Textile wing fabric for emergency response UAS

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ABSTRACT – REZUMAT

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The fabrics used to manufacture parachutes and paragliders must have several specific characteristics: the mass of fabric per unit of surface must be low while the other physical-mechanical characteristics (the axial breaking strength load, the relative and absolute elongation, the tear resistance of the fabric and the assemblies, air permeability) must have high values. The paper deals with the analysis of qualitative aspects of several parachute fabrics that are used as a baseline in the development of a novel fabric. The results of experiments have materialized in statistical data, diagrams and graphs and their interpretation leads to the determination of the fabric variant that best meets the requirements of the destination. The destination is a patent pending inflatable wing design that utilizes a single skin construction and solid reinforcements in the sewing for shape stability. It is worth noting that the experimental results were compared with values indicated in specific international testing norms.

Keywords: *parachute, paraglider, single sail, technical textile, fabric testing*

Țesătura aripii unui UAS pentru situații de urgență

Țesăturile utilizate în realizarea parașutelor și parapantelor trebuie să aibă câteva caracteristici specifice: masa țesăturii pe unitatea de suprafață trebuie să fie scăzută, în timp ce celelalte caracteristici fizico-mecanice (rezistența la rupere axială, alungirea relativă și absolută, rezistența la rupere a materialului și a asamblărilor, permeabilitatea la aer) trebuie să înregistreze valori ridicate. Lucrarea tratează analiza aspectelor calitative ale mai multor țesături pentru parașută, care sunt utilizate ca bază în dezvoltarea unei țesături noi. Rezultatele experimentelor s-au materializat în date statistice, diagrame și grafice, iar interpretarea acestora duce la determinarea variantei de țesătură care corespunde cel mai bine cerințelor impuse de domeniul de utilizare. Domeniul de utilizare este o aripă textilă brevetabilă, care utilizează o singură pânză extrados și întărituri solide în asamblare pentru stabilizarea formei. De remarcat că rezultatele experimentale au fost comparate cu valorile indicate în normele internaționale specifice de testare.

Cuvinte-cheie: *parașută, parapantă, aripă, textile tehnice, testarea materialului*

INTRODUCTION

The laws of mechanics and aerodynamics apply to the performance and stress analysis of parachute systems. However, the textile fabrics used in parachute construction have distinctly different mechanical and environmental characteristics than metals or composites.

This paper depicts the early phase in the research development for an integrated support system tailored for emergency response actions and remote sensing. In this phase we try to develop a fabric that is tailored for use in the manufacturing process of a paraglider type wing design [1] that utilizes a single skin construction [2] and solid reinforcements in the sewing for shape stability.

In order to achieve this we used as a baseline several commercial fabrics and tried to determine the best combination of yarn, weave and finishing method in order to best suite our paraglider wing.

We mention that this is a preliminary work and is subject to change if the prototype performances will not fall within the projected limits.

MATERIALS AND METHODS

In order to establish a baseline for the fabric characteristics several readily available fabrics were analysed. The fabrics used in the testing were selected so they cover a wide array of parachute types.

Therefore we selected as material one (S1), a fabric commonly used in paraglider manufacturing. This fabric is a rather heavy fabric having polyurethane and silicone coating for UV protection.

The second material (S2) is a fabric used in most of the Ram-Air parachutes available today. It's a light fabric with polyurethane coating for zero air permeability.

The third material (S3) is a fabric with similar structure as S2 but without polyurethane coating. This fabric is only calendered and it is commonly referred to as F111 type fabric. This type of fabric has some air permeability therefore is mainly used in reserve ram-air parachutes or partially on the intrados side of main parachutes.

Testing of the tear resistance of the samples was done on the Tinius Olsen Dynamometer H5KT dynamometer (figure 1). The device is designed to test a wide range of materials (yarns, fabrics, leather) for traction, flexion, and assembly strength (made by sewing, thermofusion etc.).

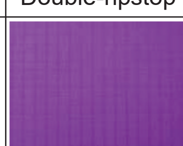
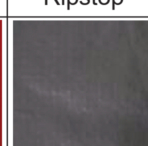
Further on we extracted yarns from the fabrics in order to determine the yarn characteristics.

