ANALYSIS OF MAIN CHARACTERISTICS OF FABRICS USED IN PARACHUTE MANUFACTURING

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REZUMAT. Tesaturile folosite pentru obtinerea parasutelor trebuie sa aiba urmatoarele carcteristici de calitate: masa unitatii de suprafata cat mai redusa in conditiile in care valorile caracteristicilor fizico-mecanice (sarcina la rupere pe directie axiala, alungirea relativa si absoluta, rezistenta la sfasiere a tesaturii si a asamblarilor, permeabilitatea la aer) trebuie sa fie la nivel maxim. Lucrarea abordeaza analiza aspectelor calitative ale catorva tesaturi folosite in constructia parasutelor. Rezultatele experimentarilor s-au materializat in date statistice, diagrame si grafice iar interpretarea acestora conduc la stabilirea variantei de tesatura care corespunde cel mai bine cerintelor impuse de destinatie. De remarcat este faptul ca rezultatele experimentale au fost comparate cu valori indicate in norme international specifice de testare.

Cuvinte cheie: Parasuta, Textile tehnice, Teste tesatura.

ABSTRACT. The fabrics used to make parachutes must have the following 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 be at a maximum. The paper deals with the analysis of qualitative aspects of several parachute fabrics. 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. It is worth noting that the experimental results were compared with values indicated in specific international testing norms.

Keywords: Parachute, technical textiles, Fabric testing.

1. 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. The two primary groups of textiles are those of natural fibers and those of man-made fibers. Fiber is a generic name that refers to all materials used in the manufacture of textiles. Natural fibers include wool, cotton, silk, hemp, flax (linen) and many others. Out of the natural fibers only silk and cotton are of limited interest to parachute designers [1].

Man-made fibers are classified by their origins. Mineral fibers, the only nonorganic fibers, include glass fiber and metal thread used in woven metals such as metal shielding for electrical wiring. All other man-made fibers are based on cellulose, protein or resin composites. The cellulose group includes rayon; the protein and resin groups include Nylon, Dacron, Kevlar, and others. Cellulose, protein and resin are referred to as organic fibers. For parachute fabrics the Nylon is by far the most used material. Dacron, Spectra, Kevlar, Vectran are trademarks of fibers that are mainly used in parachute line manufacturing.

Nylon: Nylon developed shortly before World War II by DuPont for use in clothing, has become the primary fiber for parachute fabrics. Nylon is a synthetic resin (polyamide) with high tenacity caused by long, highly oriented molecules and high intermolecular forces that resist slippage. Nylon tenacity ranges from 2.5 to 9.5 grams per denier; its elongation ranges from 29 to 40%. Nylon type 6.6, used for parachute fabrics, is rated at 6.6 grams per/denier, approximately equivalent to a tenacity of 115,000 lb./inch^2, which compares favorably to other materials used in the aerospace industry. Nylon is abrasion resistant, durable, and little affected by humidity, fungus, bacteria, organic solvents and alkalis. Nylon is sensitive to ultraviolet radiation (sunlight) this sensitivity can be reduced but not eliminated by appropriate treatment of the fabric. Nylon melts when subjected to fire but does not burn. This fabric can be used, with little loss in strength, at temperatures of up to 250F. Nylon loses 50% of its strength at about 330F, becomes sticky at higher temperatures. and melts at 480E If subjected to repeated stresses, nylon exhibits a certain hysteresis in its strain characteristics, but fully recovers after few minutes [2]. But long exposure to high mechanical stresses and high temperatures notably decreases the strength of the fabric.

2. PARACHUTE FABRICS

Weave type: Parachute fabric is woven in 36, 48, 60 and 72-inch widths. A typical parachute fabric has 122 warp threads, called ends, per inch width, resulting in 4392 ends for 36-inch-wide material. The warp ends are wound on a spool called a beam. The warp ends are guided through the loom using several devices for straightening, lifting and lowering the warp threads in preselected groups before inserting the fill thread. The sequence of lowering and raising the warp groups and inserting the fill thread determines the type of weave. The most common weaves are plain weaves where one fill thread goes over and less than one warp thread, and the more complex are twill, taffeta, satin, and other weaves.

