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Mathematical Models for the Assessment of the Composite Structures of Cylindrical Elements Level of Performances, Used in Brackish Seas

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ABSTRACT

This The safety of life and navigation in the areas with high risk potential adjacent to the coast, the fight against pollution with oil fractions, as well as the protection of marine biodiversity represent the central objective of this research action. The developed regression equations express the influence on the resistance to tearing for the transverse/longitudinal system of both: i) mass, resistance and elongation at break of the composite matrix structure and ii) resistance and elongation at break, resistance to knot and loop breaking of the yarn from composite matrix structure. The two tested variants of composite matrix material were differentiated by the fibrous composition for the longitudinal // transversal systems (45//55%PES//PA6.6, ratio: 1:1//100//100 PES//PES, ratio 2:1). Four mathematical models that are approximately normally distributed and follow the cumulative percentage line described by the normal curve were created. The mathematical models demonstrated that, in the design stage, for dynamic conditions (impact factor 2.5) the tear resistance value should be considered in both systems. It was demonstrated that the analised outliers, represented by the mechanical characteristics of the composite materials, component of the signaling system (braking resistance, tear resistance, braking elongation) and their joints (material-material and material – graingross band) do not have a negative impact on the textile structure, because they have values higher than the average for each set, so they will not influence the behavior and the functionality of the system in ground.

Keywords: Database, Statistic analysis, Circular cylinder, Regression equation, Correlation coefficient

INTRODUCTION

The technique of signalling of the risk areas for the marine domain in general, and for brackish water in particular, takes into consideration the following specific situations: i) for inland waterways, and in international waters, the particularities are related to the hydrological characteristics (Borsa, 2014; Borsa, 2015)defined by: the cross-section, flow rate, level and slope of the watercourse, bathymetric curve, valley, navigable channel and its overall dimensions (Atanasiu, 2022); ii) for the protection of marine biodiversity, this is especially related to the coastal geomorphology, the bottom configuration of the aquatic environment (Bejan et al. 2019; Georgescu, 2021) the thermal regime of the water in the shore area, etc.; iii) for oil spills, which have dramatic effects on marine ecosystems, as a result of the exposure of living organisms to chemical compounds, it is particularly important to assess the state of agitation of the sea, the type-size of the stain, the hydrometeorological conditions at the time of the intervention, etc (Olteanu, 2004; Cipollari et al. 1999).

One of the critical point was to statistically assess and decide on the level of performance of the matrix structures of the modular systems with cylindrical form, designed and developed for the sustainable development of biodiversity and aquatic ecosystems for brackish seas (water with low salinity, of − 0.5 − 30 âŁ°) found in areas where a river flows into the sea or ocean (Vasiliev et al. 200; Cita, 1982; Andreescu, 1972).

For this purpose, a database that includes independent variables related to the physical-mechanical/physical-chemical values of the used raw materials was created.

Were considered 1400 values associated to the: i) mass per surface unit; ii) maximum breaking force in the warp and weft; iii) elongation at break in the warp and weft; iv) tearing force in the warp and weft; v) film type.

Moreover, 1600 values related to the raw material, were included for determination of the: resistance and elongation at break, resistance at the knot and loop.

Descriptive statistics were used for: a) determination of the parameters that evidence the homogeneity degree of the analysed data; b) assessment of the coefficients of variability that demonstrate the extent to which the data groups are homogeneous or heterogeneous; c) drawn the histograms of each variable in order to highlight the asymmetry of the distribution, with the predominance of frequencies or variables.

MATERIALS AND METHODS

The testing was carried out in accredited laboratories according to SR EN ISO/CEI 17025:2001 for 2 variants of textile structures and 2 variants of threads from their component. Relevant information related to the data structures, analyses performed and the number of determinations is presented in Table 1.

The database created includes 3000 values and 11 variables divided as follows: a) 3 independent variables representing the physical-chemical/physico-mechanical characteristics for 2 variants of raw material (V1 and V2) used to make the components of high-tech composite structures for the sustainable development of biodiversity and aquatic ecosystems, cylindrical in shape and used in brackish seas and b) 3 independent variables representing the physical-mechanical characteristics for 2 variants of raw material (PES and PA 6.6).

The tearing force in the warp and weft for the 2 variants tested were considered as dependent variables (400 values).

Table 1. Identification data of variants of structures and threads for composite materials achievement and the performed analyzes.

