Chemical Science Review and Letters ISSN 2278-6783

Research Article

Characterization of Sewability Parameters of Plain Structured Fabric with Structurally Modified Trevira CS Yarn for Defence Application

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Abstract

The longevity of any garment depends on the seam parameters and fabric quality. In the present work, different yarn structured fabrics were chosen viz., Ring, Rotor, Air jet and DREF-3 friction spun fabrics, the characteristics of the above said fabrics were analyzed and taken as controlled parameters. Now the garment longevity depends on the seam parameters like seam strength, seam slippage, seam puckering and yarn severance. After all the above trials the seam strength and seam slippage were studied for different yarn structured fabrics. The seam strength, seam slippage, was studied using INSTRON Tensile Strength Tester and also Seam puckering, Seam Appearance when studied using the subjective evaluation. The studies were performed at 6.0mm breaking load and it was observed that the breaking loads of DREF -3 friction spun fabrics were recorded higher strength than the other fabrics without seam opening. At the same time the Dref-3 friction spun fabrics showed rupture at the seam. These effects have been studied to understand the sewing performance of the fabrics, which are meant for Defence application. Hence, the Present work designed to study the seam parameters of the garment when the structure of the fabric and structure of the yarn modified.

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Keywords: Seam Strength, Seam Slippage, Woven Structure, Seam Performance, Seam Breaking Load

1. Introduction

In general, the seam quality mainly depends on the strength and the appearance of the seam itself. Seam strength and appearance affects both the functional and aesthetic performance of an apparel product and is important to its scalability and durability. A good quality seam must have flexibility and strength with no seaming defects such as puckering or skipped stitches; and the overall appearance of the seam must meet the design requirements of the apparel products. Besides the consideration of the quality level of the apparel product, the judgment of seam quality requires consideration of the purposes of the apparel products as well. For some functional garments such as sportswear, the requirements of seam strength may be higher than the need for seam appearance, while for some apparel products such as nightgowns, the appearance of the seam is of higher importance. A fabric can be thermally damaged if the needle has a high warming- up value which results in the melting of the material being sewn. Seam damage also results due to high friction between the needle and the fabric. The damaged places are generally dense spread. There are especially dense fabrics which are sensitive to sewing damage. During the stitch formation the cloth being stitched may be damaged in a way which is more mechanical rather than thermal. Generally, in the seam operation, finishing with silicone reduces the friction (mechanical abrasion) between the fabric and the needle. Consequently, the needle penetration force and damage to the fabric is also decreased. The silicone finish reduces the friction between fabric yarns by increasing their mobility. Experience has demonstrated that the strength of many woven fabrics is considerably reduced by the sewing operation. Also, if the seam efficiency ratio falls below 80%, the fabric experiences excessive seam damage by sewing operation. The result of sewing should be a flawless seam, which is only possible when the sewing parameters are coordinated with thread and fabric properties. Hence, in the present study, an attempt has been made to study the sewing performance of the structurally varying Cotton and Polyester/Cotton woven fabric structure with Cotton and Polyester spun sewing thread respectively.

The seam performance and quality depend on various factors such as seam strength, seam slippage, seam puckering, seam appearance and yarn severance. Sewing needle penetration forces and fabric deformation during sewing are effective factors for seam performance, too. Appearance and performance of the seam are dependent upon the quality of sewing threads and their dynamic behavior. One essential requirement of any thread is that it must be compatible with the needle size, various sewing machine settings (sewing speed, thread tension) and the fabric on which it is being sewn. Seam damage can be a serious cost problem, often showing only after the garment has been worn. The most important parameters that have an influence on seam damage tendency are fabric construction, chemical treatments of the fabric, needle thickness and sewing machine settings with sewing thread. Fibre content, yarn construction, tightness and density are important parameters for fabric construction on seam damage. Seam damage caused by the needle penetration through the fabric may affect its seam performance. Needle cutting or yarn severance occurs due to stiffness of the fabric, yarn and its lack of the mobility. Instead of moving and deforming, when the needle penetrates the fabric structure, the yarn is ruptured or burned.