In table 1 are listed the test results and methods used for these fabrics.

The values of the structural parameters of the fabrics (air permeability, mass, thickness, etc.) were used in conjunction with the extracted yarn test results to determine the multivariate regression equations in which the independent variables were considered the breaking strengths in warp and weft (figure 2). In this figure on x-axis we have the displacement of the clamping device, in mm. We notice a very inconsistent reading, as if the yarn is partially slipping, compared with the clean regular Nylon 6.6 yarn. We suspect this to be because of the residual polyurethane coat-

Fig. 1. H5KT dynamometer

Table 1

TEST RESULTS					
Test Name		**S1**	**S2**	**S3**	**Testing method**
Fabric mass (g/m^2)		59	47	40	SR EN 12127:2003
Yarn count (threads/10 cm)	Warp	474	534	532	SR EN 1049-2:2000; Method A, B
	Weft	432	508	524	
Yarn linear density (DTex den)	Warp	61.8 (55.62)	41.2 (37.08)	32.6 (29.34)	SR 6430:2012; Method A
	Weft	69.4 (62.46)	46.4 (41.76)	32.2 (28.98)	
Yarn breaking strength (N)	Warp	1.943	1.728	1.522	SR EN ISO 2062:2010; Method B
	Weft	1.803	1.582	1.498	
Yarn elongation at breaking force (%)	Warp	25.64	38.80	27.87	
	Weft	27.70	38.52	32.57	
Fabric breaking strength (N)	Warp	541	431	450	SR EN ISO 13934-1: 2013
	Weft	480	412	450	
Fabric elongation at breaking force (%)	Warp	24.9	27.8	27.4	
	Weft	29.1	39.3	33.9	
Fabric tearing strength (N)	Warp	20.7	66.1	35.8	SR EN ISO 13937-3: 2002
	Weft	20.7	66.3	29.2	
Fabric bursting strength (KPa)		370.8	334.2	334.3	EN ISO 13938-2/2002
Fabric bursting strength (mm)		43.2	42.2	36.6	
Fabric air permeability (l/m^2/s) at 200 Pa		0	0	11.57	SR EN ISO 9237:1999
Raw material		100% PA	100% PA	100% PA	SR 13231-95
Coating		PU and Silicone coating	PU coating	Calendered	SR ISO 1833-95
Link type		Double-ripstop	Ripstop	Ripstop	-
Fabric image					-

