Research Article

Effect of Weave Type on Tensile Strength of Cotton Fabrics

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Abstract: Fabrics are made with different types of fibers and yarns for multiple reasons. It is very crucial to choose the right and appropriate type of construction technique for various functional purposes. Because it plays an important role in determining the performance behavior of finished fabric. Weaving is one of the commonly used technique and different types of weaves have different effects on mechanical and physical properties of fabrics. The study was experimental in nature. It was aimed at investigating the effect of weave type on tensile strength of cotton fabrics manufactured with various interlacing patterns. Fabrics were manufactured by following three key structures of weaving such as plain, twill and satin. Tensile strength of each prepared fabric was determined by following Strip Methods ISO 13934-1. The results depicted that plain weave structure had better tensile strength both in warp and weft directions followed by twill and satin weave. It was due to the less interlacing per unit area of the prepared fabric. Moreover, plain weave helped to create more compact structure that resisted the pressure applied by using tensile tester. It is suggested to use plain interlacing pattern for manufacturing durable structures both for apparel and upholstery industry. This study can help textile manufacturers to alter their construction specifications for preparing strong fabrics for various end uses.

Received: January 11, 2020; **Accepted:** May 23, 2020; **Published:** June 22, 2020
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Citation: Ijaz, M., 2020. Effect of weave type on tensile strength of cotton fabrics. *Journal of Engineering and Applied Sciences,* 39(1): 65-69.
DOI: http://dx.doi.org/10.17582/journal.jeas/39.1.65.69
Keywords: Tensile strength, Weave type, Interlacing pattern, Warp, Weft

Introduction

The performance of fabrics used for any end use largely depends on certain parameters that can be controlled during the manufacturing process. Fabric is a complex structure made up of different types of fibers and yarns. It is not always possible to predict its physical characteristics, as it may undergo many changes during production process (Das, 2010). These parameters include nature of fiber, type of yarn, type of twist, amount of twist, yarn count, interlacing pattern, threads per inch in a fabric, tear strength, tensile strength, elongation, stretch-ability or finishing treatments etc. Out of all these, behavior of yarn is the most important indicator in defining quality of fabrics (Frydrych *et al.*, 2000). There are some other factors that can indirectly affect the performance of fabrics such as temperature, humidity, surrounding environment, type of loom used for interlacing or interloping techniques etc. (Gabrijelcic *et al.*, 2008).

Weaving is one of the most commonly used fabric construction technique. It is done by interlacing of two sets of yarns at right angle, one running in lengthwise direction known as warp or ends, other set running in the crosswise direction known as weft, fillings or picks (Aisyah *et al.*, 2018).

Mechanical properties play an important role in serviceability of textile materials. A fabric that serves its functional purpose but unable to give required strength, can no longer be considered as a suitable

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material for the said purpose (Ijaz, 2017). Tensile strength is considered as the ability of any material to resist external force without damaging it. It is a predicator to measure the quality of fabrics for any end purpose (Malik *et al*., 2011; Uttam and Gangwar, 2006). For example, it is usually observed that low quality of yarn produces less durable fabric and vice versa (Gordon and Hsieh, 2007). So, a minimum strength demanded by buyer must always be communicated to the manufacturers while defining specifications of the order to ensure right quality (Malik *et al*., 2011).

Relevant literature explores that tensile behavior of fabrics is largely based on the interlacing pattern of yarns in warp and weft directions at right angle to each other. Number of yarns in a specific fabric, weave type, ratio of warp and weft must always be taken into consideration in determining tensile behavior of woven structures (Mishra *et al*., 2013) Woven fabrics behave in anisotropic manner by showing different actions in different directions, so these materials should always be evaluated in lengthwise and crosswise directions. They also vary in their oblique direction (Winnie, 2001).

Textile structures are used to prepare material for apparel, upholstery and industrial purposes. The selection of end use largely depends on its durable characteristics. The strength and durability are well studied by tensile behavior of fabrics. There is very less research work conducted specifically on the manufacturing process of woven materials in order to make comparisons on weave structures. This study emphasized the role of interlacing patterns in making fabric more durable and strong. This study can be considered as a helpful tool for the manufacturers to make decisions while preparing woven fabrics for various end uses.