There are various factors which can affect the seam strength and seam appearance. Many previous studies [3], [4], [7], [26] showed that seam appearance and performance depend on the interrelationship of fabrics, threads, the stitch and seam selection, and sewing conditions, which include the needle size, stitch density, the appropriate operation and maintenance of the sewing machines etc. The combination of materials that are assembled with the sewing thread and sewing conditions vary from individual to individual. Selection of sewing thread and sewing condition for a particular type of material is an integral part of producing a quality seam.

The different parameters of sewing thread such as the thread type, size and finish would have a definite effect on seam strength and appearance [14], [31], [15]. The clothing industry tends to use the polyester spun thread with standard finish for most apparel products unless special requirements are demanded. In the apparel industry, after a particular type of seam and stitch is selected for the construction of an apparel product, the apparel designer and/or manufacturer needs to select the thread size and to determine the seam boldness required for seam construction. Seams with different degrees of boldness serve different purposes as design features. Some types of garments such as the jeans prefer a seam with more prominent design, while other garments such as the dress shirt conventionally prefer the Seams be sewn more inconspicuously. The seam boldness is an important element of determining the seam appearance, and the size of sewing thread becomes the primary factor for the manufacturers to consider for the required seam quality. The sewing conditions such as the thread tensions and pressure of pressure foot should be adjusted based on the thread size and the material to be sewn. However, the stitch density may vary at different seam locations. Stitch density was deemed to be an important attribute in seam quality because it assembles the fabric components together. The change of stitch density exerts a great influence on seam strength and appearance.

Basically, seam quality may be examined from two main aspects: functional and aesthetic performance. Most previous studies [8], [3], [37] investigated the functional performance of seam mainly in terms of the seam strength and/or seam efficiency. There are also numerous studies [9], [13], [37] on the seam quality based on the aesthetic performance. However, these studies focus mainly on the seam defects such as the seam puckering [13], [37], seam damage [9]. Furthermore, few studies had been evaluated the seam quality from both aspects of seam: the functional and the aesthetic [4],[21].

However, in these studies, in order to evaluate the seam quality, the authors did not combine the functional and aesthetic performance of the seam. Up to now, very limited work has been done to study the seam quality on functional and aesthetic performance together. This study attempts to analyze the seam quality from the aspects of both functional and aesthetic performance, and to study the effect of thread size, fabric properties and stitch density on seam quality in various types of fabric materials. The success of this study could help apparel manufacturers to evaluate the seam quality more effectively when a particular sewing thread size and stitch density arc applied to a particular type of fabric. In turn, this would facilitate apparel engineers in the production planning and quality control.

The cut and sewn apparel product industry convert a two-dimensional fabric into three- dimensional apparel. Many processes are involved during apparel production, till the stage of finished apparel to be seen in a shop-window, on a tailor's dummy, or on a coat hanger is reached. While there are other methods of shaping fabrics into apparel products, stitch seaming is by far the most common method used worldwide [32], [6].

For common apparel products, the seam is an essential part of the garment [22]. A seam is manufactured employing sewing methods, with the idea that the seam should satisfy all the requirements imposed by a number of end-users of apparel products [30], [33]. For any apparel product, it is necessary to clearly understand the seam, as it is the basic element of an article of clothing.

In the apparel industry, overall seam quality defined through various functional and aesthetic performances desired for the apparel product during their end use. The functional performance mainly refers to the strength, tenacity, efficiency, elasticity, elongation, flexibility, bending stiffness, abrasion resistance, washing resistance and dry cleaning resistance of the seam under conditions of mechanical stress for a reasonable period of time [24], [32], [9], [14]. Properties like as, strength, tenacity and efficiency is required for determining the serviceability of apparel. Elasticity, elongation, flexibility, and low bending stiffness of seam are needed to easily elongation, flexibility, and low bending stiffness of seam arc needed to easily bend, shift, and fold without damage to the seam or change to the silhouette of the garment. Seam also comes under abrasion with body parts at wear or at the time of washing or dry cleaning. It is expected that seam should have good abrasion and/or washing and/or dry cleaning resistance. There are also certain aesthetic requirements of a seam to the consumers' body sensory mechanism (hand, eye) [32], [9], [14]. For proper appearance, seam should not contain any defects including skipped stitches, unbalanced stitches, looseness, seam grin, distortion or unevenness or puckering, unsteadiness, improper drapeability, uneven seam density and yarn severance or damage. A defect free seam is required for consumer satisfaction at the point of sale of apparel and helps to increase the scalability.

