NC STATE
Wilson College of Textiles

JTATM
Journal of Textile and Apparel, Technology and Management

Volume 11, Issue 2, 2020

Quality Aspects of Sustainable Handloom Denim Fabrics Made of Hand Spun and Machine Spun Cotton Yarn

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ABSTRACT

The denim industry, and the products of which are largely used in textile clothing, is an important subsector of the textile industry. Today the industry is facing many criticisms due to huge amount of energy consumption, water consumption and the hazardous nature of various chemicals being used throughout the vertical channel right from raw material extraction till disposal phase and disturbing the eco system. In spite of environmental concern, the trend indicates that the worldwide demand of denim products over the last few decades has increased tremendously. Considering the global jeans production estimated to be more than 3.5 billion unit per annum, the extent of environmental damage caused by this industry is quite evident. Hence the question of sustainable production arises in denim industry. Keeping this in view, denim fabric produced by handloom weaving is evaluated. The effect of using hand spun yarn as the weft of fabric and impact of handloom weaving on denim fabric is considered. It is found that higher stretchability, better crease recovery, lower flexural rigidity, lesser tensile and tear strength for handloom denim using hand spun yarn in weft direction when compared with industrial denim fabric.

Keywords: Sustainable, Handloom, Denim

1. Introduction

The denim industry has grown tremendously over the last few decades and is projected to grow further (Kumar et al., 2016). The denim industry, though, an important subsector of the textile industry, is being condemned as one of the most polluting sector having inconsiderate effect on environment and human health. Denim products consume a huge amount of carbon and water footprints from raw material extraction till disposable phase (Pal 2017). The production stages of denim jeans is responsible for approx. 59% of the climate change impact, whereas the use of jeans and end-of-life process accounts for the remaining 41%. This causes denim jeans to

be responsible for about 2 kg of CO_2 per functional unit (Karthik & Murugan 2017). Denim is also on top of the pyramid of water consuming textiles, with a total volume of 2900 gallons (approx. 11000 liters) consumed per pair of jeans (Sanchez 2013; Pal et al 2017b). In spite of all these environmental concerns, the trend indicates that the worldwide demand of denim products over the last few decades has increased tremendously. Considering the global jeans production estimated to be more than 3.5 billion unit per annum (Garcia 2015; Luiken & Bouwhuis 2015], the extent of environmental damage caused by this industry is quite evident**.** Hence the question of sustainable production arises in denim industry. Keeping this in view, denim fabric produced by handloom weaving is evaluated. Literature reveals a very limited research on handloom denim and hence this research characterizes physical properties of handloom denim and compares it with industrial denim of similar construction specification to inform the future direction of handloom denim. All the samples use same machine spun yarn in warp direction while in weft: machine spun yarn, hand spun yarn and machine spun imitation of hand-spun cotton yarns are used. The study discusses the constructional details, handle and mechanical properties of denim samples. The effect of using hand spun yarn as the weft of fabric and impact of handloom weaving on denim fabric is considered. Cotton denim samples developed on handlooms are evaluated in terms of constructional parameters like thread density, yarn count, crimp %, thickness and GSM. The handle properties in terms of crease recovery & flexural rigidity and mechanical properties like tensile & tear strength are also evaluated and compared with industrial denim fabric.

2. Materials and Methods

2.1 Samples preparation

Single small warp beam with 10 Ne machine spun cotton yarn is prepared to weave 36 inch width twill structure fabric on frame loom. The reed size of 24 dents per inch with three ends per reed dent was used to match with the EPI of the denim fabric produced industrially (S4). From the same warp beam, three samples with 3 up 1 down right hand twill weave interlacement pattern using three different weft yarns are prepared. The yarns used for weft are: machine spun yarn (S1), hand spun yarn (S2) and machine spun imitation of hand-spun cotton yarns (S3). Hand spun yarn was produced by well experienced spinner on Charkha i.e. hand operated spinning wheel. The constructional specification details of all samples are shown in Table 1.

