables) evidenced that there is no tendency for the average to deviate from the median, the skewness values not exceeding ±1.96.

- the negative kurtosis values recorded for breaking resistance (Y2 and Y3), knot resistance and loop resistance (Y3) demonstrate that the distribution is platykurtic, so there is a large variation in the values of the respective variable, simultaneously with the weak variation in frequencies.

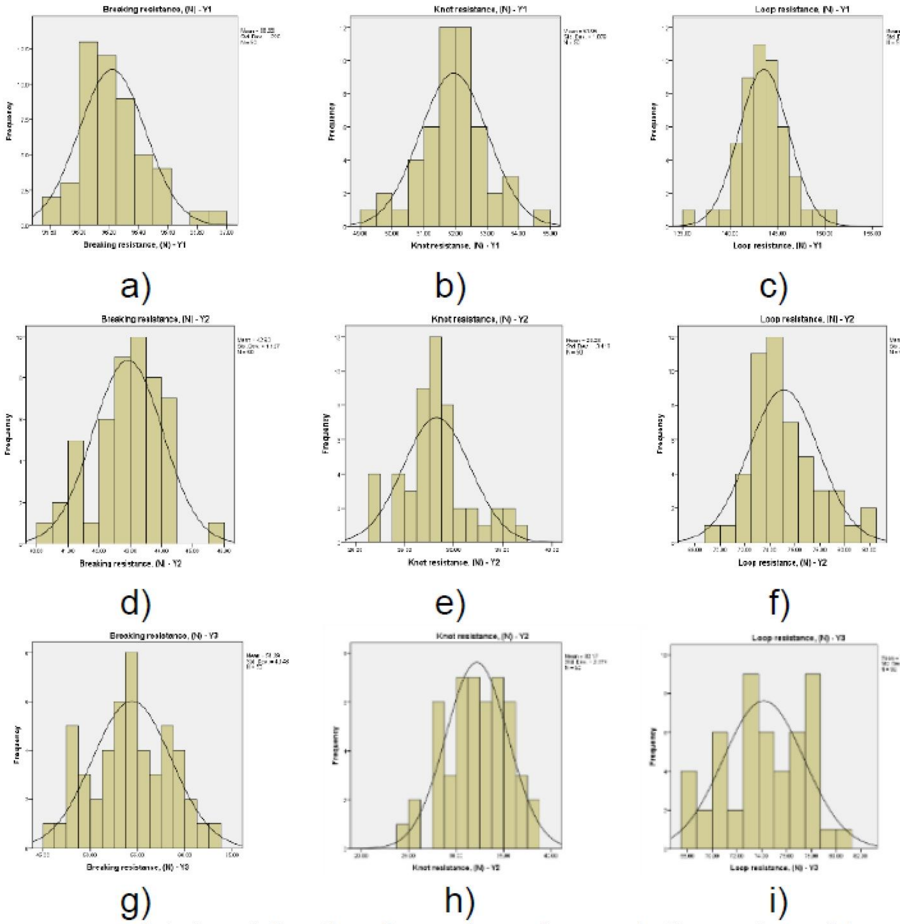

Figure 2: Histograms obtained for the 9 analysed populations: breaking resistance a) Y1, d) Y2, g) Y3; knot resistance b) Y1, e) Y2, h) Y3; loop resistance for c) Y1, f) Y2, i) Y3.

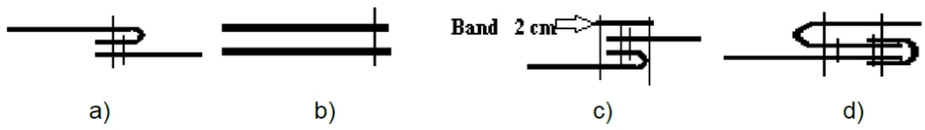

Figure 3: Joining types used for panels testing: a) 301-LSa-1, b) 301-SSa-1, c) 301-SSd2-4, d) 301-BSa-4.

- the semi-quartile amplitude and the interquartile variation coefficient demonstrate that for all 9 variables there is no great data variability (for example, the interquartile variation coefficient does not exceed 25%), so the series reveals a high degree of homogeneity, the average being representative.