Apart from all the above aesthetic mentioned requirements, seam should also meet the design requirement of the consumers for apparel. The different degree of boldness of seam can help to fulfill different purposes as design features and affect the appearance of the garment. In the apparel industry, seam boldness is commonly used as a prime dimension for evaluating the design prominence of a seam [36], [38], [4]. Therefore, overall quality of a seam depends on the requirements imposed by the consumers. Good overall seam quality is essential for the longevity of an apparel product, which together with consumer satisfaction during wear and care procedures affect its salability. The apparel industry uses different dimensions for the evaluation of seam quality on the basis of the requirements of a seam from the consumers' point of views ([19]). In order to understand various seam performances, knowledge of various factors affecting the seam quality is necessary. Seam quality is governed by a broad spectrum of factors including sewing thread type and size, fabric, sewing machine speed, needle kind and size, stitch type and density and operator skills [34], [15], [40], [21] etc. For better seam quality, it is important to consider the complete harmony of the key fabric properties, sewing thread properties and sewing condition parameters used. The functional and aesthetic performance of the seam line is the result of all these factors. Seam strength refers to the load required to break a seam. This measure the strength and tenacity of a seam. Two pieces of woven fabric are joined by a seam and if tangential force is applied the seam line, rupture ultimately occurs at or near the seam line. Every seam has two components, fabric and sewing thread. Therefore, seam strength must result from the breakage of either fabric or thread or, in more cases, both simultaneously. Research has revealed that the load required to rupture the seam is usually less than that required to break the unsewn fabric [6] [11]. A large number of studies [41], [3], [4], [6], [11], [23], [28], [37] have determined the seam strength according to ASTM 1683-04 standards, which express the value of seam strength in terms of maximum force (in Newton (N)) to cause a seam specimen to rupture. This is measured by using the following equation:

$$S_s = KS_b$$

Where: S_s= sewn seam strength (N); K = a constant equal to 1000 for SI units; S_b = observed seam breaking force (N)

The ASTM 1683-04 seam strength standard is worth emphasizing due to its accuracy and ease in processing measurements. Hence, this method is widely used by the apparel industry for the evaluation of seam strength worldwide. Seam slippage is expressed as the transverse ratio of seam strength to fabric strength including the ratio of elongation of fabric to the ratio of elongation at the seam [5], [20]. Any movement of the warp and weft yarns away from a seam line under transverse stresses exacerbates the potential slippage. A lot of scholars [4], [6], [37], [16] has suggested measuring seam slippage according to the ASTM 1683-04 standard for evaluation of seam quality. In this standard, the force required for slippage of 0.6mm of seam has been determined. The measurement of seam slippage from the ASTM 1683-04 standard is well established as an international standard and most apparel industries follow this method to evaluate seam slippage.

A few researchers [39], [9] conducted research on the effect of thread finishes on seam quality. They stated that the lubrication finish is used on a sewing thread to assure better seam quality due to its protective nature from needle heat in the course of garment manufacturing. Lubrication finish protects the thread from strength reduction and/or breakage during sewing, which, in turn, produces high seam efficiency and less chance of seam damage [2], [39].

There are various types of finishes; however, in general the clothing industry tends to use standard lubrication finish for better seam performance in apparel [38], [14] stated that mercerized and glazed cotton thread have higher strength, durability, abrasion resistance than normal soft cotton threads.

Increased strength, durability and abrasion resistance help to get greater seam efficiency, seam strength and seam slippage. Additionally, they mentioned that other finishes like, water resistance, soil resistance, flame resistance is specific to the end use of the apparel and fabric to be sewn [38].

