Advance Research in Textile Engineering

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Austin Publishing Group

Research Article

Effect of Fabric Structure on the Mechanical Properties of Woven Fabrics

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Received: September 26, 2017; **Accepted:** October 13, 2017; **Published:** October 20, 2017

Abstract

Understanding the fabric performance is important to investigate the working process. The fabric properties depend to a great extent on constructional parameters, methodology and machine conditions. This paper shows the variation of mechanical properties (Tensile strength, Tearing strength, Abrasion resistant, Pilling resistance & stiffness) of cotton woven fabric from different weave structures. It was assumed to have variations in properties due to different weave structures and by this work we found a bridge on the theoretical conceptions to the practical work. It was found that the tensile strength of plain weave is higher than twill weave, but tearing strength is more in twill than in plain weave. The stiffness, abrasion& pilling resistance is higher in plain weave than in twill weave. The results are shown in the further progression with the necessary data and graphs.

Keywords: Tensile strength; Tearing strength; Abrasion; Pilling; Stiffness

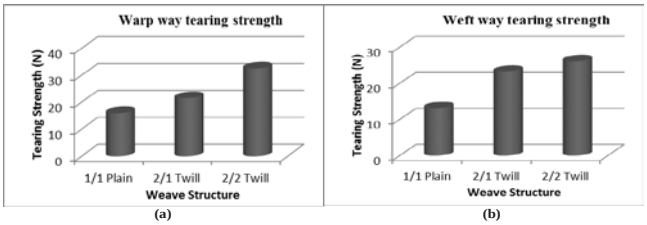
Introduction

Fabric is a kind of basic textile materials made of fibers and or yarns in the form of thick or thin sheet. Fabric or cloth is a kind of supple sheet materials which is made up of a network (non-woven) / interlacement / interlocking of natural or artificial fibers or yarns. Fabric can be different types such as woven fabric, knitted fabric, non-woven fabric & Braided [1].

Woven fabric is the most versatile fabric for its construction which is produced by the interlacement of two sets of yarn one is called warp yarn that is longitudinal & the other is weft yarn that is transverse. It is the most sophisticated & aristocratic fabric available with different designs. Due to the variation of interlacement it is possible to produce different designs like plain, twill, satin etc. These variations of the designs have some effect on the mechanical properties of woven fabrics. For textile fabric it is described as a result of the material's resistance on the activity of external forces causing the change of shape [2]. The response of the textile material depends on the Mechanical properties, the way of load and its tension is applied. Mechanical properties that are important to a design engineer differ from those that are of interest to the manufacturing engineer. In design, mechanical properties are important in order to resist permanent deformation under applied stresses & subsequent uses [3]. For designing apparel as well as for other uses, the knowledge about the Mechanical properties of woven fabrics is important. Strength and elongation are the most important performance properties of fabrics governing the fabric performance in use Thus; the focus is on the end use application such as protective clothing, preform materials for composites etc. [4]. The aim of this study is to identify the important mechanical properties of plain and twill fabric and compare them for further end use application. From literature it is possible to detect that due to variation of fabric construction (designs) the mechanical properties of the fabric also vary. Among various properties, for this experiment tensile strength, tearing strength, abrasion resistance, pilling resistance & stiffness of three different types of fabric designs was tested [5]. Fabric woven at improper yarn tension not only having effects on fabric construction (thread density and GSM value) but also have an effect on fabric properties. Strength of Plain weave is higher than 2/1 Twill & strength of Twill 2/1 is higher than Twill 2/2 [5]. The prediction of tensile strength of polyester/cotton (52/48) blended woven fabrics was done by keeping constant all the constructional parameters. The outcome of the research was that, warp way plain is stronger than twill & also weft way plain is stronger than weft way twill [1]. However, how much they change due to the increase of interlacement point was not studied. To study the effect of weave design on warp & weft wise tensile strength of the fabric, comparison is made between the tensile strength of plain and twill fabrics that warp-wise tensile strength of plain weave is higher than the twill weave. Similarly, weft-wise tensile strength of plain weave is also higher than twill weave [2]. Mechanical properties (strength & stiffness) of different woven fabrics (plain, 2/2 twill & 5 end satin) were predicted by investigating two factors such as Crossing Over Factor (COF) & Floating Yarn Factor (FYF). The value of COF is higher in plain than twill & satin. Oppositely the value of FYF is more in satin than twill & plain. However, the effect of weave structure in the stiffness of woven plain and twill fabric was not specific. Tearing strength was tested for different twill samples (3/1 twill & 2/2 twill) & found that tearing strength is more in 2/2 twill than 3/1 twill due to double yarn is inserted as weft by taking the count 30 tex [6]. The general concept of mechanical property (tearing strength) was not investigated or proofed with experimental data. The tearing strength may be used to give a reasonably direct assessment of serviceability, and a textile fabric with low tearing strength is generally regarded as inferior product. Here taking different fabric constructions of basic plain & twill structure it was shown that the greater the difference in warp & weft yarn density the greater the difference in tearing resistance [6,7]. Abrasion is the mechanical deterioration of fabric components by rubbing them against another surface. Abrasion