Materials and Methods

Ring spun yarns were used to manufacture three sets of woven fabrics. Fibers were first opened and cleaned from impurities such as dust, dirt or foreign matter. Fibers were then carded to convert in a strand. They were combed to separate short and long ones. Final yarns were made smooth, fine and even to convert into a fabric structure. The resultant yarns were twisted with adequate number of twists to induce required strength in them. Yarns were collected into form of bobbins and then packaged for weaving process.

Three sets were manufactured by following plain, twill and satin weave structures respectively. Details of manufactured fabrics are given in Table 1.

Table 1: *Construction details of manufactured fabrics.*

Weave type	Interlacing pattern	Mass (GSM)	Threads per inch	Linear density (warp)	Linear density (weft)
Plain	1/1	105	176	8.652	8.956
Twill	2/1	107	154	8.652	8.956
Satin	5/1	115	147	8.652	8.956

Weaving was done of sample loom at Nishat Mills private Limited. Firstly, the warp yarns were placed over the loom structure by drawing in process. The number of harnesses was selected according to the type of weave such as 1/1, 2/1 and 5/1 for plain, twill and satin, respectively. Then the filling yarns were inserted into each structure to complete the process. The warp yarns were raised and lowered with the help of harness in order to prepare a shed which creates a space for weft yarns to pass through. Weft and filling yarns were inserted with the help of a shuttle through this prepared shed. Weft yarns were pushed back to make a fabric compact and closed. The manufactured fabric was wound on to the beam and finally the fabric was carefully removed from the loom without damaging the yarn. Plain weave was interlaced with 1/1 pattern by raising and lowering of one warp thread over the other filling yarn. Twill weave was made in 2/1 by raising two warp threads over one weft. Satin weave was made in 5/1 by raising five warps over one filling yarn. Warp threads were fed into the loom strongly and similarly filling yarns were pushed back into their place through beating which made the fabric compact. This ratio of warp and filling yarns made their density and measured per inch. The prepared fabric was carefully removed from the loom. All sets of fabrics were desized to remove sizings prior to weaving process. Bleaching was done to remove the raw color from surface and add whiteness to them as a finishing process.

Fabrics were then analyzed for their tensile strength by following instructions given in Strip method ISO-13934-1 (ISO, 1999). Two specimens from each set of prepared fabrics were cut, one running in the lengthwise direction served as warp, and the other running in the crosswise direction as weft. Selvedge

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area was avoided while cutting the specimens. Each specimen was cut with the dimensions of 200x50 mm. The test specimen was vertically clamped between the jaws of a tester. The force was applied, that made the clamps to move apart and the specimen was stretched out till its rupture. The maximum force used to break the specimen was recorded on an electronic device attached with the tester. Average values of all tested groups in both directions were calculated and noted for results.

Results and Discussion

All the collected data was analyzed by using SPSS version 22. Quantitative values were depicted with mean ± S.D. ANOVA was applied to measure the difference among plain, twill and satin weave structures. P-value ≤ 0.05 was considered as significant.

A total of ten tests from each set of weaves were made, five in warp direction and other five in weft direction. The average values and standard deviations were calculated. Type of weave plays a major role in determining the tensile behavior of fabrics. It has a strong relationship with yarn deformation in a specific fabric. The weave that presents many crossovers per inch, will better able to grip the yarns with each other and will provide better protection against applied load as compared to the weave followed by less crossovers per inch in a fabric (Eryuruk and Kalaoglu, 2015). So, many crossovers also serve as a shelter against pull out yarns due to less friction among them. That's why plain weave had better tear and tensile strength as compared to other weave structures.

It was observed from Table 2 that plain weave was the strongest in terms of its tensile strength followed by twill and satin weave structures in both directions. There is a difference among number of inerlacings in a fabric. The difference can also be statistically observed as the p-value is 0.03, 0.02 and 0.02, respectively for plain, twill and satin structures. More interlacings were observed in the plain weave and less was seen in satin structures. It was due to the stress that uniformly travel in warp and weft yarns and was perpendicular to the load direction. It was mainly because of their isotropic behavior (Salman *et al*., 2015). On the other hand, fabric manufactured with satin weave had less uniformity in load distribution to support the constituent yarns with each other. There was a loose arrangement of yarns due to the long floats in satin weave throughout its structure.