2.2 Characterization

The physical properties of denim samples are measured at 27°±2° C and 65±3 % relative humidity under standard measuring conditions. Yarn counts are measured by Beasley balance and thickness is measured under 0.5 kPa pressure using thickness tester. Thread density is determined through pick glass and the weight per unit area (gm/m^2) is measured by using a circular specimen of 100 cm^2. For crease recovery, bending length, tensile and tear strength testing, the instrument used are crease recovery tester, stiffness tester, tensile strength tester and Elmendorf tear testers respectively. Fabric flexural rigidity is calculated by the following formula:

Flexural rigidity (G) = W X C^3 mg-cm

Where W is weight per unit area in mg/cm^2 and C is bending length in cm.

The complete results are shown in Table 1 and Table 2.

3. Results and Discussion

3.1 Yarn Count

Results in Table 1 and Fig. 1, reveals that actual yarn count (Ne) used in handloom denim (S1, S2 and S3) is slightly on coarser side, the difference of which is insignificant when compared with warp yarn used in industrial denim (S4).

Table 1.

Sample ID	Yarn	Yarn count (Ne)		Thread Density per inch		GSM g/m^2	Thickness (mm)	Crimp %	
	weft	Warp	Weft	Ends	Picks			warp	weft
S1	m/c spun	9.7	9.7	70	39	292	0.91	12.0	6.5
S2	hand spun	9.7	9.4	68	37	295	1.02	15.0	8.0
S3	m/c spun*	9.7	8.8	66	34	288	1.16	18.0	6.0
S4	m/c spun	10	10.2	72	44	300	0.80	10.0	8.0

S1, S2 and S3 are denim fabric produced on handloom with machine spun, hand spun and machine spun imitation* of hand-spun yarn respectively. S4 indicate industrial denim fabric.

Table 2.

Sample ID	Crease Recovery Angle		Bending Length (cm)		Flexural Rigidity (mg.cm)		Breaking Load (Kg)		Elongation (%)		Tearing Strength (Kgf)	
	Warp wise	Weft wise	Warp wise	Weft wise	Warp wise	Weft wise	Warp wise	Weft wise	Warp wise	Weft wise	Warp wise	Weft wise
S1	115	94	4.3	2.9	2322	712	78	37	17	11.5	5.18	3.05
S2	127	111	3.7	2.5	1494	461	63	26	24	15	4.75	2.82
S3	134	123	3.8	2.4	1580	398	64.5	31	26	13	5.07	3.46
S4	108	92	4.7	2.9	3114	732	87	44	14	13.5	5.38	3.97

However the count of hand spun weft yarn (9.4 Ne) in S2 and machine spun imitation of hand-spun cotton yarn (8.8) in S3, are on coarser side and having significant count difference.

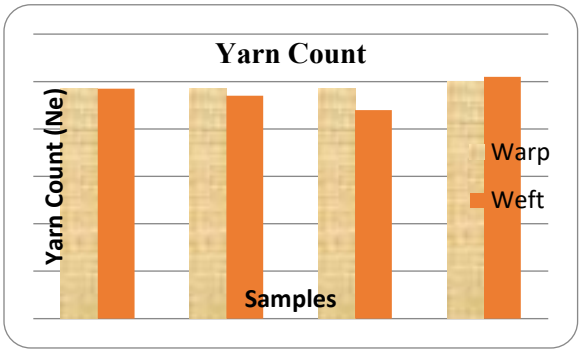

Fig. 1: Yarn count comparison

It is very difficult to control the linear density of hand spun yarn and also to produce machine spun yarn which imitates hand spun cotton yarn with exactly the same count as of industrially spun on machine. Sample S4 represents the denim sample which is produced in industry with 10 Ne nominal count in warp and weft direction. While sample S1, as earlier mentioned is the denim fabric woven on handloom with machine spun yarn in warp and weft direction.

3.2 Thread Density

The specification set on handloom in terms of keeping the thread density is same as that of industrial denim produced.

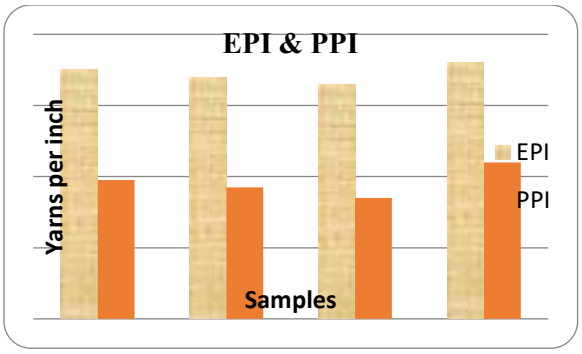

Fig. 2: Thread Density

However result reveals significant difference between thread densities for hand spun weft yarn sample S2 and machine spun imitation of hand spun weft yarn sample S3 when compared with samples S1 and S4 which are made from machine spun weft yarn (Table 1, Fig. 2). This happened because of variation in spun yarn count and manual control on handloom weaving.