For NES panels made of flexible composite material:

- the values obtained after the descriptive statistical analysis highlighted the fact that all 12 independent variables (breaking resistance in warp and

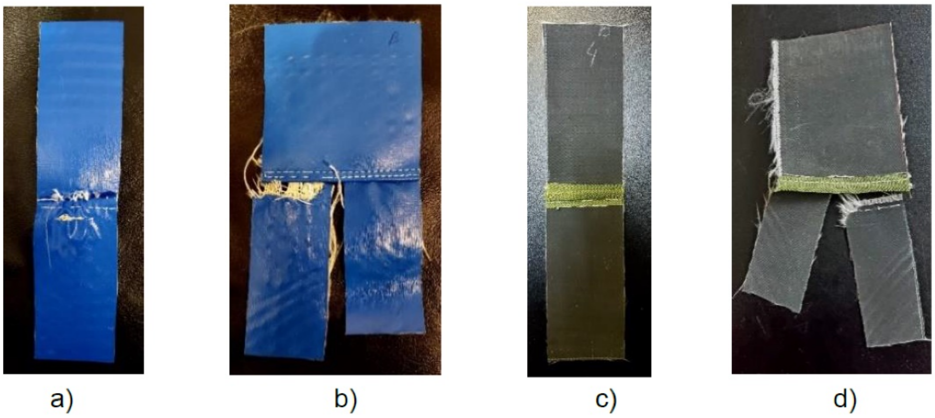

Figure 4: Tests at the level of loins of the flexibe panels: a) sample of strip type, join with 301-LSa-1; b) sample of fin type, join with cu 301-SSa-1; c) sample of strip type, join with 301- SSd2-4; d) sample of fin type, join with 301- BSa-4.

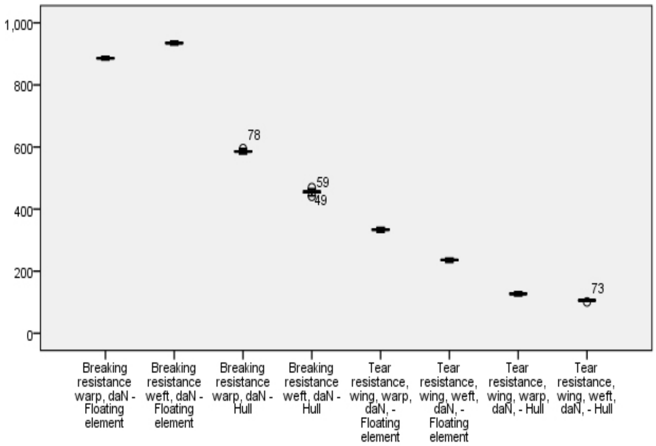

Figure 5: Boxplot graphics – for variables of the floating element and hull.

weft, breaking elongation in warp and weft, tear resistance, wing probe, in warp and weft) have an average close to the median, the values skewness being included in the interval [-0.263, 0.233].

- positive kurtosis values recorded for breaking resistance in warp and weft and tear resistance, wing sample, in weft for hull made from 50%/50% p-aramid/ PES, as well as breaking elongation in warp for floating element made from 45%/55% p- aramid / PA6.6 demonstrated that these variables have a leptokurtic distribution, with a small variation of the variable in parallel with a strong variation of the frequencies.
- the interquartile variation coefficient is below 21%, so for all 12 variables there is no data variability, and the series present a high degree of homogeneity, for which the average is representative.
- the boxplot graphs demonstrated that there is no great variability in the data.

Whiskers were drawn from the lowest to the highest detected value and are positioned within 1.5 "box" lengths. Thus, for breaking resistance in warp – hull, case 78 (value 239.14 daN), breaking resistance in weft – hull, cases 49 and 59 (values 582.04 daN and 590.09 daN) and tear resistance, wing probe in weft – hull, case 73 (value 100.92 daN) are considered outliers because they are positioned at 1.5-3 lengths from "box". There were no extreme cases, i.e. values at more than 3 box lengths.

CONCLUSION

Statistical analysis conducted evidenced the following: statistic populations are homogeneous (coefficient of variability is max. 11%, for the joint composite material), so the parametric tests can be applied, the identified higher values (compared with averages) of the outliers do not have a negative impact and will not influence the behaviour of the NES in real conditions (open sea with possible 4 – 6 Beaufort degree).

The values for strength, breaking elongation and tear force obtained for composite material specimens enabled the determination of the values ranges for the technical-operational characteristics of NES, respectively: storage capacity: 5 m3 -500 m3; maximum navigation speed: 3 knots; length: 17.7 – 25m, width: 4.1 – 5 m; breaking strength: min. 500 daN; tearing force: min. 800 N.

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