Table 2: *Tensile Strength of fabrics in warp and weft direction.*

Weave type	Tensile strength (N) (warp)		p value	Tensile strength (N) (weft)		p value
	Mean	SD		Mean	SD	
Plain	525	2.71	0.03	517	1.85	0.01
Twill	513	1.98	0.02	502	2.65	0.02
Satin	487	2.21	0.02	471	2.12	0.02

The results are similar to another study conducted by Jahan (2017) that there is a difference between warp and weft yarns of manufactured fabric. It has also been observed that plain weave was more durable than twill weave in its warp direction. The reason was many crossover points such as one by one as compared to two by one and five by one. Moreover, plain weave is less porous and more compact due to many interlacings per inch. In another study (Ijaz *et al*., 2020) it was concluded that plain weave depicted with high abrasive strength due to the compact structure followed by twill and satin interlacings.

Less number of interlacings help the plain weave to resist high stress and hold the constituent yarns strongly with each other. It also results in less yarn slippage (Aisyah *et al*., 2018). One possible cause of the depicted result was the damage occurred in the satin weave structure due to the interfacial de-bonding among yarns. So, fibers pulled out more easily and cause breakage of yarns. This phenomenon was also supported by the findings of Zhou *et al*. (2017) that de-bonding makes the fibers weak and causes them to pull out of their structure more easily, when a specific force is applied on them.

The same was observed by Malik *et al*. (2011) that tensile strength of plain woven fabrics in their warp direction was better as compared to the weft direction. Similarly, plain woven fabrics in weft direction are more durable in terms of their strength than twill fabrics. This difference was observed due to the variation in interlacing pattern of yarns, as the contact area of both directions was high in plain weave than other types.

The breaking force of tested fabrics not only depends on the breaking ability of component yarns but there are many other variables that must be studied

(Gabrijelcic *et al*., 2008) such as kind of fiber, amount and type of twist and more importantly type of weave used to interlace the pattern on fabric structure. It is also supported by the fact that when a certain force is applied in order to measure the tensile behavior of fabrics, the yarns clamped between the jaws of a tester undergo the process of extension. This elongation is greatly depending on the fabric geometry that how it is composed of yarns. The rate of elongation at break shows greater values for plain weave when compared with twill weave (Yahaya *et al*., 2014). The tensile strength of tested fabrics was significantly different in warp and weft directions, even when the type of fiber remained same throughout. This was attributed to variation in yarn waviness and tightness incorporated during weaving process (Hu *et al*., 2020).

This was mainly attributed to the equal distribution of applied load transfer in 1/1 weave structure, where less floats were observed. Similarly, long floats such as in twill weave followed by satin weave did not present uniform distribution throughout the fiber. It was also investigated in another study that kenaf fiber woven with satin weave presented low tensile strength as compared to the plain weave (Aisyah *et al*., 2018). Chow *et al*. (2004) studied that composites manufactured by following plain interlacing pattern had better tensile strength, elongation at break and modulus than other patterns. One possible reason was the force caused due to the applied load distribution throughout the fiber in a specific direction.

It was observed that weave with less dense structure showed high rate of tear strength in cotton fabrics. The interlacing pattern that provides easy movement of component yarns result in better tensile strength. The yarns which are strongly adhere to each other during their construction process, will resist blocking of yarns, result in low rate of tear and tensile strength (Eryuruk and Kalaoglu, 2015).

Woven fabrics have certain spaces between supporting adjacent yarns and are considered as open packed fabrics. Whereas, some of the yarns are closely packed to each other without spaces or gaps are known as closed packed fabrics. The more closeness brings more strength to the fabric structure. The abrasive and tensile strength of fabrics are also related to this closeness and compactness of yarns (Villegas *et al*., 2019).

Mechanical characteristics of fabrics are very important to study as these helps to make a base line or structure. It is essential for all fabrics to resist certain deformation due to applied pressure and force in many manufacturing and finishing processes. Strength is one of the most crucial aspect in determining overall quality and performance of fabrics. It is an important phenomenon to consider that more interlacings induce more strength in fabrics (Rupesh and Turukmane).

Conclusions and Recommendations

The present study illustrated the effect of weave type on tensile strength of cotton fabrics. It concludes that dense structure made with more number of interlacings such as in the case of plain weave was better able to induce tensile strength in the finished fabric in both directions. Whereas, less number of interlacings had less strength such as in twill and satin weave. Findings of this study can establish a framework for the manufacturers to alter their weaving specifications for various end uses.

Novelty Statement

This study is investigates the idea of inducing the strength in fabrics through right selection of interlacing patterns during weaving stage.

Conflict of interest

The authors have declared no conflict of interest.

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