Citation: Jahan I. Effect of Fabric Structure on the Mechanical Properties of Woven Fabrics. Adv Res Text Eng. 2017; 2(2): 1018.

Figure 1: 1/1 plain, 2/1 Twill, 2/2 Twill fabric has been taken from the test specimen.



Graph 1: Shows the comparative analysis of Tensile Strength (a) Warp way, (b) Weft way.

ultimately results in the loss of performance characteristics, such as strength, but it also affects the appearance of a fabric. One of the results of abrasion is the gradual removal of fibers from yarns. Therefore, the factors that affect the cohesion of yarns will influence their abrasion resistance. The float length in woven fabrics can affect their resistance to abrasion. Long floats in a weave are more exposed and will abrade faster, usually breaking the yarns. A satin fabric will abrade more easily than a twill weave& a twill weave fabric will abrade more easily than a plain weave [8,9]. Furthermore, why this fabric abraded more or less was not explained by experimental results.

Woven fabrics are manufactured for many different end uses, each of which has different performance requirements. The chemical and physical structures of woven fabric determine how it will perform, and ultimately whether it is acceptable for a particular use. Fabric testing plays a crucial role in gauging product quality, ensuring regulatory compliance and assessing the performance of textile materials. It provides information about the mechanical properties of the woven fabrics [1,5,10]. The aim of the study is to find reliable experimental result so that can get a clear concept about mechanical properties of woven fabric.

Experimental

Materials

Cotton yarn was collected from Israq Spinning Mills Ltd. Same fabric construction was maintained for plain and twill fabric. Cotton Plain and Twill weave fabric samples were woven on shuttle loom at constant warp yarn tension. In this experiment 1/1 plain, 2/1 Twill, 2/2 Twill fabric has been taken from the test specimen. Cotton gray fabric was tested in order to avoid parameter change due to finishing. Fabric properties such as pilling and abrasion tendency and strength are important quality parameters may be varied due to the finishing process (Figure 1).

Fabric Specification:

(EPI x PPI) / (Warp count x Weft count) x Fabric Width

Fabric construction: (100 x 70) /20 x10 x 42”

Methodology

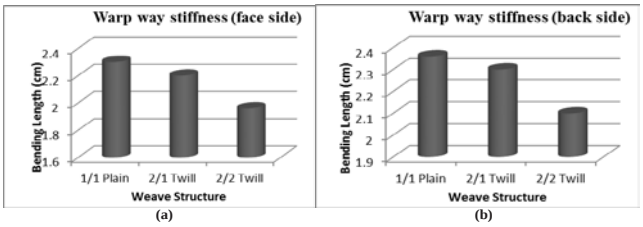
After preparation of test specimen, all the fabric is tested in the standard testing atmosphere 65% Relative Humidity and temperature 20±2°C Temperature and following test are done to assess the mechanical properties.

