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Analyzing Chemical and Physical Variations in Selected Cotton Wires at Ambient Temperatures and Conditions

Clara Silvestre de Souza and José U.L. Mendes

Abstract

Cotton, a hydrophilic textile fiber, has unstable characteristics and, for this reason, it varies its properties according to the environmental changes. Moisture and temperature are the two most important factors that lead a cotton spinning sector and influence its quality. Those two properties can change the entire spinning process. Understanding this, moisture and temperature must be kept under control during the spinning process; once the environment is hot and dry, the cotton yarns absorb moisture and lose the minimal consistency. According to this information, this chapter was developed testing four types of cotton yarns, one kind of cotton from Brazil and the others from Egypt. The yarns were exposed to different temperatures and moisture in five different tests, and in each test, six samples were examined through physical and mechanical tests: resistance, strength, tenacity, yarn's hairiness, yarn's evenness, and yarn's twisting. All the analyses were accomplished at Laboratório de Mecânica dos Fluidos and at COATS Corrente S.A., where it was possible to use the equipment which were fundamental to development of this chapter, such as the STATIMAT ME, which measures strength, tenacity; Zweigler G566, which measure hairiness in the yarn; a skein machine; and a twisting machine. The analyses revealed alterations in the yarn's characteristics in a direct way; for example, as moisture and temperature were increased, the yarn's strength, tenacity, and hairiness were increased as well. Having the results of all analyses, it is possible to say that with a relatively low temperature and high humidity, cotton yarns have the best performance.

Keywords: temperature, moisture, cotton yarn, yarn twisting, yarn hairiness

1. Introduction

The cotton fiber is the basic raw material for cotton spinning mills in cotton wires production. This fiber is the largest input material for cotton wire production used in clothing due to mainly comfort characteristics it contains. Cotton, being a natural fiber, possesses several irregularities in its physical characteristics and plenty of impurities during harvesting and ginning process. From the cotton harvesting to the yarn, some processes are necessary, and they are known as the cotton mill process.

The lack of quality and the incidence of imperfections on cotton wires may result in major financial losses for the company that produces them and for the client who buys them. For this reason, the objective of a successful spinning is to produce high quality cotton yarns, economically. It is only possible by the oriented and controlled utilization of the raw material in the spinning process.

The humidity and the temperature are very important factors in a textile industry. Given that the cotton is a hygroscopic fiber, it is capable of absorbing a great amount of water, and it is necessary to keep it conditioning in an environment with relatively high humidity. To avoid fires or rupture accidents, the air temperature should be relatively medium, around 20–25°C. The humidity measured inside a cotton mill is, indeed, the relative humidity of the air, which means relative humidity is the water vapor ratio present in the air and the percent (%) of the maximum possible water vapor quantity that is currently in the air. As the maximum humidity is temperature dependent, relative humidity changes with the temperature even when absolute humidity remains constant.

With the objective of analyzing cotton wires, derived from the ring spinning, and the effect caused by the temperature and the humidity in its manufacturing process, this write-up was conducted in partnership with Universidade Federal do Rio Grande do Norte and COATS Corrente S.A.. The analyses carried had the aim of testing the different behaviors presented by cotton yarns when exposed to distinct values of temperature and humidity. The characteristics analyzed were count, nepiness, twist threads, and tensile strength. The experiments were performed in the COATS Corrente S.A. Laboratory of Quality Control. The tests were carried using three types of cotton material: Giza 88 carded, Giza 86 (carding and drawing), and Meridional carded. For each type of cotton, six bobbins were used. Daily analyses were conducted, and there were changes in the temperature and the humidity for each test day. After the analyzing the material and observing the results, it has been found that the carding and drawing wires submitted to different values of temperature and humidity presented strength and nepiness values directly proportional to the temperature increase.

Hence, this work was aimed to analyze physical and mechanical properties of cotton yarns, deriving from ring spinning, suffering temperature and humidity variations.