The size of sewing thread is denoted by linear density (Tex, cotton count, metric count etc.) or ticket number (equal to three times the metric count of the thread). Tex is the universal system used to represent the sewing thread size [1] [14] [12] showed the impact of sewing thread size on seam strength. Higher sewing thread size was subjected to greater friction during sewing, which ultimately reduced its strength. This consequently led to poor seam strength. On the other hand, Sundaresan et al., [35] found that sewing thread size is one of the important factors affecting seam strength. Generally, higher sewing thread size leads to greater seam strength for any apparel. Lin, Gribaa et al., and Tarafdar et al., Also corroborated the fact that higher sewing thread size has a strong positive impact on seam strength [23] [15] [37].

Fabric properties which affect the seam quality are discussed by many previous researchers [8], [17], [18], [25], [23], [37]. These properties are cover factor, weight, thickness, strength, extensibility, bending rigidity, bending hysteresis, shear rigidity and shear hysteresis. In the following sections these fabric properties are discussed in brief.
Behera, Miguel et al., Tarafdar et al. Emphasised That fabric cover factor has considerable effect on seam strength and/or seam efficiency. Their study revealed that fabrics with high cover factor have an increased tendency to break the fabric yarns (warp and/or weft) at the time of sewing [5], [27], [37]. The breakage of yarns in fabric ultimately reduces the seam functional performance such as seam strength and seam efficiency [29], [6].

There are various factors for seam quality: fabric properties, sewing thread and sewing conditions and others (human factors, environmental factors). Fabric is the basic raw material for the apparel products. Generally, all the fabric properties such as; Weight, cover factor, thickness, strength, extensibility, bending rigidity, bending hysteresis, shear rigidity, shear hysteresis and coefficient of friction have considerable effect on seam quality of apparel products. The different parameters of sewing thread are typed; ply, finish, twist and size would have a definite effect on the functional and aesthetic performance of the seam. If there is no special requirement, the apparel industry mainly selects the spun-polyester, 3-ply; normal twist and standard finish sewing thread for all types of sewing fabrics [38]. However, the size of the sewing thread is the most crucial for that seam quality as the improper selection of sewing thread size directly affects the seam quality of apparel products. There are also a lot of sewing conditions such as stitch type, seam type, stitch density, sewing machine speed, needle size, pressure of pressure foot, feed dog. Thread tension and needle plate, which affect the seam quality. Among the above mentioned sewing conditions, stitch density is the only attribute, which can vary at different seam locations and has a direct impact on the quality level of apparel products [14] [37]. Therefore, stitch density deemed to be a most important sewing condition in the course of garment manufacturing. The remaining sewing conditions are adjusted during the course of apparel manufacturing based on the thread size and/or the material to be sewn. So, these are not considered as important factors for seam quality analysis in the present study.

2. Experimental Procedure

The detailed Experimental Procedure involved in carrying out this project work is described below

2.1 Procurement of Yarn

The Trevira CS yarn of Dref-3, Rotor, Air jet and Ring spun yarns of 20s count was procured.

Table 1 Specification of Plain fabric

Yarn Type	Count (Ne)	EPI	PPI	GSM	Thickness (mm)
DREF 3	20	60	58	199	**0.43**
Rotor Spun	20	60	58	179	**0.39**
Air Jet	20	60	58	164	**0.43**
Ring Spun	**20**	**60**	**58**	**106**	**0.32**

2.2.1 Sample Preparation

- Fabric dimension for visual assessment was taken as 6x2 inch.
- Two fabric pieces was stitched at the middle using lock stitch machine.
- The fabric samples were given 5 washes at a temperature of 60 degree Celsius for 10 minutes and dried. Samples are clearly shown in figure 1