3.3 Crimp %

Crimp % of denim fabrics made on handloom (S1, S2, S3) demonstrates more crimp % in warp direction (Fig. 3) as compared to Industrial denim fabric (S4). So handloom-denim fabrics are more stretchable. The reason can be attributed to more tension on warp yarn on warp beam and as well as during weaving on industrial loom. Crimp % for machine spun imitation of spun yarn woven on handloom (S3) was found to be the maximum followed by hand spun yarn denim (S2) woven on handloom. However there seems to be not much difference in crimp % in weft direction for all the samples.

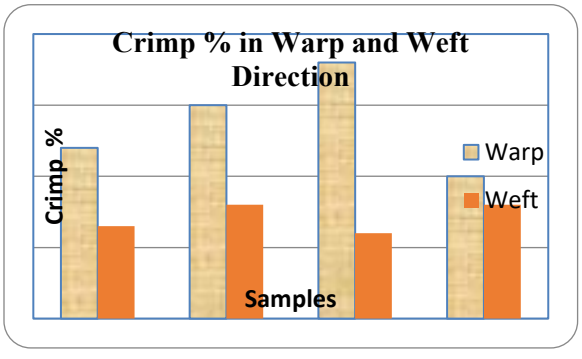

Fig. 3: Crimp % in warp and weft direction

Overall crimp % in weft direction is much lesser than warp crimp % for all the samples. The reason may be attributed to yarn tension as well as coarse weft yarn count for handloom denim samples.

3.4 Thickness

Thickness of industrial denim fabric sample S4 is least (Fig. 4), which may be due to finer & uniform machine spun warp and weft yarn and lesser crimp %, when compared with other handloom denim samples. Thickness for sample S3 is the maximum followed by sample S2.

The reason is attributed to low twisted & irregular hand spun and machine spun imitation hand spun yarn as well as more crimp %. Low beat-up forces employed in hand weaving may be another reason responsible for higher thickness than industrial denim.

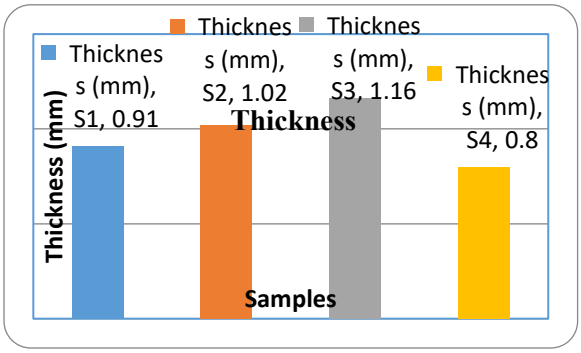

Fig. 4: Fabric thickness

3.5 Fabric weight in gsm (gm/m^2)

Fabric weight for all the samples range from 288 gm/m^2 to 300 gm/m^2. Results indicated (Fig. 5) no significant difference in fabric weight among all denim samples either produced in industry or on handloom.

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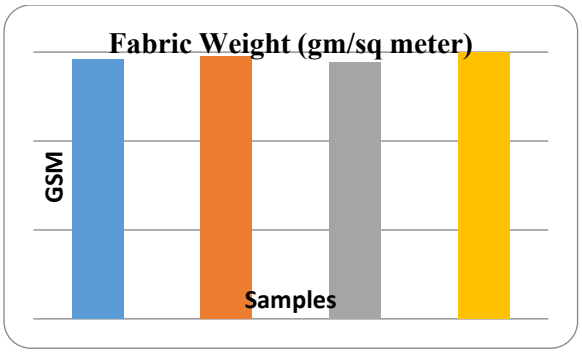

Fig. 5: Fabric weight per unit area

Since the fabric weight depends upon yarn count, thread density and crimp %, the deliberation of which has already been discussed.

