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A REVIEW OF KNITTED STRUCTURAL EFFECT ON MECHANICAL PROPERTIES OF FABRICS

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Abstract. *In the modern knitting world, the customer is more concerned with the performance characteristics of the fabrics. Normally, fabric structures are developed for use in winter or summer, depending upon the structural properties concerning materials. Previously, the work has been done on developing fabrics with single structures and studying their properties. To achieve the optimum properties between summer and winter wear, multiple combinations of structures have been developed by changing the arrangement of cams and needles. The hybrid structures have been made, in which each fabric has a combination of two different structures in its construction, including Single Jersey Plain, Single Jersey – Single Pique, Single Jersey – Double Pique, Single Jersey – Single Lacoste, Single Jersey – Honey Comb, Single Pique – Double Pique, Single Pique – Single Lacoste, Single Pique – Honey Comb, Double Pique – Single Lacoste, Double Pique - Honey Comb, Double Pique - Single Lacoste, Double Pique - Honey Comb, Double Pique - Single Lacoste, Double Pique - Honey Comb, Honey Comb, Honey Comb – Single Lacoste. The effects of these combinations have been studied on the mechanical properties of fabrics. It is concluded that by developing structures this way, the appearance and mechanical properties of the fabric have been improved as compared to the conventional single structured fabrics.*

Keywords: *knitting, knitting designs, single jersey, hybrid knitted structures, mechanical properties*

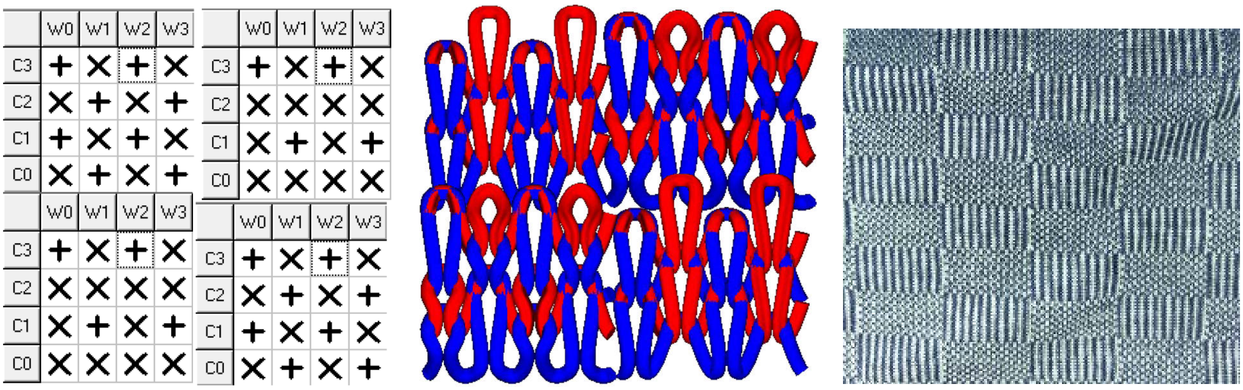
1. Introduction

Knitting is the intermeshing of yarns which is classified as weft & warp knitting [1][2]. Weft knitting is divided into single jersey & double jersey knitting. Structures are formed on machines with the help of knit miss-and-tuck stitches [3]. Single jersey structures include plain, honeycomb, single Lacoste, double Lacoste, single pique, double pique, weft loc-knit, cross-miss, bird's eye, single creep design, & popcorn design [4]. The properties of the fabrics vary with respect to the structure combinations used. The mechanical properties of the fabric include their bursting strength, abrasion resistance, pilling grade, stiffness of the fabric, and stretch & recovery of the fabrics. Single knitted structures with tuck stitches were found to have better abrasion resistance, TIV, air permeability, bending, compressional, shearing, and total hand value properties [5]. The burst strength decreased with an increase in the number of tuck & miss stitches. The bursting strength for the miss-stitched fabrics was more than the bursting strength of the tuck-stitched fabrics. Fabrics having all knit courses in their structure possess more bursting strength compared to structures without all knit courses [6].

Although a lot of investigations have been done for the single-jersey fabrics, there are still a few detailed works on the structure combinations of the single-jersey fabrics that need to be done. A lot of work has been done by different scientists on the development of fabrics with single structures and on studying their properties. These structures were for summer wear or winter wear depending on material and structure. To achieve the optimum properties between summer and winter wear, multiple combinations of structures have been developed by changing the arrangement of cams and needles. The objectives of this study were to develop combinations of different structures to improve their mechanical properties and to compare which combination of structures gives better mechanical properties.