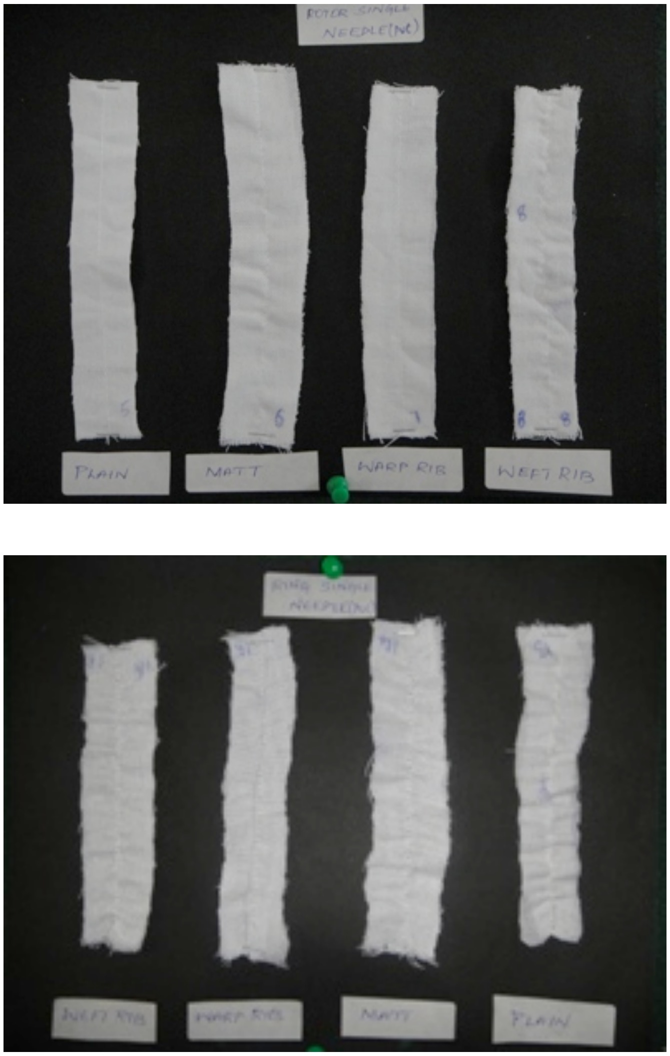

Figure 1 Sample Preparatory Image

2.3 Measurement of Fabric Tensile Characteristics

The samples were tested on an Instron for tensile characteristics, like seam strength, seam slippage. The fabric samples were tested at 500 mm gauge length at a constant speed of 5000mm/min and Pretension of 0.50cN/tex on Instron 7000 tensile tester. For each sample, required tests were conducted and the average values of breaking force, breaking time, tenacity, breaking elongation, breaking work are computed.

2.4 Subjective Evaluation of Seam Puckering

In this study experts were asked to evaluate 8 stitched seam samples and both rank them (in increasing order from least pucker to most pucker) and once this was done to grade them into 5 different groups to the best of their ability, using the semantic scale. They were given a coding sheet that they were requested to use for this purpose. They were to write down the rank numbers (1- lowest pucker to 5- highest pucker) under the appropriate fabric samples. They were then asked to physically arrange the samples in that order and then to grade each sample according to their preference. The experts individually evaluated and entered the value of each stitched sample at their own speed and the time of evaluation was not limited. The assessment involved the use of both touch and sight. The seam puckering of the samples was studied using the Table 2

Table 2 Test Method: AATCC 88B-1992

Semantic scale for Grading	
Grade	**Description**
1	No perceptible pucker
2	Light pucker
3	Medium pucker
4	Marked pucker
5	Heavy pucker

2.5 Subjective Evaluation of Seam Appearance

Mount the test specimen on the viewing board with the seam in the vertical direction. Place the appropriate single or double needle standard seam smoothness replicas beside the specimen to facilitate the comparative rating. Confine observations in the area influenced by the seam and disregard the appearance of the surrounding fabric. Assign the numerical grade of the photographic standard which most nearly matches the appearance of the seam in the test specimen. Seam smoothness grade of SS – 5 is equivalent to the appearance of standard number 5, the best level of seam appearance: a seam smoothness grade of SS – 1 is equivalent to that of standard number 1 which represents a very poor level of seam appearance. The appearance of the samples was studied using the Table 3

Table 3 Test Method: AATCC 9.5.4 A

Semantic Scale for Grading	
Grade	**Description**
SA-5	Very smooth, pressed, finished appearance
SA-4	Smooth, finished appearance
SA-3	Fairly smooth but non pressed appearance
SA-3.5	Mussed, non pressed appearance
SA-2	Rumpled, obviously wrinkled appearance
SA-1	Crumpled, creased and severely wrinkled appearance

 ISSN 2278-6783

3. Results and Discussions

The following test results have been observed when the samples are tested under Instron Tensile Strength Tester (Table 4).

