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PARACHUTE FABRIC AND ITS MANUFACTURING PROCESS

[1]Fatma ÇİTOĞLU and [2]Bestem ESİ
[1]Marmara University, Faculty of Technology, Department of Textile Engineering, İstanbul, Turkey
[2]Gedik University, Faculty of Fine Arts and Architecture, Department of Fashion and Textile Design, İstanbul, Turkey
E-mail: [1]fcitoglu@Marmara.edu.tr, [2]bestemesi@gmail.com

Abstract: A parachute is a device used to slow the motion of an object through an atmosphere by creating drag. Nowadays it is a tourism sport especially in holiday regions. The importance of textile materials used in parachute production. The most important of these is the canopy department of parachute. The canopy section allows the air to slow down in the air.In this study, textile materials used in parachute production and manufacturing steps of these materials were examined together with test methods to give general information about parachute textiles.
Keywords: Parachute, parachute fabrics, canopy, cord.

1. Introduction

According to the online version of Encyclopedia Britannica, the parachute is "a device that slows the vertical descent of a body falling through the atmosphere or the velocity of a body moving horizontally."The word "parachute" is a combination of two French words: para (protect or shield) and chute (the fall). Thus, it literally means fall protection. From all this definitions, parachute can be defined as a "device protecting oneself when falling from a height due to earth's gravity"[1].

- **Pilot chute:** Small parachute that deploys the canopy; to open the parachute, the sky diver opens the pilot chute, which pulls the canopy out of the pack.
- **Slider:** Part that slows down the deployment of the canopy to absorb the impact of deceleration as it opens up.
- **Brake loop:** Two cables that control the parachute's direction.
- **Suspension line:** Cables that connect the canopy to the harness.
- **Canopy:** Structure made of fabric cells that, when filled with air, forms a rectangular surface with the aerodynamic properties of an airplane wing.
- **Stabilizer:** Fabric triangle attached to the sides of the canopy; it is used primarily to stabilize the parachute.

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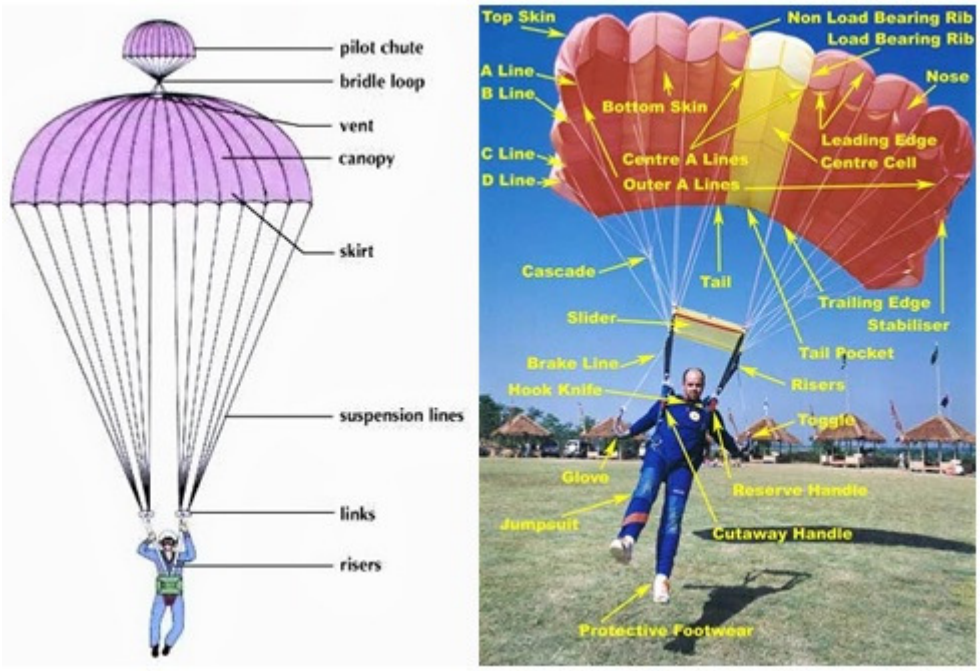

Figure 1. Parts of Parachute [2,4]

• **Harness:** Arrangement of straps that connects the sky diver to the suspension lines of the main and reserve canopies; it is stowed in a pack before departure [3].

Today, in the market, so many parachute designs, various kinds of parachute shapes, and application opportunities can be seen, even some with navigation systems [1]. Although, in the beginning, parachutes were intended to use for landing human safely to the ground, afterwards, they started to be used indifferent applications such as sport parachuting, aircrafts, boats, and race cars decelerating, ordnance, and bombs stabilization [5].

Figure 3. Parachute of different designs such asrectangular, sphere and multiple canopies [6,7,8]

There are many parachute manufacturers all over the world. The most important ones are Carrington Novare (England), Porcher Marine (France), Gelvenor Textiles (South Africa), Perseverance Mills (England), Toray Ind. (Asia), Sofileta (France), Teijin (Japan).