The type of weave desired is shown in a weave pattern bellow. The black squares indicate the thread on top, and the white squares the thread on the bottom. The warp threads are called ends, and the fill threads are called picks. The pattern in the figure (2.1a) shows the weave pattern for a plain weave with one end going over and under one pick, and so on. Frequently the selvage edge of the fabric may have a slightly different pattern to ensure a more rigid, form-preserving edge.

The (2.1b) figure shows the weaving pattern for 1.1-oz/y2 ripstop nylon of MIL-C-7020, the material used in most military personnel parachutes. This fabric has a reinforcing rib woven in to stop small rips and prevent new rips from starting [3].

Weight: Nylon cloth is weighed in ounces per square yard, i.e., 1.1 ripstop is a ripstop weave fabric, one square yard of which weighs no more than 1.1 ounces. Note: the weight of the cloth has nothing to do with its permeability.

Tear strength: Woven textiles possess certain unique mechanical properties unlike other sheet materials such as paper or film. The great improvement in the tear strength is due to the geometry of the matrix into which the fibers have been formed; the yarns are sometimes twisted and then they have been interwoven at right angles into a material sheet. The crossing yarns are free to slide over one another. When a tear is started, the threads move and the stress is distributed around the end of the tear.

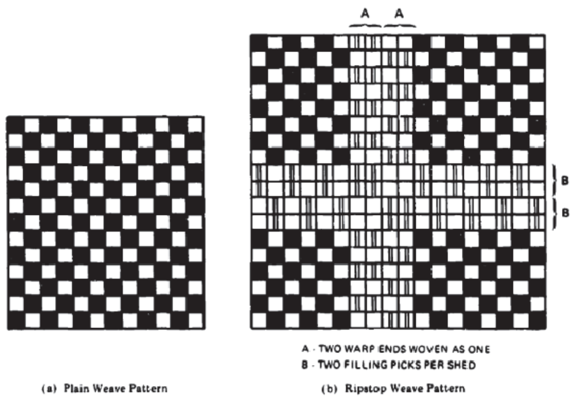


Fig. 2.1. Parachute typical ripstop weave

The threads of a piece of paper, on the other hand, cannot move and continuing a tear is relatively easy. Any treatment or coating of the fabric which reduces this deformability will reduce the tear strength. Therefore, it is normally inadvisable to coat canopy fabrics though sometimes very light coatings will reduce permeability with minimum reductions in tear strength. New coatings are being developed that may even increase tear strength [4].

Most round personnel parachutes were designed to use 36" bolts so that the selvage edges of the cloth would be caught in the diagonal seams. When the fabric weavers switched to wider 72" looms, only one selvage edge could be utilized. The Air Force Flight Test Center at Edwards AFB ran tests on parachutes and found no reduction in structural integrity when constructing diagonal seams of selvage to non-selvage or non-selvage to non-selvage edge material.

Finishing: After weaving, the nylon cloth is sometimes scoured, dyed and dried. It is then calendered.

This is a rolling process using pressure and heat (temperature in excess of 200F) to force the fibers closer together and to spread them out. This process determines the permeability.

Permeability: Permeability is defined as the number of cubic feet of air which will pass through a square foot of cloth in one minute under .5" of water pressure. Nylon threads are not fuzzy and the fabric must be woven quite tightly to restrict the air flow. Permeability is very difficult to control, hence the wide range (e.g. 80-120 cfm for Type I in MIL-C-7020) which is acceptable. In Great Britain, measurements are taken under 10" of water pressure [5].

Material: The nylon yarn used in the manufacture of canopy fabric is a bright, high tenacity, multifilament polyamide prepared from hexamethylene diamine and adipic acid or its derivatives. It has a melting point of 482F, plus or minus 10.