Table 4 Test Results of Warp and Weft Direction Samples

Samples		Seam Strength (kgf)	Seam Slippage (kgf)	Fabric Breaking Force (kgf)
Dref - 3 Plain	Warp	37.6	>22.5 (SONO)	32.12
Ring Plain	Warp	4.8	1.8	17.4
Rotor Plain	Warp	24.85	>13.2 (SONO)	23.1
MJS Plain	Warp	28	>13.5 (SONO)	26.7
Dref - 3 Plain	Weft	45.2	18.2	44.2
Ring Plain	Weft	17.8	11.5	23.5
Rotor Plain	Weft	29.1	14.8 (SONO)	27.5
MJS Plain	Weft	26.5	14 (SONO)	26

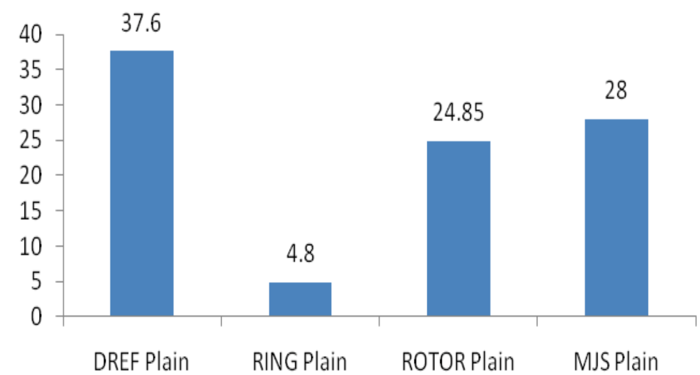

Figure 2 Seam Strength of Plain Weave fabrics in Warp Direction

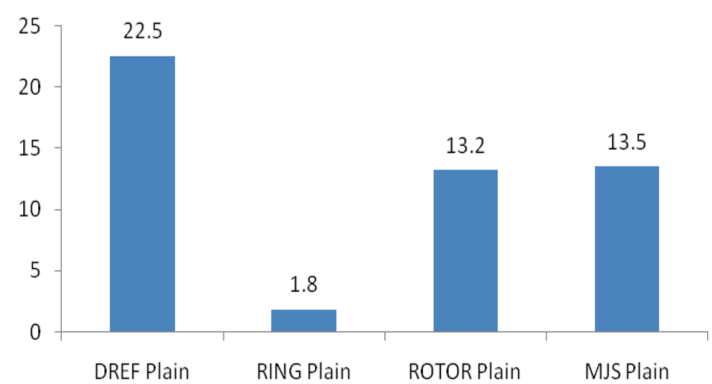

Figure 3 Seam Slippage of Plain Weave fabrics in Warp Direction

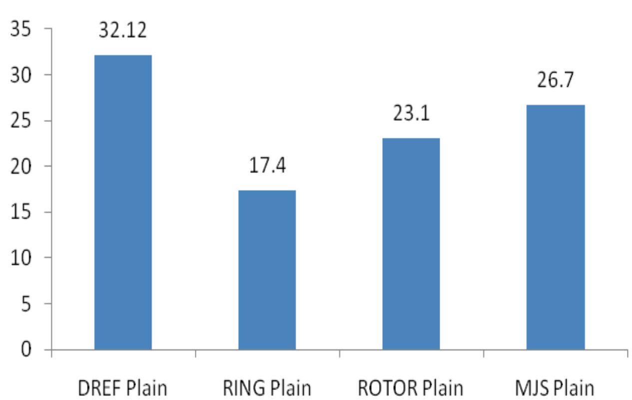

Figure 4 Breaking Force of Plain Weave fabric in Warp Direction

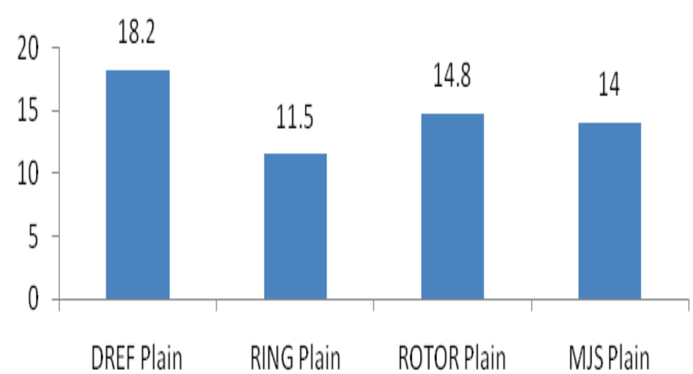

Figure 5 Seam Strength of Plain Weave fabrics in Weft Direction

From the Figure 2-4 it is understood that DREF-3 Friction spun fabric is depicted the higher Seam strength, Seam Slippage, Fabric Breaking Force respectively. It is also clear that the Rotor spun Fabrics and Airjet Spun Fabrics are depicting lower than DREF-3 friction spun fabrics but equal level of performance than the Ring spun fabrics. In this case fabric breaking force is lower for DREF-3 friction spun fabrics. The fabric breaking force is higher for all other samples and Seam slippage of all the samples are also low, since the binding points of the fabrics are placing higher role than the sewing thread. Lower seam slippage is due to the lower density of the fabrics, more warps and less weft per inch. Less seam opening in the warp direction sample is due to the fabric tear at Jaw or thread rupturing at the seam line. All these effects are due to the structure of the fabric, yarn structures, sewing thread types used. These performances are considered only in the warp direction of the fabrics.

If the same sample is tested in weft direction all the samples were depicting higher seam strength than the fabric breaking force but the seam slippage is lower than both seam strength and Fabric Breaking force. The fabric strength is lower due to the higher % of fabric crimp in weft direction but the seam slippage is equally 50% lower than the fabric breaking force and seam strength. The reason for higher breaking force and higher seam strength is twist direction and level of twist present in the yarn and the method of interlacement of the sample. It is all very clearly understood from the Figure 5-7.