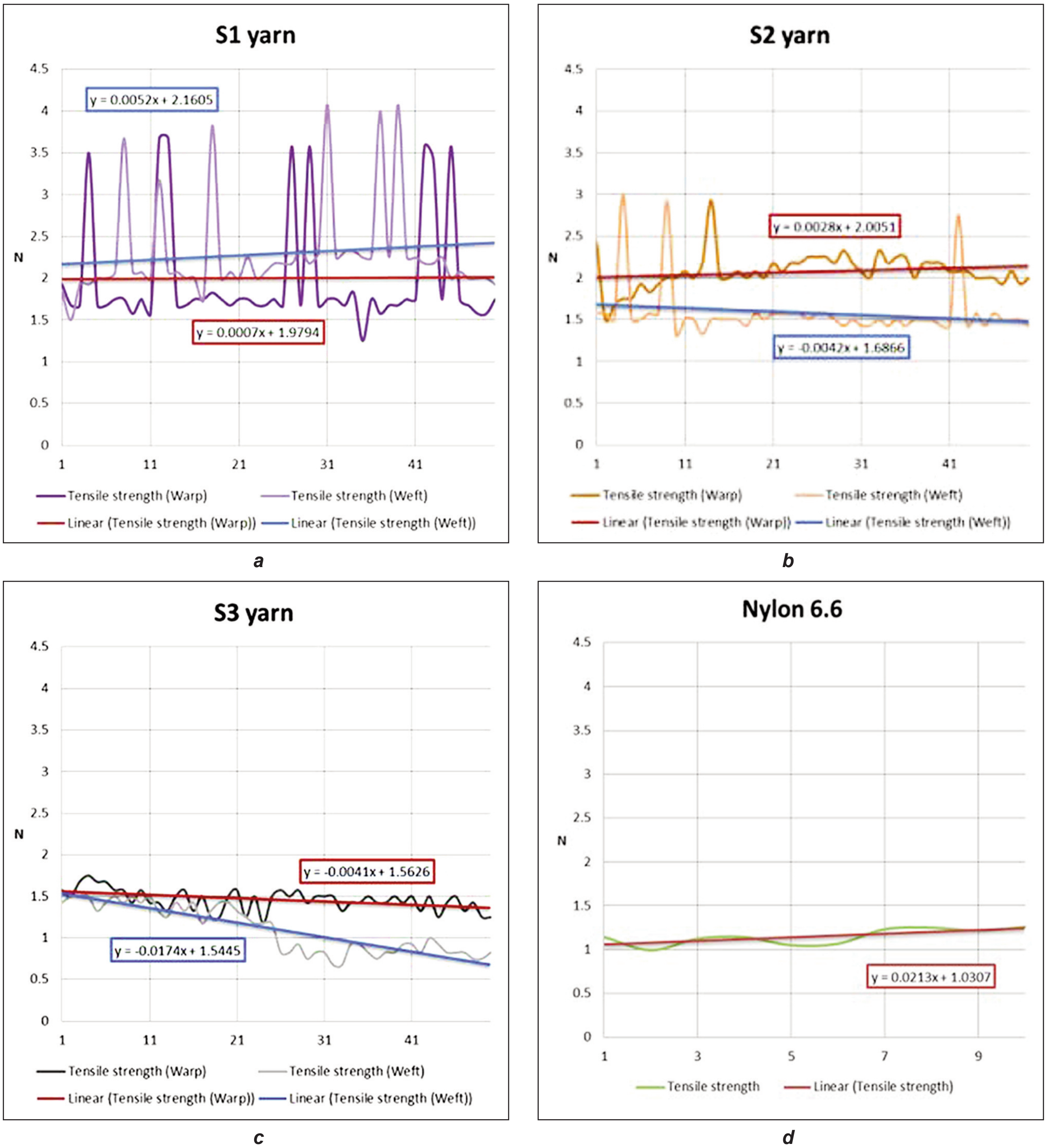


Fig. 2: Breaking strength and trend line for each analysed yarn: *a* – S1 yarn; *b* – S2 yarn; *c* – S3 yarn; *d* – Nylon 6.6

ing present on the extracted yarns. S3 sample, that was not coated, had smaller reading spikes. A statistical smoothing of the readings puts the breaking strength of the extracted yarns roughly on a value that is double than that of the regular Nylon 6.6 yarn. This is the tell-tale sign that we are dealing with HT Nylon 6.6 yarns. At the time of the testing we did not have stocked HT Nylon 6.6 to make a direct comparison.

RESULTS AND DISCUSSION

Further on we can assess the strength transfer coefficient [4] given mathematically as:

$$C = \frac{Tf_2}{Tf_1} \tag{1}$$

where Tf_1 is yarn tenacity before its integration in fabric expressed in N/Tex calculated with the equation:

$$Tf_1 = \frac{F_{bkg(t)}}{Tex} \tag{2}$$

Tf_2 is theoretical yarn tenacity after its integration in woven structure, including the influence of the weave structure/finishing treatments and is expressed also in N/Tex:

$$Tf_2 = \frac{F_{bkg(t)}}{P \times b \times Tex} \tag{3}$$

The strength transfer coefficient C for the given samples has the following values:

- *S1 sample:* Warp 1.14; Weft 0.97;
- *S2 sample:* Warp 0.78; Weft 1.03;
- *S2 sample:* Warp 1.16; Weft 1.56.

Closer these coefficients are from unity the more linear is the transfer rate, above one means the existing woven structure and treatment strengthens the yarn properties. From this we observed S1 and S3 structures to be superior in this regard.

One of the most important properties for these fabrics is the air permeability [3,4] and we tried to reduce this by catering several aspects:

– Yarn torsion of the two systems;

– The use of specially designed connections like ripstop or double ripstop type, with a binding segment of maximum two which interrupt the tendency of the wires of one system to slide towards the wires of the other system (not recommended to use the connections D2/1, R2/1, R1/2 or P2/2).