Paraglider fabrics are the same as above sports fabrics but they may have other coatings applied such as Urethane Amino Modified Poly Siloxane Blend coating. This polyurethane coating is an extremely durable and hard-wearing finish which gives zero air-permeability and sufficient fabric rigidity for good aerofoil maintenance. The UV inhibitor gives an added protection against ultra-violet light and the double coating will decrease the dirt collected by the fabric.

Treatment: Military nylon canopy fabric may be treated with 0.3% to 0.5% silicon oil based on the weight of the dry cloth. One type is Dow Chemical Company's Silicon Emulsion ET 112A. Low permeability (0-3 cfm) fabric may be treated with fluorocarbon finishes such as Zepel®.

Manufacturer's Identification: The colored threads woven into the selvage edge of some fabrics identifies the manufacturer. Identification colors are listed in ANA Bulletin No. 195 and MIL-STD-851 [6].

3. METHOD AND TEST RESULTS

The fabrics used in the testing were selected so they cover a wide array of parachute types.

Therefore we selected as material one (*Sample 1*), a fabric commonly used in paraglider manufacturing. This fabric is a rather heavy fabric having poly-urethane and silicone coating for UV protection.

The second material (*Sample 2*) 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 (*Sample 3*) is a fabric with similar structure as Sample 2 but without polyurethane coating. This fabric is only calendered and it's commonly referred to as F111 type fabric. This type of fabric has some air permeability there-fore 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. 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.).

Fig. 3.1. H5KT dynamometer

We also did testing with extracted yarns from the weave to establish a baseline for tests.

The testing results were centralized in Table 1 for both fabric and yarn tests.

Comparative graphs for breaking strength of yarn and fabric are detailed in figures (3.2, 3.3 and 3.4)

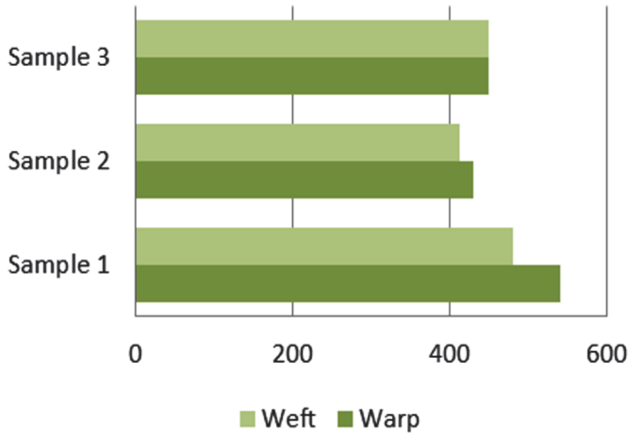


Fig. 3.2. Fabric breaking strength (N)

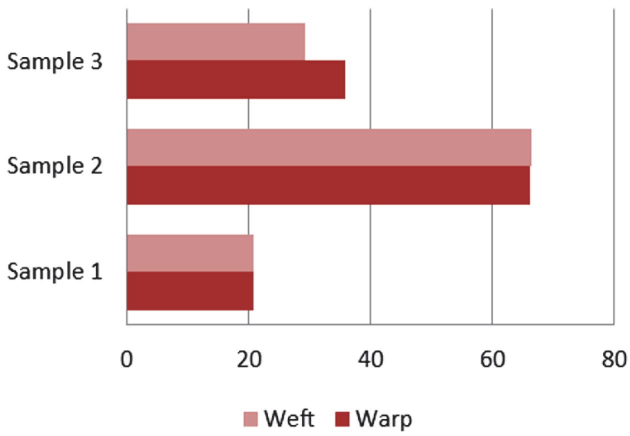
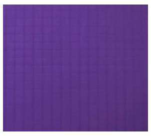
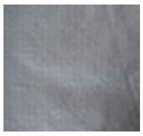


Fig. 3.3. Fabric tearing strength (N)