2. Method

Cotton yarn (100%) having a count of 20 Tex was used to develop hybrid structures and study the mechanical properties of the developed single jersey and derivative fabrics. Yarn testing was performed including the composition of yarn, which was 100% cotton, yarn count (ASTM D 1907) 20 Tex, lea strength (ASTM D 1578) 65.5 lb., CLSP 1973, TPM (ASTM D 1422) 809, breaking strength 285.9 CN, elongation 3.69%, tenacity 14.53 CN/Tex and yarn unevenness (ASTM D 1425) 139.5.
The conventional Fukuhara Japan single jersey machine (1992 FXC-3S) with 4 tracks, having 30 inches diameter, 20 gauges, 90 feeders, and 1884 needles was used. A total of eleven samples were developed on the machine by changing the cams for each design, while the needle arrangement remained the same throughout the sample making. The samples were developed, each comprising of two structures in which structure 1 cam was arranged on track A & B up to 1-24 feeders and on track C & D up to 25-48 feeders, while for structure 2 cams were arranged on track C & D up to 1-24 feeders and track A & B up to 25-48 feeders. The same process was repeated for all samples. Explanation of the development of two different structures in one fabric (machine design setting, design appearance in fabric form).



(a) (b) (c)

Figure 1 - (a) Symbolic Notation, (b) Graphical Notation, and (c) Sample Picture.

The samples developed included Single Jersey, Single Jersey – Single Pique, Single Jersey – Double Pique, Single Jersey – Single Lacoste, Single Jersey – Honey Comb, Single Pique – Double Pique, Single Pique – Single Lacoste, Single Pique – Honey Comb, Double Pique – Single Lacoste, Double Pique - Honey Comb, Double Pique - Single Lacoste, Double Pique - Honey Comb, and Honey Comb – Single Lacoste. To analyze the mechanical behavior of the developed fabric samples, some tests were performed including the Martindale abrasion resistance test (ASTM D4966), pilling test (ISO 12945-1), and fabric stiffness test (ASTM D4032).

3. Results and Discussion

The fabric parameters of the developed samples are given in Table 1.

Table 1
Fabric parameters of samples

Sr no.	Sample	Sample Code	Courses/cm	Wales/cm	Stitch Density (cm^{-2})	Stitch length (cm)	Tightness factor
1.	Single Jersey	SJ	15.75	9.45	148.80	0.32	1.38
2.	Single Jersey – Single Pique	SJ - SPQ	14.57	10.24	149.11	0.306	1.45
3.	Single Jersey – Double Pique	SJ - DPQ	15.35	10.63	163.22	0.31	1.43
4.	Single Pique – Double Pique	SPQ - DPQ	12.99	9.84	127.88	0.302	1.47
5.	Single Jersey – Honey Comb	SJ - H.COMB	14.96	9.84	147.25	0.31	1.43

Sr no.	Sample	Sample Code	Courses/cm	Wales/cm	Stitch Density (cm^{-2})	Stitch length (cm)	Tightness factor
6.	Single Pique – Honey Comb	SPQ - H.C	14.17	8.27	117.18	0.304	1.45
7.	Double Pique – Honey Comb	DPQ - H.C	12.99	8.27	107.42	0.304	1.45
8.	Single Pique – Single Lacoste	SPQ - S.L	11.81	7.87	93.00	0.334	1.32
9.	Honey Comb – Single Lacoste	H.C - S.L	12.60	7.87	99.20	0.314	1.4
10.	Double Pique – Single Lacoste	DPQ - S.L	13.39	7.48	100.13	0.314	1.4
11.	Single Jersey – Single Lacoste	SJ - S.L	13.78	8.27	113.93	0.316	1.4

In this research, the abrasion resistance, pilling resistance, and fabric stiffness of the samples were analyzed to show the trends of the different structures being made and the results of the tests being applied. The data were analyzed as is presented in the Figures. The samples were tested for their mechanical properties and the results obtained are given in Table 2.

Table 2

Mechanical Properties of Hybrid Structures

Sr no.	Sample	Sample Code	Abrasion resistance (cycles)	Pilling Grade	Stiffness of Fabric (gram)
1.	Single Jersey	SJ	6000-8000	2-3	71
2.	Single Jersey – Single Pique	SJ - SPQ	5000-6000	3	82.33
3.	Single Jersey – Double Pique	SJ - DPQ	2000-3000	3-4	68
4.	Single Pique – Double Pique	SPQ - DPQ	3000-4000	3	82.66
5.	Single Jersey –Honey Comb	SJ - H.COMB	1000-2000	3-4	76.33
6.	Single Pique – Honey Comb	SPQ - H.C	6000-8000	3-4	66.66
7.	Double Pique – Honey Comb	DPQ - H.C	5000-6000	3	71
8.	Single Pique – Single Lacoste	SPQ - S.L	3000-4000	3-4	66.66
9.	Honey Comb – Single Lacoste	H.C - S.L	5000-6000	3-4	71.66
10.	Double Pique – Single Lacoste	DPQ - S.L	3000-4000	3	66.33
11.	Single Jersey – Single Lacoste	SJ - S.L	2000-3000	3-4	68

3.1 Abrasion resistance

The abrasion resistance of the fabric is its mechanical property to note down the mechanical behavior of the fabric upon abrasion against any other material.