– Finishing treatment, polyurethane coating.

Two woven types of fabrics were developed accordingly to the following weave diagrams and general characteristics:

- Yarn fiber composition: 100% PA6.6HT;
- Yarn linear density: 30 den/32 f;
- Yarn count warp: 495 threads/10 cm;
- V1 Yarn count weft: 504 threads/10 cm (figure 3);
- V2 Yarn count weft: 508 threads/10 cm (figure 4).

Four fabric variants were developed as follows:

– a fabric with ripstop connection (V1 and V3) and

– another double-ripstop (V2 and V4).

Each connection variant was made in two finishing variants:

– calendering (V1 and V2) and

– polyurethane coating (V3 and V4) thus resulting in four variants of finished fabrics.

In table 2 are listed the test results and methods used for these finished fabrics.

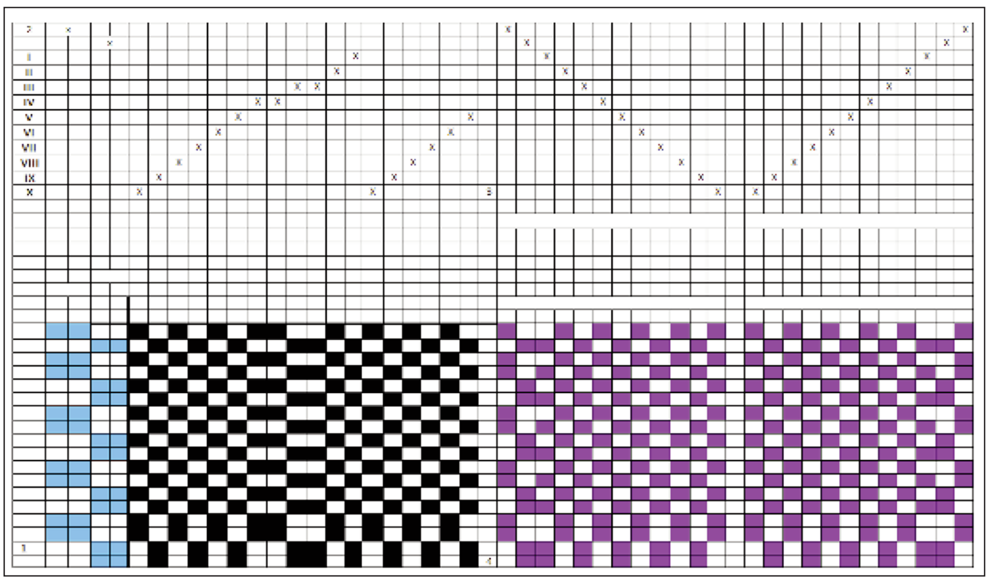


Fig. 3. Programming card for weave structure V1 (Ripstop weave)