2. Bibliographic review

Cotton consists in a fibrous material surrounding the seeds of cotton, belonging to the mallow family, *Gossypium* spp. It is used in textile industry and is a plant of hot weather that cannot handle cold. According to the older documents, it is originated in India, expanded through Iran and Western Asia, in a westerly and northerly direction.

Cotton can be classified in various ways, including length, type of cotton, uniformity of length, index or contents of short fibers (%), fineness, resiliency, strength, elasticity, flexibility, reliability, balance, maturity, humidity and regain, color, shine, and light reflectance.

With respect to mechanical characteristics of the cotton fibers, they are probably the most important properties, contributing for fibers behavior during the process, and its properties on final product. Due to their magnitude, the most important mechanical properties of the fibers are the tensile strength properties, its behavior under the application of forces, and deformities along the axis of the fiber. One of these, the easier to study, experimentally, is the extension (elongation), and finally rupture, under a load that increases in ascending order.

The tensile strength is a measurement of the force applied in order to break the yarn or the fiber. For a single yarn, the strength is measured according to the breaking load, and when multiple twisted yarns are tested, the breaking load is also called tenacity. When the elongation is measured before breaking the yarn, the most important point to verify is the tension that every yarn may sustain, as it may be observed in the results. Another mechanical property tested was the rupture point, the necessary energy to burst the yarn.

Yarns are textile material constituted by natural or manufactured fibers, presenting fineness and high ratio of length, formed through various spinning operations. They are characterized by their regularity, diameter, and weight; the last two characteristics determine the count of the wire. Overall, the yarn can be defined as a grouping of linear fibers or filaments, which form a continuous line with textile characteristics. These textile characteristics include high tensile strength and high flexibility.

The staple fibers or filament wires, flat and textured, could be twisted with the purpose of increasing water resistance. Made from a single yarn, or inside a single yarn, a variety of effects in the wire may be created, **Figure 1** [1].

The cotton yarns used in this study were derived from the ring spinning. The bobbins containing the wires were donated by COATS Corrente S.A., which manufactures, mainly, sewing and embroidery threads. The single yarns manufactured and used in the analyses were three types: Giza 88 combed (200 dtex), Giza 86 carded and combed (220 and 222 dtex), and Meridional carded (660 dtex). For each analysis, six bobbins had been used for each type of cotton.

The ring spinning process occurs when the cards output the cards output fuses fibers and the input on a runner, where they are duplicated herewith with other fuses and then, join together again to form a fuse, this function is used to reduce mass variation per length. After that the fuses go to the roving machine in order to twist the fuse into a wick, and then wind on bobbins throughout a ring in a spinning machine. In the final part, they go from the bobbins to the cones on the cone winder. The yarn made by this method is named carded yarn. With conventional spinning, it is also possible to manufacture a combed yarn. The difference during the process is an addition of two more machines after carding, which are the Assembling Winder and the Comber, whose main function is to extract short fibers resulting in the production of high quality yarns, less nepiness, and higher strength, beside the production on very fine yarns [2].

Aiming to avoid yarns break during the spinning process, a properly humidified area and a significant cooling are necessary. The control of the room humidity ensures an increase in production due to a superior strength and flexibility of the

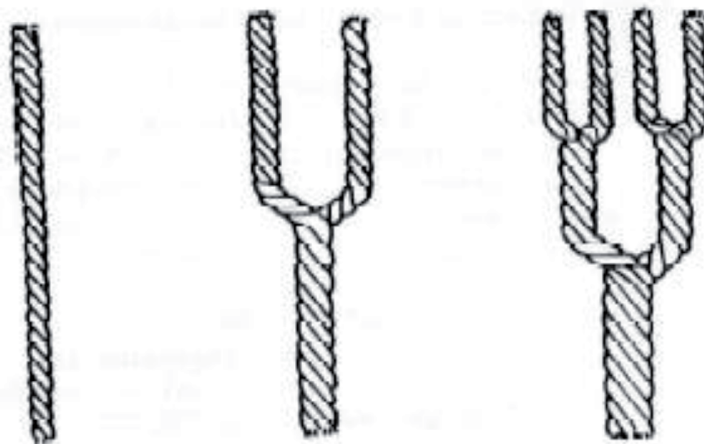


Figure 1.
Single twisted yarn; multiple twisted yarn; multiple twisted yarn twice twisted [1].