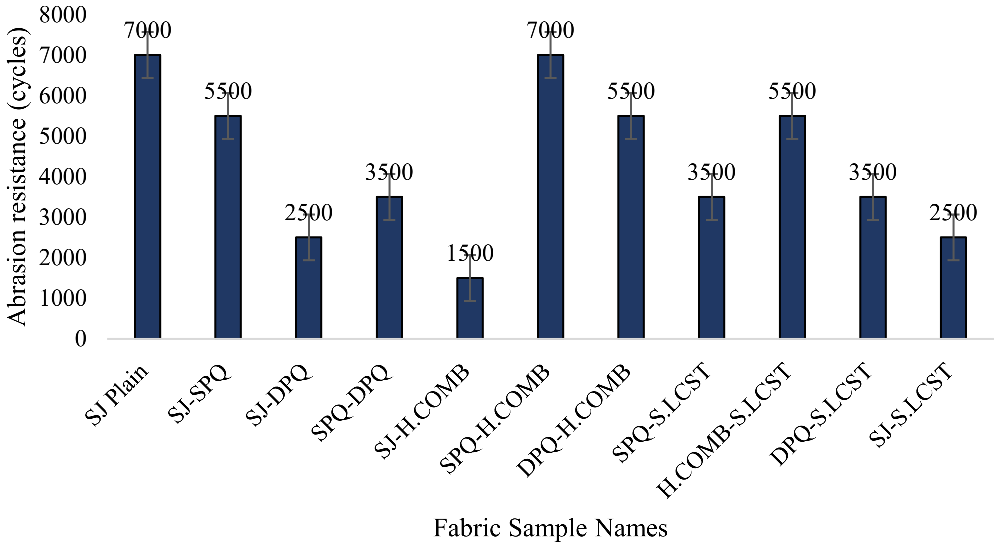


Figure 2- Results of abrasion resistance (cycles) of fabrics samples.

The lower the abrasion resistance, the greater the loss of mechanical properties of the fabric. The abrasion resistance was observed more for the SJ-plain and SPQ-H.C samples, and the abrasion resistance was observed less for the SJ-H.C samples, which shows that as the compactness of the fabric reduces, the abrasion resistance reduces. The SJ-plain possessed the highest value of abrasion resistance as it possessed an all-knit structure that is more compact compared to structures containing tuck stitches. The denser the resistance to structure, the higher the abrasion resistance [7]. The single Pique – Honey Comb structure also showed higher resistance to abrasion due to tuck stitches in both combinations.

3.2 Pilling Grade

The pilling of a fabric is its mechanical property to resist mechanical rubbing. Fabrics are subjected to rubbing and their grades are noted. Excessive pilling of the fabric reduces its mechanical properties. The more pilling, the more fiber is lost in the form of pills and hence resulting in the loss of strength of the fabric. There are five grades of pilling in which 5 shows the best, that is, no pilling while 1 shows the worst, that is, severe pilling. The results of our samples were somewhere in between. The grade was 3-4 for most samples that show a slight change in the appearance of the fabric. They included SJ-DPQ, SJ-H.C, SPQ-H.C, SPQ-S.L, H.C-S.L, and SJ-S.L. While for some samples it was 3 which means a moderate change, and for SJ Plain, it was 2 which shows a significant change in the appearance of the fabric.
As the number of tuck stitches increases, the resistance to pilling increases due to fewer contact points due to the non-smooth surface of tuck stitches [8], [9]. As the thickness of the resistance to fabric increases, the pilling resistance increases. Increased porosity also increases the pilling resistance of the fabric [9].