Tensile strength: Testing method ISO 13934-2-2014 is used for tensile properties of fabric sand determination of maximum force was done using the grab method. The apparatus tensile strength tester is used for the experiment. The apparatus brand was Tinius Olsen and origin was England. Sample Size for the experiment was taken 6 inch x 4 inch and the no of sample was 5 warp way & 5 weft way (for each plain & twill). In the apparatus, the gauge length used was 3 inch & the speed was adjusted so that the sample is broken in 20±3 sec.

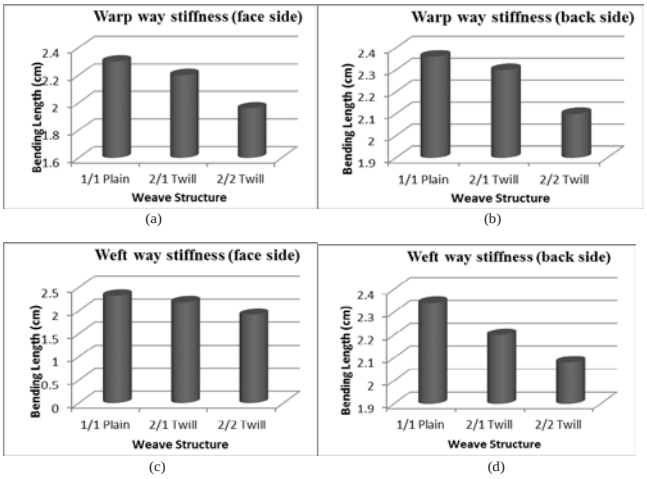
Tearing strength: ASTM D1424-09(2013)-Standard Test Method used for Tearing Strength. In this experiment the tear strength of the cotton plain and twill fabric was determined by using Falling Pendulum Elmendorf’s Apparatus(Origin Germany) and the sample size was (template) 7.5cm × 10cm. The no. of sample was 5 warp way & 5 weft way (For both plain & twill).

Abrasion resistance: Abrasion is the physical demolition of fibers, yarns and fabrics, resulting from the rubbing of a textile fabric surface over another surface. The rubbing of textile material occurs during wearing, cleaning or washing process and this may distort the fabric, cause fibers or yarns tobe pulled out or removed fiber ends from the surface. The ultimate result of abrasion is the loss of performance characteristics, such as strength and appearance of the fabric which is directly related to serviceability of that material. ISO 12947-1-1998 Textiles-Determination of the abrasion resistance of fabrics by the Martindale method-Part 1: Martindale abrasion testing apparatus (Brand: SDL Atlas, Origin: UK) was used for this experiment. Sample Size (dia): 38mm × 140mm, five warp way & five weft way (For both plain & twill) fabric samples are taken for the experiment.

Standard of pilling test: Pilling is a condition that arises in wear due to the formation of little ‘pills’ of entangled fibre clinging to the fabric surface giving it an unsightly appearance. Pills are formed by a



Graph 2: Show the comparative analysis of Tearing Strength (a) Warp way, (b) Weft way.



Graph 3: Shows the comparative analysis of Stiffness (a) Warp way (face side), (b) Warp way (back side), (c) Weft way (face side), (d) Weft way (back side).

rubbing action on loose fibers which are present on the fabric surface. For all weave types, sample 2,000 revolutions were given. After that average result for 5 samples of each weave structure is studied for the outcome. ISO 12945-2-2000 Textiles-Determination of fabric propensity to surface fuzzing and to pilling and Modified Martindale method is used for this experiment in same apparatus used for abrasion test.

Stiffness: The resistance offered by a material to a force tending to bend it. It is opposite to drape. Stiffness is measured by cantilever principle. Stiffness is depended on the bending length. Shirley Stiffness Tester apparatus (Brand: SDL Atlas, Origin: UK) is used for this experiments. Sample Size for measuring stiffness was 6inch ×1 inch (For both plain & twill). Three warp way (face & back) & three weft way (face & back) samples are taken for the test.