Characteristics	Variant 1	Variant 2
Data for textile structures identification		
Raw material:Warp	100% PES	100% PES
Raw material:Weft	100% PA6.6	100% PES
Length of density: Warp	1000den/195fx1/120Z	1000den/195fx1/120Z
Length of density: Weft	940den/120fx1/80Z	1000den/195fx1/120Z
Film type/colour	polyurethane film /green	teflon/orange film
Performed analyzes /No. of determinations		
Textile structures	mass per surface unit/200 data maximum breaking strength in warp and weft/400 data elongation at break in warp and weft/400 data breaking strength in warp and weft/400 data	
Raw materials (yarns) PES and PA6.6	Braking resistance and elongation/800 data knot resistance /400 data loop resistance /400 data	

Using descriptive statistics: a) were determined the amplitude, standard deviation and dispersion; b) were calculated coefficients of variability and was evidenced the homogeneity or heterogeneity of the data groups; c) were drawn the histograms of each variable; d) were represented the level and dispersion indicators - the box - plot graphs.).

The histograms drawn for all 11 studied characteristics for raw materials (yarns: PES and PA6.6 and 2 variants of textile structures) are presented in Figure 1 and 2, and the boxplot graphs for the same characteristics (Figure 3 and 4). Statistics are presented in Table 2.

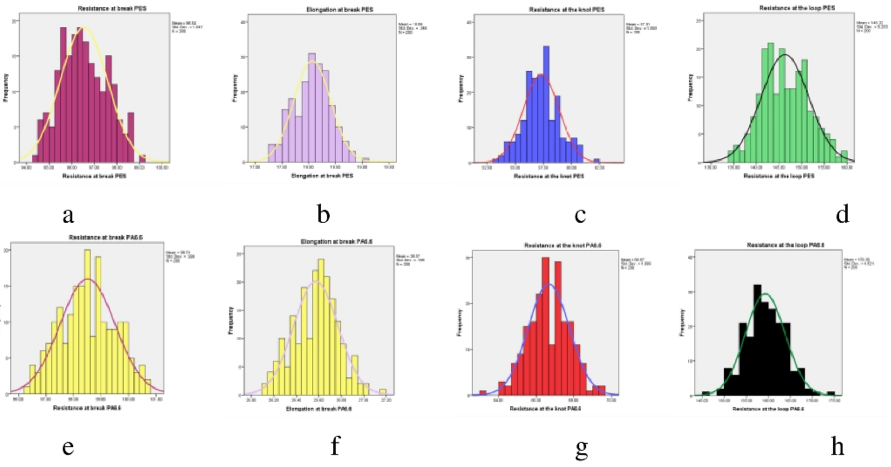

Figure 1: Histograms for raw materials (yarns): - breaking resistance: a. PES, e. PA6.6; - braking elongation: b. PES, f. PA6.6; - knot resistance c. PES, g. PA6.6; - loop resistance d. PES, h. PA6.6.

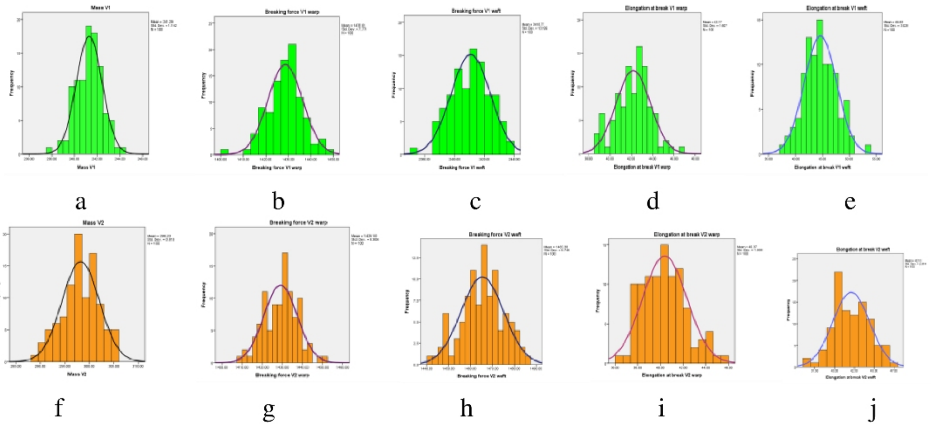

Figure 2: Histograms for textile structures: - mass a. V1, f. V2; - breaking force in warp b. V1, g. V2; weft c. V1, h. V2; - breaking elongation in warp d. V1, i.V2, weft e.V1, j. V2.