textile fibers when processed between 65 and 70% relative humidity. Furthermore, these conditions guarantee the reduction of air dust. Most textile fibers, especially natural fibers, are hygroscopic, that is to say, they are capable of absorbing or releasing humidity. When there is the excess or lack of humidity in the environment, the fiber's physical characteristics like weight, strength, etc., are altered. For example, linen and cotton show a considerable strength increase when their humidity increases. The quantity of humidity in a fiber sample may be described as Regain or recovery, or even in terms of humidity content [3, 4].

Cotton fiber Regain may change physical properties and interfere with the capacity of spin of the fiber, hence altering the results. In addition, it is known that humidity distributions along the yarn are not homogenous; therefore, humidity changes, imperfections, and defect levels shall be expected. Preconditioning in a dry atmosphere for several days and a subsequent conditioning for, at least 24 h, are some cares that must be observed [5]. Thereby, any influence resulting from thermo hygrometers conditions is completely eliminated. Therefore, textile fibers hygroscopicity is a remarkable property because of its effect on textile articles properties. Leonardo Da Vinci (1452–1519) once mentioned the property hygroscopicity in his notebooks, imagining a scale in which one plate e put cotton an in the other one, an equal mass of wax.

3. Methodology

For the carried out experiments, six bobbins (100% cotton) were donated by COATS Corrente from four types of cotton, which were Giza 88 combed 200 dtex, Giza 86 carded 222 dtex, Giza 86 combed 220 dtex, and cotton Meridional combed 660 dtex. The cotton characteristics may be checked in **Table 1**.

To get the analysis conducted, a refrigerator Consul, 120 l capacity, has been used. To take measures, a Thermo Hygrometer Oregon Scientific, temperature variation at –20 to 60°C and relative humidity 25 to 90%, has been chosen.

By choosing the refrigerator as a climatic chamber, some difficulties appeared; for example, the fact the equipment loses relative humidity to the same extent the temperature decreases. Also the abrupt reduction of the temperature compromised the research. Aiming to find the righteous temperature and humidity required by the chapter, there has been a lot of research conducted on the equipment intending to adapt the refrigerator into a climatic chamber.

After the equipment acquisition, first, analyses were made to test its capacity. The refrigerator has a thermostat for three different temperatures: MIN, MAX, and MED, as shown in **Table 2**. The refrigerator analyses were conducted in Laboratório de Mecânica dos Fluídos at Núcleo de Tecnologia da Universidade Federal do Rio Grande

COTTOM	COLOR	LENGTH	MICRONAIRE	WEIGHT
GIZA 88	SLIGHTLY YELLOW	38 – 40 mm	4.3	110 g
GIZA 86	WHITE	34 – 36 mm	4.75	110 g
MERIDIONAL	SLIGHTLY YELLOW	30 – 32 mm	3.8	110 g

Source: Author

Table 1.
Types of cotton used in the analysis and their characteristics.

THERMOSTAT POSITION	TEMPERATURE
MAX	$\pm 5^{\circ}\text{C}$
MED	$\pm 3^{\circ}\text{C}$
MIN	0°C

Table 2.
Temperature corresponding to the thermostat position.

do Norte, and, the yarn analyses, in Laboratório de Controle de Qualidade at COATS Corrente, in November and December, 2010, and in February and April, 2011.

After an overall evaluation of their results, it that the temperature which is best suited to analyses is the temperature reached with the thermostat on MAX. This was owed to the coordination with Brazilian technical standard NBR8428, which sets out that the ambient temperature must be around 20°C and relative humidity 65%.

With temperature variations analyses accomplished, there was a need to keep constant humidity inside the refrigerator. It was complicated, since the refrigeration equipment works taking off the humidity from the room where it is planning to refrigerate, leaving the climatic chamber dry. As there was an absence in this respect, it was necessary to supply it. The first analysis was carried in order to measure the decrease in humidity inside the refrigerator.