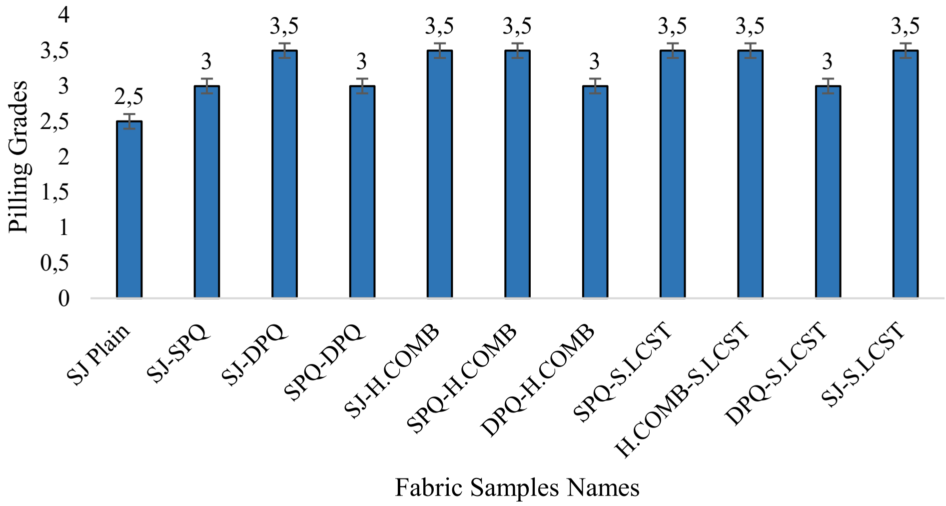


Figure 3 - Pilling classification of investigated kitted fabric samples.

3.3 Fabric Stiffness

Stiffness is the mechanical property of the fabric related to the drape of the fabric. It also contributes greatly to the comfort of the wearer.

The stiffer the fabric, the less comfortable the wearer will have. Stiffness is induced in the fabric due to the presence of a greater number of tuck stitches. Fabric stiffness was highest for the SPQ-DPQ structure, while lowest for the DPQ-S.L structure, and optimum for the sample SJ-SPQ.

Fabric stiffness was highest for SPQ-DPQ followed by the fabric stiffness value for SJ-SPQ, SJ-H.C, H.C-S.L, DPQ-H.C, SJ, SJ-S.L, SJ-DPQ, SPQ-S.L, SPQ-H.C, DPQ-S.L. As the number of tuck stitches increases, the loops become close to each other due to high tension in the yarn, and the stiffness of the fabric increases [10].

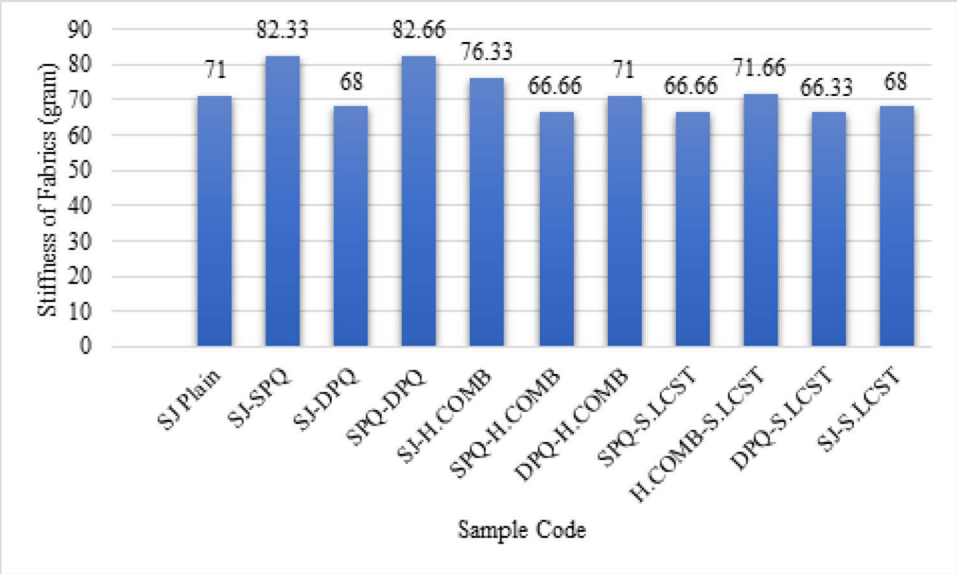


Figure 4- Stiffness results of investigated knitted fabric samples.

4. Conclusions

In this study, the effect of the combination of the knitted fabric structure on the mechanical properties including stiffness, abrasion resistance, and pilling grade was investigated and the yarn count, loop length, and machine parameters were kept constant. From the investigation, it was found that;

- The abrasion resistance was highest for SJ, SPQ-H.C and lowest for SJ-H.C, which shows that the SJ-H.C combination samples are very sensitive to abrasive forces.
- The pilling grade was highest for SJ-DPQ, SJ-H.C, SPQ-H.C, SPQ-S.L, H.C-S.L, and SJ-S.L and lowest for the SJ PLAIN fabric sample, which shows that the tuck stitch reduces the pilling of the fabric.
- The stiffness of the developed samples was highest for the SJ-DPQ structure and lowest for the DPQ-S.L structure, and the combination of the structure with the highest stiffness offers less comfort to the wearer.

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