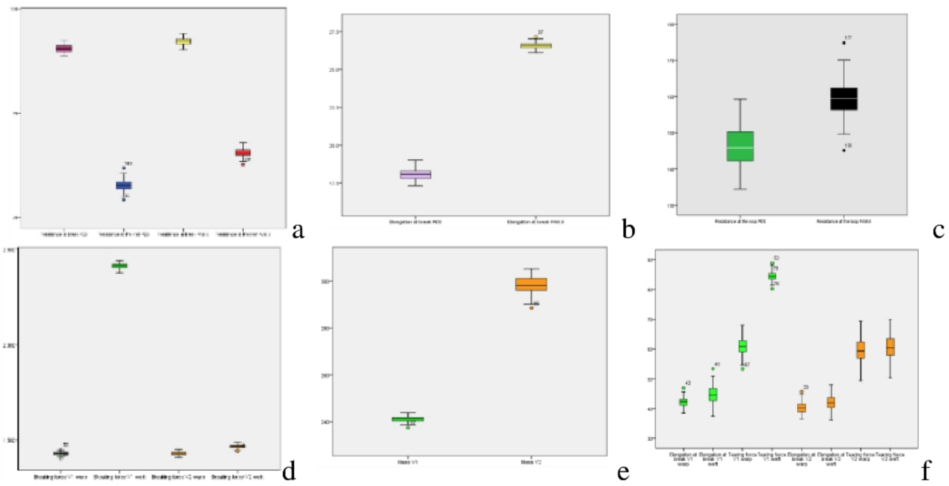

Figure 3: Box plot graphics - variable for raw materials (yarns): a) breaking and knot resistance for PES vs. PA6.6; b) breaking elongation for PES vs. PA6.6; c) loop resistance for PES vs. PA6.6; - variable for textile structures: d) breaking force for V1, V2 warp, weft; e) mass V1, V2; f) breaking elongation V1, V2 warp, weft, tearing force V1, V2 warp, weft.

The obtained asymmetry indicators evidenced that for all variables the series present left or positive asymmetry, with small values predominating.

Skewness negative and much different from zero (Table 2) demonstrates that the data series is strongly negatively asymmetric, the curve being elongated to the left.

For positive Kurtosis values the curve is sharp, so the distribution is leptokurtic, and for negative values the curve is platykurtic with a strong variation of the variable in parallel with a weak variation of the frequencies.

Table 2. Statistics.

Characteristics	N	Mean	Skewness	Kurtosis	Percentiles		
					25	50	75
Raw materials (yarns) - PES							
Breaking Resistance, N	200	96.5	0.180	−0.659	95.73	96.45	97.40
Breaking Elongation, %	200	18.1	−0.036	−0.410	17.83	18.01	18.32
Knot Resistance, N	200	57.3	0.124	0.094	56.26	57.31	58.31
Loop Resistance, N	200	146.3	0.169	−0.419	142.23	145.93	150.25
Raw materials (yarns) – PA6.6							
Breaking Resistance, N	200	98.5	0.022	−0.628	97.79	98.53	99.24
Breaking Elongation, %	200	26.6	−0.036	−0.243	26.44	26.59	26.71
Knot Resistance, N	200	66.6	−0.050	−0.002	65.91	66.64	67.40
Loop Resistance, N	200	159.3	0.094	0.323	156.34	159.42	162.37
Textile structures: V1							
Mass,g/sqm	100	241.3	−0.250	0.383	240.44	241.35	242.03
Warp Breaking Force,N	100	1428.7	−0.327	0.842	1423.94	1429.15	1433.07
Weft Breaking Force, N	100	2410.8	−0.138	−0.468	2401.53	2411.05	2420.92
Warp Braking Elongation, %	100	42.2	−0.082	0.186	41.14	42.29	43.16
Weft Braking Elongation, %	100	44.7	0.140	−0.053	42.58	44.60	46.76
Warp Tearing Force, N	100	61.0	−0.108	−0.347	59.02	60.88	62.87
Weft Tearing Force, N	100	84.4	0.375	0.386	83.49	84.29	85.32
Textile structures: V2							
Mass,g/sqm	100	298.2	−0.289	−0.353	296.05	298.20	301.06
Warp Breaking Force,N	100	1429.1	−0.077	−0.203	1422.29	1430.24	1434.87
Weft Breaking Force, N	100	1465.4	−0.229	−0.302	1459.74	1466.39	1471.47
Warp Braking Elongation, %	100	40.4	0.396	−0.228	38.84	40.34	41.54
Weft Braking Elongation, %	100	42.1	0.059	−0.172	40.46	41.90	43.83
Warp Tearing Force, N	100	59.3	−0.268	0.246	56.91	59.25	62.37
Weft Tearing Force, N	100	60.1	0.169	−0.279	57.93	60.38	63.47

RESULTS AND DISCUSSIONS

An extensive study has been conducted and the obtained results evidenced the following.