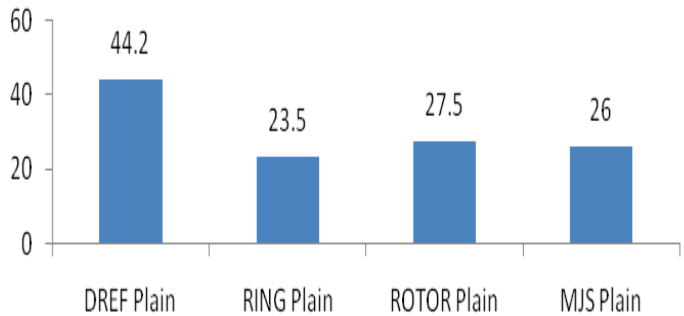

Figure 6 Seam Slippage of Plain Weave fabrics in Weft Direction

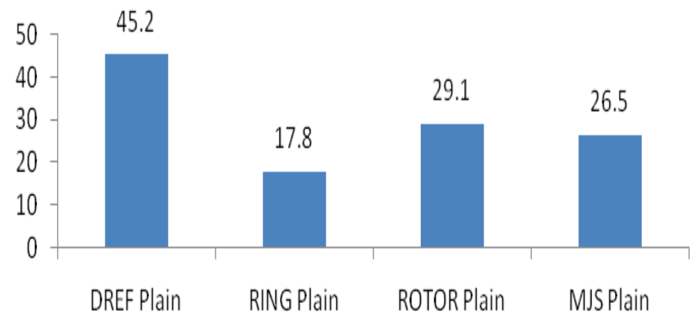

Figure 7 Fabric Breaking Force of Plain Weave fabrics in Weft Direction

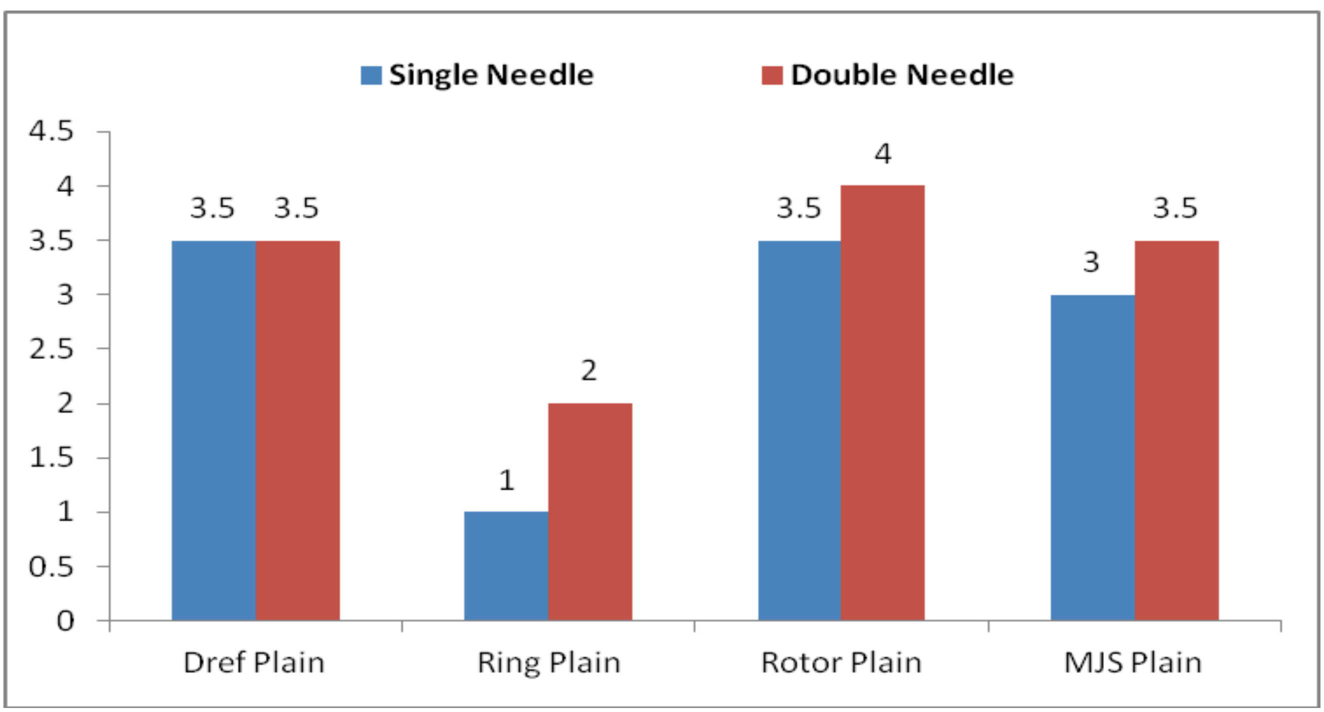

Figure 8 Seam Appearance of Plain Weave Fabrics

From the figure 8 it is clear that the Ring spun fabrics are showing poor appearance. Since the Feel of the fabric is too good but there is no frictional contact between the threads present in the fabrics, which leads to poor seam appearance.

Conclusions

1. The structure of the fabric is playing a major role in the performance of the seam.
2. The results are showing excellent due to the plain structure and it has balance structure.
3. The present study gives a clear understanding about the variation in the requirement of load for plain weave structures.
4. From the study it is concluded that the plain fabric has a good seam performance.
5. The test results explained that there were no seam opening observed at 6.0mm (seam slippage) in the comparative graph. Instead, the fabric tears at the seam or in most of the cases the sewing threads were broken due to the application of load.
6. It is very clear that the seam strength and seam slippage are influenced by the structure of the yarn and fabric. But the structure is not influencing the Seam Appearance, and Seam Puckering since the surface characteristics of these fabrics alone influencing these two parameters.

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Received : 18th August, 2012
Revised : 30th August, 2012
Accepted : 05th September, 2012
Online : 27th September, 2012