2. Raw Materials and Other Fabric Components of Parachutes

Main materials used to form parachute are fabrics, webbings (tapes), cords, lines, threads, hardware, plastics, synthetics, fasteners, housings, ripcords, cables and swages [10]. Parachute canopies were first made of canvas. Silk proved to be more practical because it was thin, lightweight, strong, easy to pack, fire resistant, and springy. During World War II, the United States was unable to import silk from Japan, and parachute manufacturers began using nylon fabric. The material turned out to be superior to silk because it was more elastic, more resistant to mildew, and less expensive. Other fabrics, such as Dacron and Kevlar, have recently been used for parachute canopies, but nylon remains the most popular material. More specifically, parachutes are made of "ripstop" nylon that is woven with a double or extra-thick thread at regular intervals, creating a pattern of small squares. This structure keeps small tears from spreading [11].

Figure 4. Nylon ripstop fabric for parachutes

Figure 5. Zero porosity ripstop nylon for canopy cloth

Nylon has been used in parachutes for many years, so this discussion will place emphasis upon Kevlar material properties and their application to parachute design and construction. Kevlar-29 is an aramid fiber manufactured by DuPont and is being used on parachute systems requiring high strength-to-weight ratios or sustained strength at high temperatures. Tests of parachutes using Kevlar webbing, braided cords, ribbons, and thread have demonstrated that these Kevlar materials can be used successfully in ribbon parachutes with no detrimental effects on performance. Using Kevlar suspension lines, radials, ribbons, reefing lines, bridles, and skirt bands are presented to show that they are much lighter and more resistant to aerodynamic heating than all-nylon parachutes. Nylon continues to be an important material for high-performance parachute systems, however. New nylon weaves have resulted in lighter weight, stronger ribbon materials with excellent sewability characteristics [12].

Other fabric components such as reinforcing tape, harness straps, and suspension lines are also made of nylon. Metal connectors are made of forged steel that is plated with cadmium to prevent rusting. Ripcords are made from stainless steel cable [11].

2.1. Fabric

A parachute is a device, used to slow the motion of an object through an atmosphere by creating drag, or in case of ram-air parachutes, aerodynamic lift. Parachutes are usually made out of light, strong cloth, originally silk, most commonly nylon.In addition to the structural analysis of the cloth, the properties measured are weight, breaking strength, tear resistance, elasticity, and air permeability.

Cloth should possess a high resistance to the continuation of a tear already started, whereas breaking strength always applies to the simultaneous breaking of system of yarns.

Parachute’s quick and positive opening, depends largely on the ability of the layers of the cloth to spring apart along the folds, thus permitting air to rush in and quickly inflate the envelope. The elasticity of cloth tends to distribute the sudden load more uniformly over the envelope, thereby preventing development of excessive stress in the region of the envelope.

What’s more, strength, elongation characteristics of the fabric is other significant parameters both affected on air permeability of the fabric and the performance of the parachute. It is certain that, if fabric is easily elongated then gaps will be formed between yarns that drawn away from each other and permeability will be increased. In addition, the importance of tensile properties of the fabric is because of its absorbing role of excess forces. Especially during deployment, opening shock creates excess forces and if canopy fabric has not required tensile strength, some part of the canopy fabric can be torn or deformed [11].

2.2. Cords

Unlike fabric, cords are one-dimensional components and they are affected by gravitational and drag forces across their longitudinal axis. Therefore, for getting good performance results generally they are produced in braided structural form.

The expected properties of cords are to present low drag, high strength, optimum elongation, good stabilization, lower volume packing, non-twisted lines, good durability, lower cost, good abrasion resistance, easy handling/sewing techniques requirement, less weight and so on.

Nylon was the first synthetic yarn that used in cords and it has a medium drag, good durability, inexpensive cost, good elongation, but high bulk and heavy weight properties. Nevertheless, subsequent innovated materials was heavily accepted in the market, so nylon use as cords can be seen so limited today.

Other materials frequently used in cords are **Kevlar** and **Spectra**. Although Kevlar and Spectra have very similar performance characteristics with Nylon and Dacron, in case of some properties they display clear differences such as low bulk, low drag, expensive cost and high strength [13].