The series are very homogeneous, with reduced variation. As the variability coefficient for all variables $V \leq 5\%$, could be concluded that the representatively is the average value of the analysed series.

For all 11 variables the box-plot graphs demonstrate a very low variability of the results, because the dimensions of the box are small and, in most cases, median. The central tendency overlaps its edges.

The links between the considered variables were established according to the values of the correlation coefficients for each of the studied composite structures.

The correlation analysis carried out highlighted that the modulus of the correlation coefficient is in the interval [0.646; 0.903] for V1 in the interval [0.646; 0.900] for V2, and that there are strong links between them.

The quadratic multiple correlation coefficient determined with the help of a specialized software demonstrates that for the corresponding mathematical model for tearing force in warp V1, 100% of the variation of the dependent variable is explained by this model. The regression equation is:

Tearing force V1warp = 324.7 − 0.9 mass + 0.1 F_{max} break elongation V1U – 1.95 brake elongation V1U − 0.06 break elongation V1B − 0.49 Knot R_{break} PES

For the corresponding mathematical model of tearing force in weft V1, 75% of the variation of the dependent variable is explained by the model and the predictive power is approximately 83%. The regression equation for tearing force weft is:

Tearing force V1weft = 30.3 − 0.14 masa + 0.03 F_{max} BreakV1U - 0.001 F_{max} BreakV1B – 0.36 breake elongation V1B − 0.47 breake elongation V1B − 0.04 R_{break} PA6.6 − 0.06 Knot R_{brak} PA6.6 − 0.07 Loop R_{break} PA6.6.

The value of the quadratic multiple correlation coefficient of 61.4% demonstrates that, for the corresponding mathematical model tearing force in warp V2, the variation of the dependent variable is explained by this model. The regression equation is of the form:

Tear resistence V2U = 576.9 − 3.2 mass + .08 F_{max} breakV2U − .007 F_{max} breakV2B + 3.39 breaking elongation V2U + 3.9 breaking elongation V2B + 3.2 R_{break} PES − .6 knot R_{break} PES − .42Loop R_{breaj} PES

The significance threshold for the F test has a value of 0.945, which leads to the idea that the model explains significantly more variation if other unforeseen or uncontrolled factors are considered (design on systems, connection, mounting and adjustment parameters, thickness of deposit on the surface, etc.)

It was demonstrated that the Mathematical Model for predicting tearing force in weft V2 is of 93.7% from the variation of the dependent variable and is explained by the model. The regression equation for Tear Strength V2B is:

Tear resistance V2B = 1191.2 − 3.8 mass − .16 F_{max} breakV2U -.18 F_{max} breakV2B – 2.5 breaking elongation V2U - 11.3 breaking elongation V2B − 10.37 R_{break} PES − .61 Knot R_{brak} PES + Loop1.36 R_{break} PES

It can be stated with a probability of 95% that there is a dependency between the variables considered for each version of the woven structure and this aspect must be considered in the design stage of the fabrics. In addition, considering the sign of the correlation, that is positive, there is a directly proportional relationship between the analysed variable.

CONCLUSION

For the V1 variant, the mathematical models created for the tear resistance in the warp and the weft highlighted the fact that for the prediction of the value of the tear resistance of the composite element, the values of this characteristic in the warp must be considered. For the values of this characteristic in the weft, it is necessary to introduce additional independent variables. In the design stage for the woven structure, this aspect must be considered as a function of the tear resistance value in the weft under dynamic conditions (impact factor of 2.5).

For the V2 variant, the value of the significance threshold for the F test highlights the fact that the mathematical model for the V2 tearing force in warp explains significantly more variation if other unforeseen or uncontrolled factors are considered (system design, connection, mounting and adjustment parameters, thickness deposition on the surface, etc.). The values obtained for tearing force Vs2 in weft are approximately normally distributed, but there is a tendency to underestimate the reality.

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