Results and Discussion

Comparative analysis of tensile strength

Measurement of tensile stress-strain properties is the most common mechanical measurement on fabrics. It is used to determine the behavior of a sample fabric while under an axial stretching load. From this, the breaking load and elongation can be obtained. The principle of the tensile strength test is simple: a test piece is held in two or more places and extended until it breaks. The tensile properties measured are generally considered arbitrary rather than absolute. Results depend on specimen geometry, the fiber type and arrangement, as well as the fabric structure [5]. Tensile strength of a yarn or fabric is defined as a maximum load that it will endure without breaking when subjected to uniaxial tensile loading. Tensile strength of a woven fabric is one of the most important properties which make it superior in many applications as compared to non-woven and knitted fabrics. Graph 1 shows the comparison of Tensile Strength. It can be seen that the Tensile Strength (warp & weft both ways) sequence from higher to lower. Overall, Warp way tensile strength is more compared to weft way strength. Tensile strength of plain weave is more than twill because plain weave is less porous & no. of interlacement of warp & weft is more in plain weave. Since the plain weave has the highest strength in warp way due to the increased number of crossover points compared to other weaves types. It is seen that, by decreasing the interlacement point such as 2/1 and 2/2 twill shows lesser strength 405N & 398N respectively compared to plain weave (415N).

Determination of tearing strength

Tear strength is the resistance of the fabric against tearing or force required to propagate the tear once it is initiated. Tearing of a fabric can occur in a wide range of products and is involved in fatigue and abrasion processes as well as the catastrophic growth of a cut on application of a force. Tear strength is the tensile force required to start, strength test is often required for woven fabrics used for applications including army clothing, tenting, sails, umbrellas and hammocks. It may also be used for coated fabrics to evaluate brittleness and serviceability [7]. From the (Graph 2) the outcome for the Tearing Strength testare found. Tearing Strength (warp & weft both ways) sequence from lower to higher in plain to twill weave [2]. Plain weave performs less tearing strength nearly 13N where as 2/1 and 2/2 twill are more stronger in tearing behavior 19N and 30N It is clear that due to lose constructions and fewer interlacing, where the

yarns can easily move and bunch together, twill weave shows higher resistance to the applied force than plain weave because several yarns are broken simultaneously [2].

Outcome of abrasion resistance test

Abrasion is just one aspect of wear & is the rubbing away of the component fibers & yarns of the fabric. It is a type of flat or plain abrasion. It is tested by the breaking of threads due to the no. of revolutions. Resistance against the breaking of threads was the main motto of this test. Which kind of weave structure is more resist to abrasion & which is less was tested. For 1/1 plain and 2/1 twill no threads are broken. Fabric quality is good. However for 2/2 twill two or more threads are broken. Due to less interlacement or more porous, twill weave is not so resistance to abrasion compared to plain weave.

Illustration of stiffness for different weave structure

Stiffness is the rigidity of an object which means the extent to which it resists deformation in response to an applied force. It increases with the increase of bending length. The length of the fabric that will bend under its own weight to a definite extend is termed as bending length [11]. The more the bending length the higher the stiffness, lower the draping. The bending length is a measure of the interaction between fabric weights and fabric stiffness in which a fabric bends under its own weight. It reflects the stiffness of a fabric when bent in one plane under the force of gravity, and is one component of drape. Thus bending length is also called drape stiffness. Bending length of plain weave is much higher 2.3cm (Graph 3a) in warp way face side and 2.32 in back side (Graph 3b) compared to 2/1 twill and 2/2 twill weave. Bending Length for warp way face side of plain weave is much higher than twill weave. However the (Graph 3a,3b,3c,3d) illustrates the similar pattern that is plain weave has higher bending length compared to the other weave structure. Here stiffness of twill weave is less as it contain less interlacement point as well as more porous & flexible (drape). On the other hand, bending length of weft way face side fabric is following the similar pattern for plain more than 2cm, for 2/1 twill exactly 2 cm and for 2/2 it decreased to 1.7cm respectively. As a result it is clear that, stiffness is reduced with the increase of interlacement points. Fabric with more interlacement point such as plain weave is stiffer than 2/1 and 2/1 weave structure is more stiffer than 2/2 twill weave.