It could be verified, as was expected, that the temperature has dropped quickly inside the equipment, reaching approximately 0°C within 2 h.

Subsequently, a nebulizer has been inserted inside the refrigerator with an aim to increase the humidity inside the refrigerator. Nebulizer has also the task of increasing the temperature and stabilizing it.

Utilizing the nebulizer, relative humidity remained stable between 54 and 57%; however, the temperature continued to fall. Subsequently, temperature stabilization was analyzed. Humidity had a slight stabilization although it was considerable as compared with the previous day. To achieve this goal, a more complex test has been done. With the nebulizer turned on, the refrigerator had a small opening near the door, 8 cm, which permitted the equipment to exchange heat with the environment.

With the opening of the door, the temperature increases immediately reaching 0°C ; however, humidity remains the same. About 2 h and 17 min of experiment later, it can be verified that temperature ranged and after stabilized, with the door opened, the humidity stabilized but decreased again.

Previous reviews have proved that nebulizer can sustain a stable humidity although it was not enough. It was also substantiated that temperature stabilizes with the door opened, exchanging heat with the external environment. Therefore, it was decided that the standard would be the use of two beakers (500 and 1000 ml) and, aiming to increase the temperature inside the refrigerator from 20 to 22°C , the door would be opened from 8 to 16 cm.

After the temperature and humidity analysis were made inside the climatic chamber, the equipment has been taken to COATS Corrente in Extremoz, Rio Grande do Norte. In the Laboratório de Controle da Qualidade da empresa, it was possible to conduct other analyses regarding tensile strength, nepiness, count, and torsion on cotton yarns.

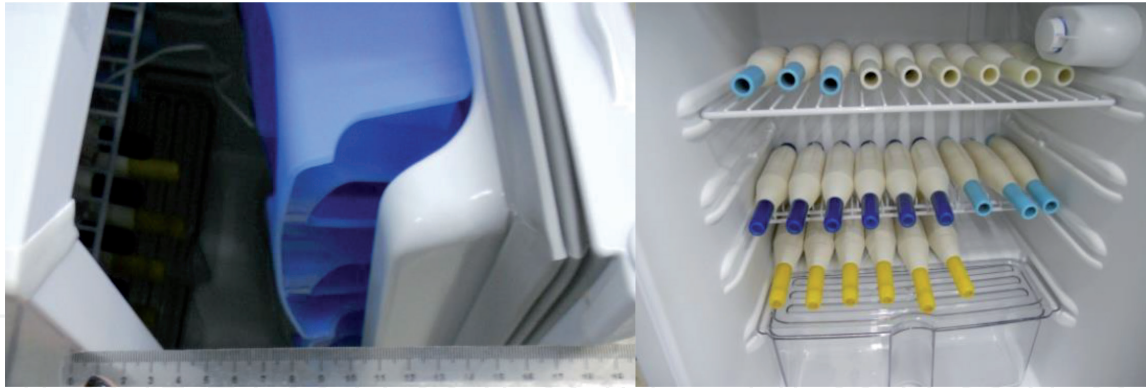


Figure 2. Refrigerator with the door opened in 8 cm and bobbins inside the refrigerator. Source: Author

Analyses and tests were carried in COATS Corrente with a time interval of 24 h, under the NBR 8428 standard specifications. After the confinement inside the refrigerator, **Figure 2**, bobbins follow to: count, torsion, tensile strength, and nepiness. Initially, with temperature 27°C, 24 bobbins were taken directly from the spinning mill to the Laboratório de Controle da Qualidade to conduct the analyses, in an atmosphere of 27°C and relative humidity 45%. Next, bobbins were placed for 24 h in a 27°C temperature and relative humidity 33% inside the disconnected chamber.

Regarding the equipment's used for testing the refrigerated bobbins, the STATIMAT ME was used to conduct tensile strength tests on wires and for nepiness, Zweigle G566 was used. The Hairiness Tester Zweigle evaluates the amount of irregularities per millimeter on the yarn.