Figure 6. Parachute Cords

Figure 7. Coil of commercial parachute cord

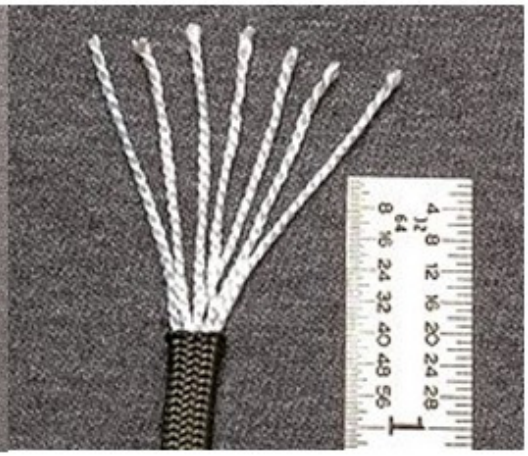

Figure 8. The sheath of this commercial parachute cord is braided from 32 strands and the core made up of seven two-ply yarns. The scale is in inches.

2.3. Thread

For sewing and stitching applications, It is important to select the material type of thread properly to find better fit thread with the material that will be sewn on. If you are using nylon based fabric then it is better to use nylon thread, if you have cotton fabric then your thread should be cotton based. Because different materials have different characteristics in use and under stress they show different behaviors. Also another important point is to select strong, flexible, heat resistant, good twisted thread to have better performance. In general as a result of heavily used nylon in canopy fabric, nylon thread is heavily preferred as well. Kevlar has not satisfied characteristic as a thread, but with Kevlar fabric and webs it can be used. Cotton is the best as a thread in use but it is like others preferred to use with cotton based fabric and webs [13].

Figure 9. Parachute Threads

2.4. Tapes, Webbings

Both tapes and webbings are used in the literature to point out woven narrow fabrics which are placed mainly on harness, risers and some as a stowing member on container and deployment bags. Cotton, nylon, Kevlar, Nomex and Dacron are the materials that are commonly used in webbing structure. The desired properties of webbings are good strength, durability, shock absorbance, less thickness, lighter weight, abrasion resistant, heat resistant and some others [13].

Figure 10. Tapes, webbings

3. Manufacturing Process

3.1. Assembling, Finishing and Rigging

The manufacturing steps of the parachutes are explained below:

1. Ripstop nylon cloth is cut according to pattern pieces by a computer-guided mechanism or manually by using a round-bladed electric knife.
2. Four trapezoidal panels are sewn together to form a wedge-shaped "gore" about 13 ft (3.96 m) long. A two-needle industrial sewing machine stitches two parallel rows. To provide sufficient strength and enclose the raw fabric edges, a "French fell" seam is used.
3. A number of gores (typically 24) are sewn together, side by side, to form a circular canopy. The seams are sewn in the same manner as in Step 2.
4. Every panel and every seam is carefully inspected on a inspection table. If any weaving defects, sewn-in pleats, or an incorrect number of stitches per inch is found, the canopy is rejected.
5. A tape the same width as the original seam is sewn on top of each radial seam using two more rows of stitching. This tape strengthens the canopy.
6. The top of each gore is a few inches (several centimeters) wide; after the gores are sewn together, their tops form a small open circle (the vent) at the center of the canopy. To reinforce the vent and to keep the cloth from fraying, the fabric is rolled around a piece of webbing and sewn with a four-needle sewing machine, which stitches four parallel rows at once.
7. The bottom of each gore is 2-3 ft (0.5-1 m) wide. Sewn together, these edges form the outer edge (the skirt) of the canopy. This edge is finished in the same manner as the vent, as in Step 6.

8. A short piece of reinforcing tape is sewn to the skirt at each radial tape. It is folded into a "V" pointing outward from the canopy. A specialized automatic sewing machine, designed for this specific operation, is used to sew precisely the same number of stitches in exactly the same pattern every time.

9. One end of a 20 ft (6 m) long suspension line is threaded through each V-shaped tab. Using a special zigzag pattern that is both strong and elastic, the suspension cord is sewn to the canopy's hem tape and to the canopy seam for a length of 4-10 in (10-25 cm).

10. After the 24 suspension lines are sewn to the canopy, 12 1 ft (30 cm) long apex lines are similarly sewn to the central vent. One end of each line is stitched into a V-tab, then the line crosses the vent to the opposite seam where the other end is stitched into a V-tab.

11. Later the canopy is attached to the harness by tying the suspension lines to steel connector links on the harness.

12. Attaching the lines to their correct sequential positions on the connecting links of the harness and making certain that the lines are straight is called rigging the parachute [11].

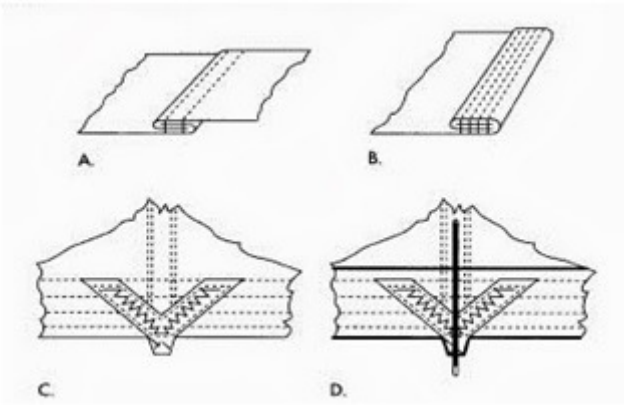

Figure 11. Different types of stitching and seams

4. Test Methods

4.1. Tear Tests

A fabric tears when it is snagged by a sharp object and the immediate small puncture is converted into a long rip by what may be a very small extra effort. It is probably the most common type of strength failure of fabrics in use. It is particularly important in industrial fabrics that are exposed to rough handling in use such as tents and sacks and also those where propagation of a tear would be catastrophic such as parachutes [14].