3.6 Fabric surface appearance

Hand spun yarn and the machine spun imitation of hand spun yarn used in the weft direction are not as even as machine spun warp yarn. Thick and thin places which are occurring in hand spun yarn appear randomly in the fabric surface. The imperfections in the fabric surface of hand spun woven fabric have aesthetic value and are not considered defects or an indication of low quality (Phoophat & Sukigara 2016).

3.7 Crease Recovery

Results in Fig. 6 indicate that for sample S3, crease recovery both in warp and weft direction is the maximum which is followed by S2. This demonstrate that hand spun yarn or imitated hand spun yarn made on machine and woven on handloom offers significant crease recovery as compared to fabrics woven with machine spun yarn.

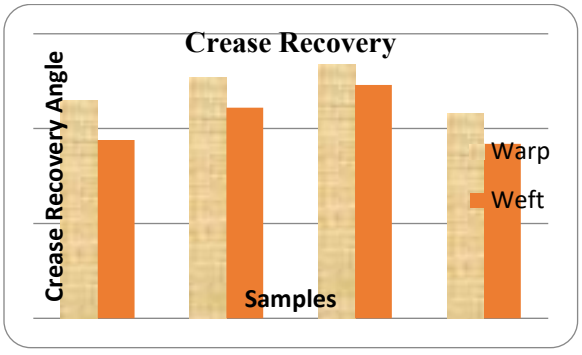

Fig. 6: Crease Recovery Angle

The reason may be attributed to more freedom to fibers in case of hand spun like yarn structures. Results also demonstrate more crease recovery in warp direction than in weft direction, which may be due to more ends per inch than picks per inch.

3.8 Bending Length & Flexural Rigidity

Bending length for S2 and S3 samples which have used hand spun yarn like structure are found to be less both in warp and weft direction than samples S1and S4 which are made from machine spun weft yarn.

The difference in bending length is not significant for S1 (made on handloom) and S4 (made in industry). Since both samples are made from machine spun yarn, this demonstrates that yarn structure has a prominent role in influencing bending length and thus the flexural rigidity. (Refer Fig. 7)

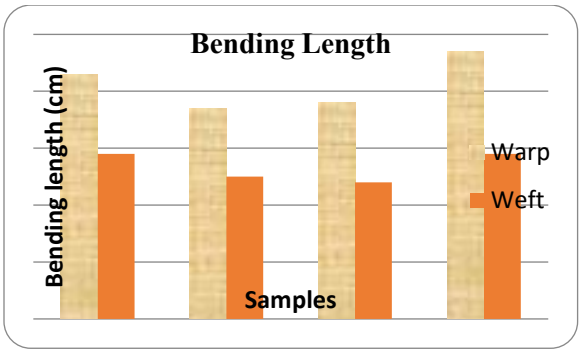

Fig. 7: Bending Length (cm)

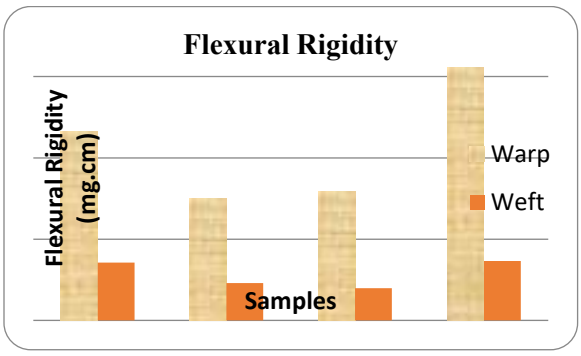

Fig. 8: Flexural Rigidity

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Another observation inferred from the result (Table 2 and Fig. 8) reveals that flexural rigidity in weft direction is lesser than warp direction, the reason of which is attributed to lesser pick density as compared to warp density. Also the hand spun yarns are bulky in nature and are not uniform in count as well as in structure.

3.9 Breaking Load

While the handle properties are in favor of handloom denim, but the results in Table 2 and Fig. 9 indicate that maximum tensile strength is obtained for industrial denim sample S4.

The tensile strength for sample S2 and S3 in both directions were significantly lower than the tensile strength of industrial denim S4 and even S1 sample woven on handloom.