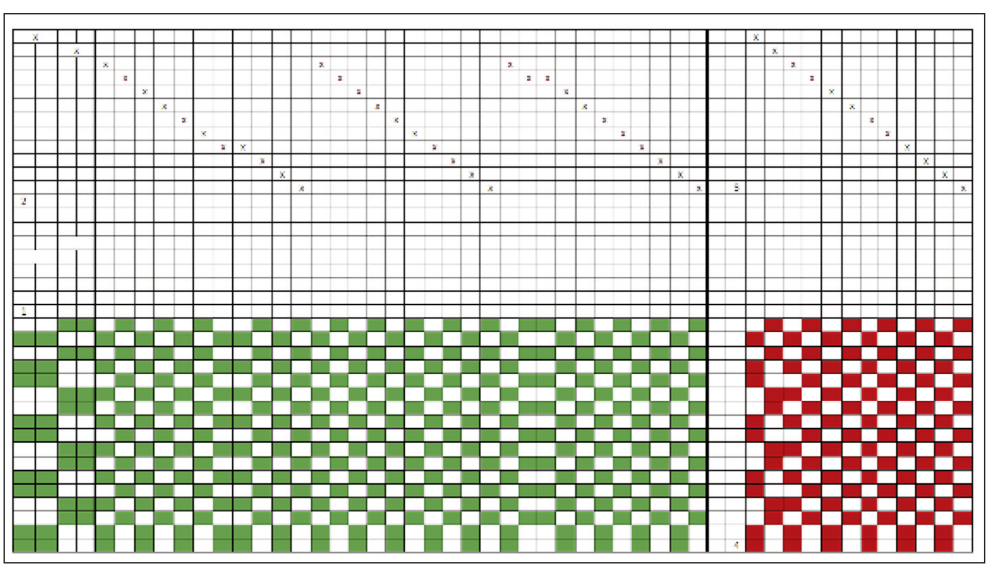


Fig. 4. Programming card for weave structure V2 (Double ripstop weave)

Table 2

TEST RESULTS						
Test Name		**Fabric V1**	**Fabric V2**	**Fabric V3**	**Fabric V4**	**Testing method**
Fabric mass (g/m^2)		40	51	47	59	SR EN 12127:2003
Yarn count (threads/10 cm)	Warp	495	495	495	495	SR EN 1049-2:2000
	Weft	504	508	504	508	
Fabric breaking strength (N)	Warp	440	554	422	541	SR EN ISO 13934-1: 2013
	Weft	445	484	410	480	
Fabric elongation at breaking force (%)	Warp	28.6	23.6	26.7	24.9	
	Weft	32.7	26.2	38.4	29.1	
Fabric tearing strength (N)	Warp	34.4	21.3	65.2	20.7	SR EN ISO 13937-2: 2001
	Weft	32.7	22.5	65.5	20.7	
Fabric bursting strength (KPa)		330.3	368.4	330.2	370.8	EN ISO 13938-2/ 2002
Fabric bursting strength (mm)		35.4	36.3	42.5	43.2	
Fabric air permeability (l/m^2/s) at 200 Pa		10.53	10.34	0	0	SR EN ISO 9237:1999
Raw material		100% PA66HT	100% PA66HT	100% PA66HT	100% PA66HT	SR 13231-95
Coating		Calendered	Calendered	PU coating	PU coating	SR ISO 1833-95
Link type		Ripstop	Double-ripstop	Ripstop	Double-ripstop	-

CONCLUSIONS

The fabric breaking strength is in line with the breaking strength of the yarn, this validates the testing methods and yarn extraction method. A strength transfer coefficient greater than one means the woven structure has higher theoretical tenacity than all the yarns combined. This means that the calendred fabric S3 woven structure amplifies better the yarn tenacity than coated fabrics; however the S1 fabric is not far behind and has way better breaking strength, lower elongation and also lower air permeability, probably because of the double-ripstop structure.

The highest yarn elongation of S2 influences in an interesting way the tearing behaviour and tearing strength results. The S2 fabric gets the highest tearing resistance due to this but is not necessarily the correct one since the fabric torn incompletely. Some threads remained in structure and influenced the results.

Due to the nature of the single sail wing, the amount of fabric used in the manufacture is almost halved therefore the fabric can be a little heavier and also can have a less than perfect air permeability because the shape is maintained by several rigid members. Thus we conclude that the fabric must use yarn of high tenacity Nylon 66; then make use of the rip-stop weave link and polyurethane coating.

The fabric variants obtained were tested and these conclusions were drawn:

- Regarding the air permeability, the most performing variants were the coated ones (V3 and V4).
- Considering the specific mass, the lightest fabric is the V1 variant.
- Considering the breaking resistances, all variants are in the same performance class but with significantly higher values in the case of double-ripstop variants V2 and V4. However, increased tear strength is observed in the case of the V3 variant, this is due to the tearing mode which opposes the propagation of the rupture. This type of tearing behaviour is presented by both V1 and V3.
- Further testing is required to decide if the fabric can be functionalized with hydrophobic properties in order to expand the operational capabilities of the UAV for rainy weather or with applied heating elements for use on sub-zero temperatures or high altitude flying.
- Analysing the results and given the desirable tearing behaviour of the V3 variant, we choose this working variant for the UAV textile structure prototype manufacturing in the next stages of system design.

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