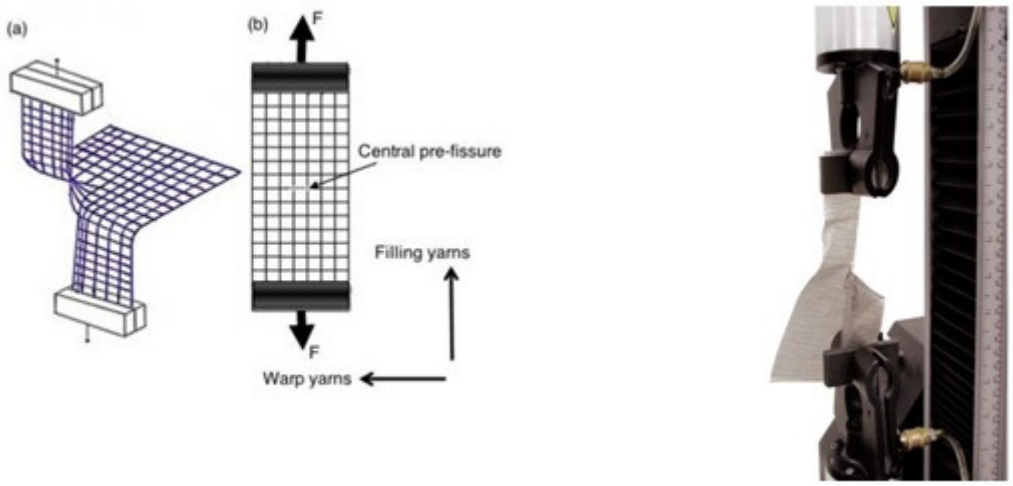

Figure 12. Single Tear Test

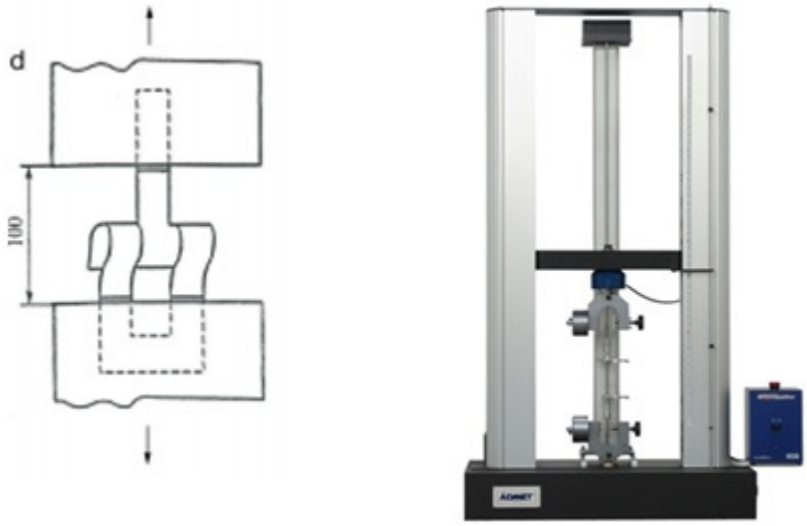

Figure 13. Double Tear Test

4.2. Bursting Strength Tests

Bursting Strength is an alternative method of measuring strength in which the material is stressed in all directions at the same time and is therefore more suitable for such materials. There are also fabrics which are simultaneously stressed in all directions during service such as parachute fabrics where it may be important to stress them in a realistic manner [14].

Figure 14. Digital Bursting Strength Tester

4.3. Air Permeability Tests

Air permeability is an important factor in the performance of such textile materials as gas filter, fabrics for air bags, parachutes.It can also be used to provide an indication of the breathability of weather-resistant and rainproof fabrics. Air permeability depends on thickness, weight and porosity of fabric [15].

Figure 15. Fabric Air Permeability Tester

5. Conclusion

In this literature review, production ofparachute fabrics and other parts and manufacturing steps of these materials were examined together with test methods to give general information about parachute textiles. Parachute material has to be light, flexible, and windproof. The other important factors density, rigidity and texture of the material to control speed and safe landing. Parachute manufacturers and scientists have efforts to improve parachute technology and fabrics for better designs.

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