The count tests were carried using a winder and an electronic scale. The winder, as main purpose, creates skeins from yarns wrapped on bobbins with a predetermined length. The COATS tests, the Giza 86 and 88 winds had 100 m long and cotton, 50 m long, because of its count, thicker.

During the test, a certain length was placed between the two claws of the torsion machine and then, one of it twists and the other gnarled the yarn.

The tests conducted in COATS were carried using company's own standards, i.e., COATS quality standard.

4. Results

The main objective of the tests analyzed in this chapter was to observe physical characteristic behaviors of cotton yarns under temperature and humidity alterations. To this end, tests were carried on the wires, varying on the fluctuation of temperature and the relative humidity of the air, **Table 3**.

4.1 Tensile strength

Tensile strength tests were divided in two: tenacity is the energy required to fracture or break a part of a sample and describes its ability to absorb energy before rupture. Elongation at fracture is also a quite important factor for the wire quality since it qualifies yarns as resistant or strong, and rupture force which is characterized by the required quantity of energy to break the wire. All tests occurred in the same equipment.

To analyze tenacity, a behavior already expected was shown by the bobbins but with higher values on the last day of tests, which means, lowest relative humidity of the room, due to air conditioning.

ANALYSES	TEMPERATURE	HUMIDITY
1 st Test	27°C	45%
2 nd Test	27°C	33%
3 rd Test	17,4°C	32%
4 th Test	19,5°C	31%

Source: Author

Table 3.
 The values of temperature and humidity for each experiment day.

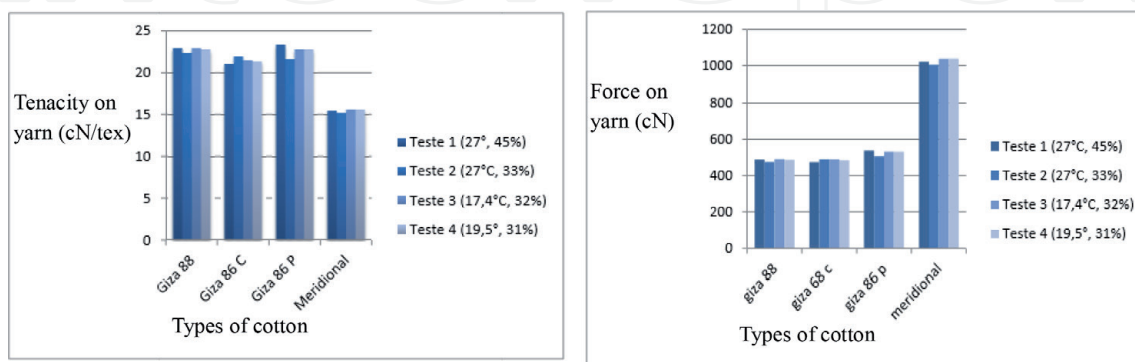


Figure 3.
 Graphs related to (a) tenacity and (b) rupture force. Elongation graphs is not presented because of a similar behavior to tensile strength which has occurred. A similar performance occurred with rupture force and work.
 Source: Author

On the other days, the values were lower due to variation in temperature and humidity. The test proved that Giza cotton has a better quality than Meridional cotton [6].

Elongation at fracture analysis has shown distinct results due to the complexity from the yarn. Meridional cotton, even with an inferior quality when compared with the other types, and a lower tenacity, presented a higher elongation, seen in Figure 3. It has also been evident that a combined cotton has higher elongation than a carded one.

Regarding rupture force, Meridional cotton had higher values. It is because of a higher count. Other analysis shown a linear behavior, almost uniform, not having force increase or loss, even varying temperature and humidity. As have been proved in the elongation test, combed cotton presented a better performance than the carded cotton.

With regard to rupture work, Meridional cotton carded 660 dtex was analyzed and, as its count is higher than the other types of cotton tested, Meridional shown a rupture work value higher than the others. The other types of cotton presented lower values.