Pilling resistance test of woven fabric

Pilling is a fabric surface fault characterized by little pills of entangled fiber clinging to the cloth surface & giving the garments an unsightly appearance. The pills are formed during wearing & washing by the entanglement of fibers which protrude from the fabric surface [10]. Table 1 shows the Rating of pilling and comments. Due to less interlacement the migratory tendency of fibers from the constituent yarn is less in plain weave than twill. As a result, it is found that plain fabric is more resistance to pill formation than twill weaves [12].

Table 1: Rating of pilling and comments.

Weave Structures	Rating	Comments	Fabric Quality
1/1 *Plain*	4	Slight Pilling	Very Good
2/1 *Twill*	2-3	Significant- Moderate Pilling	Good-Medium
2/2 *Twill*	2-3	Significant- Moderate Pilling	Good-Medium

Conclusion

In this research work, elaborate knowledge about the variation of mechanical properties (Tensile Strength, Tearing Strength, Stiffness, Abrasion Resistance & Pilling Resistance) of woven fabric due to the variation of weave structure was found when the other factors (EPI, PPI, Warp Count, Weft Count & Fabric Width) remain constant. Finally it can be concluded that tensile strength, abrasion resistance, stiffness & pilling resistance are high in plain weave compared to twill weave because these mechanical properties improved with the increasing no. of interlacement of warp & weft yarns also by decreasing the no. of floating in the weave. But tearing strength is more in twill weave because this property increases with increasing no. of floating in the weave i.e. with fewer interlacements. A clear idea about the mechanical properties of a woven fabric can lead to make further improvement of a woven fabric structure that will be helpful to many end by use applications especially protective clothing, preforms of composite as well as apparels. In the current work, the effects of mechanical properties of varying different weave structure are studied. It should be noted that: even though the fabrics parameter remains same, more complex fabric mechanical behaviours can be implemented and studied as well. Further research work can be done on this research for the enrichment of the depth.

References

1. Grosberg P. The Mechanical Properties of Woven Fabrics Part II: The Bending of Woven Fabrics. Text Res J. 1966; 36: 205-211.
2. Booth JE. Principles of textile testing: an introduction to physical methods of testing textile fibres, yarns and fabrics. 1961.
3. Dolatabadi MK, Kovar R. Anisotropy in tensile properties of plain weave fabric-Part I: The meso-scale model. Text Res J. 2012; 82: 1666-1676.
4. Aliabadi MH. Woven composites. Imperial College Press. 2015.
5. Realff ML, Seo M, Boyce MC, Schwartz P, Backer S. Mechanical Properties of Fabrics Woven from Yarns Produced by Different Spinning Technologies: Yarn Failure as a Function of Gauge Length. Text Res J. 1991; 61: 517-530.
6. Triki E, Dolez P, Vu-Khanh T. Tear resistance of woven textiles-Criterion and mechanisms. Compos Part B: Eng. 2011; 42: 1851-1859.
7. Witkowska B, Frydrych I. Static Tearing, Part II: Analysis of Stages of Static Tearing in Cotton Fabrics for Wing-shaped Test Specimens. Text Res J. 2008; 78: 977-987.
8. Doustaneh AH, Mahmoudian S, Mohammadian M, Jahangir A. The effects of weave structure and yarn fiber specification on pilling of woven fabrics. World Appl Sci J. 2013; 24: 503-506.
9. Göktepe Ö. Fabric Pilling Performance and Sensitivity of Several Pilling Testers. Text Res J. 2002; 72: 625-630.
10. Gintis D, Mead EJ. The Mechanism of Pilling. Text Res J. 1959; 29: 578-585.
11. Lomov SV, Truevtzev AV, Cassidy C. A Predictive Model for the Fabric-to-Yarn Bending Stiffness Ratio of a Plain-Woven Set Fabric. Text Res J. 2000; 70: 1088-1096.
12. Saville BP. Physical testing of textiles. Elsevier. 1999.

Adv Res Text Eng - Volume 2 Issue 2 - 2017
ISSN: 2572-9373 | www.austinpublishinggroup.com

Citation: Jahan I. Effect of Fabric Structure on the Mechanical Properties of Woven Fabrics. Adv Res Text Eng. 2017; 2(2): 1018.