Table 1. **Test results**

Test Name		**Sample 1**	**Sample 2**	**Sample 3**	**Units**	**Standard**
Fabric mass		59	47	40	g/m^2	SR EN 12127:2003
Yarn count	Warp	474	534	532	threads / 10cm	SR EN 1049-2:2000; Method A, B
	Weft	432	508	524		
Yarn linear density	Warp	61.8 (55.62)	41.2 (37.08)	32.6 (29.34)	DTex (den)	SR 6430:2012; Method A
	Weft	69.4 (62.46)	46.4 (41.76)	32.2 (28.98)		
Yarn breaking strength	Warp	1.943	1.728	1.522	N	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	Warp	541	431	450	N	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	Warp	20.7	66.1	35.8	N	SR EN ISO 13937-3:2002
	Weft	20.7	66.3	29.2		
Fabric bursting strength		370.8	334.2	334.3	Kpa	EN ISO 13938-2/2002
		43.2	42.2	36.6	mm	
Fabric air permeability		0	0	11.57	l/m^2/sec (200Pa)	SR EN ISO 9237:1999
Raw material		100% PA	100% PA	100% PA	-	SR 13231-95
Coating		PU and Silicone coating	PU coating	None	-	SR ISO 1833-95
Link type		Ripstop	Ripstop	Ripstop	-	-
						

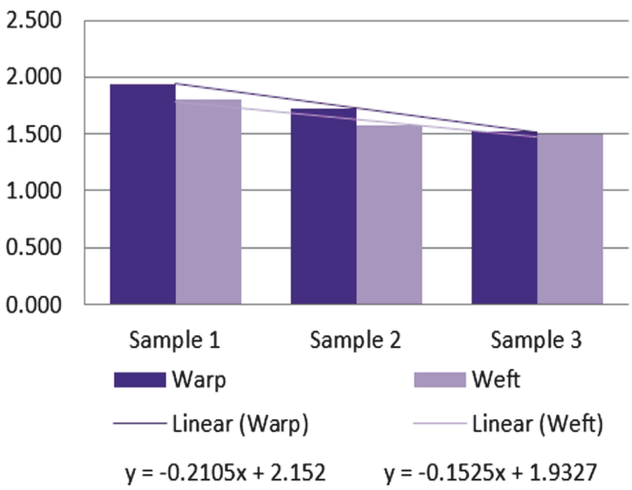


Fig. 3.4. Yarn breaking strength (N)

One important feature we observed in the tearing behavior of sample 2 and is pictured in figure (3.5)

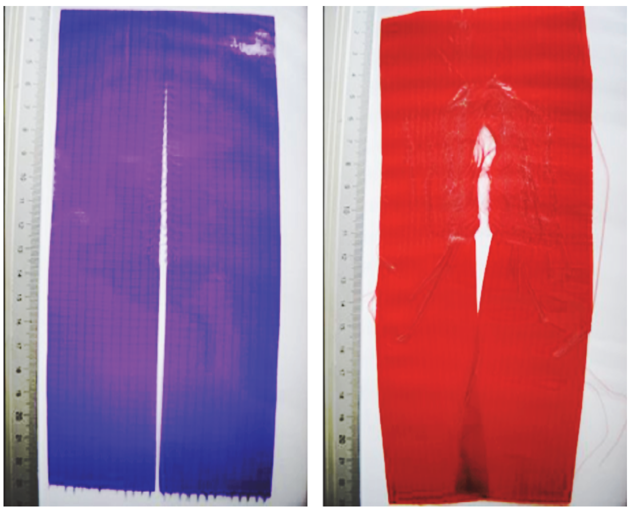


Fig. 3.5. Tearing aspect of Sample 1 (left) vs Sample 2 (right)

4. CONCLUSIONS

The fabric breaking strength is in line with the breaking strength of the yarn, this validates the testing methods and yarn extraction method.

Breaking strength of sample 1 is highest and is influenced by two factors: the yarn linear density and yarn breaking strength both are also the highest.

The highest yarn elongation of Sample 2 influences in a interesting way the tearing behavior and tearing strength results. The sample 2 fabric gets the highest tearing resistance due to this but is not necessarily the correct one since the fabric teared incompletely. Some threads remained in structure and influenced the results.

This tearing aspect can be beneficial for parachute design because it will not break entire structural cohesion at once giving time to the user to evaluate and take proper action.

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