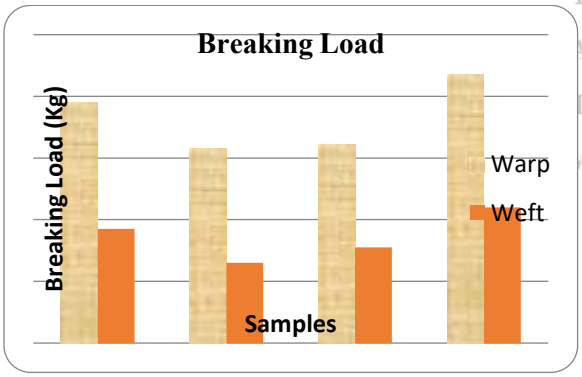

Fig. 9: Tensile Strength

The reason is the irregular structure of hand spun yarn and weak in strength offering less tensile resistance. Also the much less tensile strength, in weft direction as compared to warp direction is due to lesser pick density for all the samples.

3.10 Breaking Elongation

Breaking elongation in warp direction was found to be more for S3 and S2 when compared with S4 and S1. This demonstrates that in spite of having higher breaking strength, industrial denim is lacking in stretchability. The result trend follow crimp % and denim samples woven on handloom with hand spun yarn like structure are more stretchable. Results from Fig. 10, demonstrate higher stretchability in warp direction as compared to weft direction.

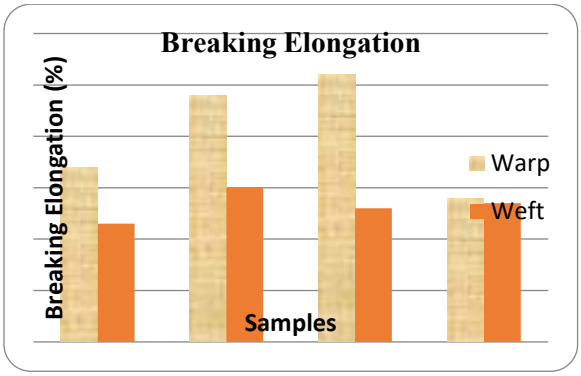

Fig. 10: Breaking elongation (%)

3.11 Tearing Strength

Tearing strength is measured on Elmendorf tear strength tester. The capacity of the installed weight is 6.4 Kgf. The results are given in Table 2 and shown in Fig. 11.

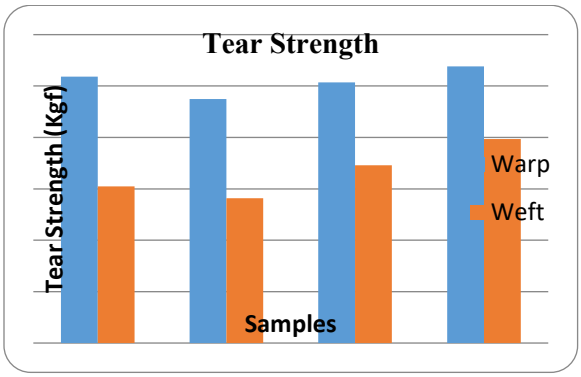

Fig. 11: Tear Strength

Result indicates S2 is having least tearing strength and sample S4 offers maximum tear resistance in both warp and weft direction. The tear strength in weft direction is much less when compared with warp direction. This is attributed to the lesser pick density as compared to ends per inch. While other two samples occupies the intermediate position.

4. Conclusion

Handle and mechanical properties of denim made on handloom using machine spun, hand spun and machine spun imitation of hand spun yarn in weft direction are compared with industrial denim along with constructional details and fabric appearance.

For all denim fabric, machine spun yarn is used in warp direction. The difference between the characteristics values of handloom and industrial denim in both directions is profound. The results indicate better handle and aesthetic appeal of handloom denim than industrial denim in terms of better crease recovery, lower flexural rigidity and higher elasticity. The imperfections in the fabric surface of hand spun woven fabric also have aesthetic value and are not considered defects or an indication of low quality. Industrial denim on the other hand found to be more durable by providing better tensile and tear resistance.

The study aimed to address the environmental concern as posed by the denim sector. Developing denim, on handloom shows potential in bringing down the carbon footprints of denim sector, apart from meeting social sustainability through handloom industry. While eco conscious and with a nice hand, the handloom denim, being a high-end product, is only going to be available to those who can afford it.

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