4.2 Count

The count of each sample is obtained through a relation between the fuse weight (grams) and the fuse length (meters). The COATS equipment used provided the weight of the sample (grams) and automatically converted into the count fuse value.

It may be said that there were not great variations on the count medium value. The variations were irrelevant and they may occur because of temperature and humidity changes, whether by the position of the wire on the bobbin, or even by the torsion applied on the spinning mill. There are many reasons for this slight alteration in the count value; however, the temperature and the humidity changes have not altered on a relevant way the bobbins medium value.

TESTES	MERIDIONAL		GIZA 86 CAR		GIZA 86 PENT		GIZA 88	
	CV (%)	σ	CV (%)	σ	CV (%)	σ	CV (%)	σ
TESTE 1	2.704	17.87	2.710	6.089	3.754	8.70	1.049	2.64
TESTE 2	3.057	20.28	1.633	3.656	3.025	7.08	0.915	1.941
TESTE 3	2.252	14.89	2.035	4.634	3.592	8.37	1.041	2.229
TESTE 4	2.047	13.58	1.470	3.329	2.928	6.86	1.090	2.339

Source: Author

Table 4.
Values of count medium variables for each of four cotton types.

Table 4 shows the quotient of count variation and standard deviation. It may be seen through these values that even with this slight modifications, there was no major changes in the medium final result, and therefore it may be concluded that temperature and humidity alterations have not affected considerably the count.

4.3 Torsion

Torsion process was similar to the count process. An arithmetic mean was carried after analyses in each of every six bobbins. To create the torsion pattern, a quality control table from COATS has been used, and it can be seen in **Table 4**.

Torsion analyses were carried through a torsion machine. The edge of the strip value is important to close the torsion because it is the maximum point which can be twisted and gnarled.

The behavior related to the torsion was similar to the count. There were no expressive variations, except for Meridional cotton; however, this is due to a major part of its formation at the spinning mill and the shape from the bobbins where it is wrapped on.

4.4 Nepiness

Nepiness testes conducted on yarns have revealed higher temperature and humidity influence on count and torsion.

For example, being a noble cotton, Giza 88 presented lower values for nepiness in all tests, mainly, when exposed to a lower temperature.

Even being a carded wire, Giza 86 presented an adequate behavior related to nepiness. Similar as happened with Giza 88 carded, Giza 86 has shown less neps on the second and third days. This is due to humidity decreased on the second day and temperature decreased on the third day.

Even passing through the combing process, which removes short fibers paralleling yarns, combed Giza 86 presented a great quantity of neps, and the appearance of 12-mm long fibers could still be noticed. Due to combing process, long fibers remained and short fibers are eliminated.

Being thicker and having a higher count value than the other types of cotton tested, Meridional cotton wires presented a different perspective in other analyses. This yarn showed a higher short fibers quantity and a negligible amount of long fibers. This fact is due to carding process, which do not remove short fibers like the combing process.

5. Conclusion

From the realization of the tests that rendered graphs and tables, some conclusions could be obtained:

- a. Yarn Giza 86 presented different results for carded and combed wires. This is because the combed yarns become more resistant to traction than the carded wire, since short fibers are removed.
- b. Count and torsion have not shown significant alterations proving that the temperature and the humidity do not influence these characteristics. However, if humidity value was higher than the one used in the test, it could have been assigned another perspective, regarding the count.
- c. The results obtained with the Hairiness tester were directly proportional to the data obtained from the tensile strength test, in other words, the lowest is the resistance to traction, the highest is the short fibers quantity. That result can also be compared with the temperature results, so with the temperature increased, it has been and increasing of both parameters.
- d. Cotton Giza 88 and Giza 86 combed have the best results for all the analyzed parameters, this is due to both yarn are combed.
- e. Cotton Giza 86 combed has shown to best performer to all parameters analyzed, and it has proven the best for the final purpose, that is to say, sewing thread.
- f. Meridional cotton, having a higher count value (thicker), has shown that a higher tensile strength to break as well as a superior resistance to the other are necessary. Due to its count value and stronger characteristics, it could not be used or delicate yarns, being used as rustic sewing threads.

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