DAFFODIL INTERNATIONAL UNIVERSITY JOURNAL OF SCIENCE AND TECHNOLOGY, VOLUME 18, ISSUE 2, JULY 2023
ISSN 1818-5878 (Print) 2408-8498 (Online)

Estimation of Warp and Weft Crimp in Denim Fabric Using Various Methods

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Abstract: For professionals working in the weaving industries worldwide, accurate estimation of warp and weft consumption is a crucial procedure. Both underestimating and overestimating have negative commercial and economic effects. The work presented here is an effort to determine the crimp percentage of denim fabric utilizing a variety of techniques, including marking, set length, and standard crimp tester methods. The investigation was place at a denim weaving facility close to Dhaka, Bangladesh. In this regard, the crimp percentage of denim fabrics with various structures was examined. The set length approach appears to be the most accurate one for calculating crimp%. The study indicates that depending on the fabric construction 10% to 13% crimp is imparted on warp at grey stage, but after finishing it becomes as high as 27% to 30%. This is due to the deliberate length wise shrinkage carried out in the finishing section after weaving. The warp crimp was found to be substantially lower than the warp crimp in denim, as expected, but the completed crimp was significantly greater than the grey crimp. We discovered that warp had a lower crimp% than weft. It's because weaving maintains tension on the warp yarns. Additionally, they are better and stronger yarn than weft. So they stop extending further. Weft yarns, on the other hand, are maintained with low tension and poor quality. in order to stretch farther. Their crimp percentage is higher as a result.

Keywords: *Crimp percentage, warp crimp, weft crimp, methods to determine crimp, crimp in denim.*

1. Introduction:

Accurate estimation of warp and weft consumption for making a particular fabric is a matter of great concern for experts working in the weaving industries. An over estimation will lead to manufacturing of excess fabric while an under estimation will lead to insufficient production than actual requirement. Thus both under and over estimation will lead to consequences harmful from business and economic point of view. Yarn consumption in woven fabric is estimated by the crimp percentage. Apart from yarn consumption, crimp has direct relation with the following properties, e.g. Abrasion, shrinkage, elongation in strength and higher flexibility in fabric design will be achieved in terms of higher crimp.[1][2]

Industry sources indicate that crimp is highly variable and ranges between 2% to as high as 30%, which is a challenge for the weaving industries to set the actual estimation of warp and weft needed to manufacture certain length of cloth. Lack of sufficient knowledge about crimp% will lead to wrong estimation. So, weaving industries usually weave extra cloth to compensate any shortage and eventually end up having huge amount of left over cloth at the end of the year.

Crimp in warp and weft yarn is calculated by measuring the length of a yarn in the woven state, Lfabric, and the length (straightened) of that same yarn after being extracted from the fabric, Lyarn, and then computed according to following equation as a percentage:[3]

$$\mathbf{Crimp, C} = \frac{\mathbf{Lyarn - Lfabric}}{Lfabric}$$

Accordingly, some mathematical equations have been derived by the researches depicting the relation between yarn crimp and other yarn or fabric parameters. Peirce, F. T delineated the following formula to relate other fabric and yarn parameters with the yarn crimp:[4]
4/3{P2(C1)1/2+P1(C2)1/2}=36e{I/N1)1/2+I/N2)1/2}
Where P1 and P2are spacing of warp and weft in mills, C1 and C2are warp and weft crimp as fractions, N1 and N2are linear density of warp and weft, and e is flattening co-efficient of threads. Researchers have figured out some correlations also between crimp of yarn and mechanical properties of fabric. Haque [5][6] criticized the existing method of measuring crimp by crimp tester method, suggested by various testing standards including BSI, since it may have some accuracy issues as

same pretension is used to test crimp of a yarn having same linear density but different amount of crimp. He considered that if a yarn forms different amount of crimp in two fabric (say 5% and 15%) then the separate pretension will be required to get the straightened length. Because the yarn with higher crimp should be straightened by greater force than the case where crimp is lower. Apart from that, it reported that crimp is affected by (i) physical properties like elasticity, rigidity, bending behavior etc. of fibers and yarns, e. g., (ii) count of warp and weft, (iii) threads/inch or cm, (iv) tension on threads during weaving, (v) yarn and fabric structure and (vi) physical and chemical treatment of the fabric after weaving.[1][2] Studies suggested that, fiber with higher crimp have lower elastic moduli and breaking stresses and extensions. They mentioned that, yarn made from these fiber exhibit same kind of mechanical properties in the fabric.[7][8] Fabric extensibility, shear and hygral expansion, bending properties are apparently related to the yarn crimp.[9][10][11] At present, crimp% is calculated using a widely practiced method suggested by British Standard Institute (BSI). However the system was reported to have some drawbacks e.g. it uses same pretension to straighten a crimped yarn having varying types of crimps.[12] Thus if the crimp cannot be estimated properly, it will not be possible to predict crimp of yarn properly, leading to wrong estimation of yarn for producing certain length of woven fabric. Though there are some studies describing the effect of crimp on different properties of fabric, there is currently no research about the techniques to determine the crimp percentage in woven fabric especially on denim fabric except by crimp tester. The present work is therefore undertaken to identify new ways of determining crimp percentage keeping in mind the different aspect like preparatory and finishing process of the woven fabric.

2. Materials and Methods:

For the present study fabric samples of different constructions were woven in the weaving mill. Table-1 shows the details of various fabric samples considered for this study. Attempts have been made to determine crimp of warp and weft yarn taken out of the woven fabric at grey and finished state. Crimp% is then calculated using the following formula [13]:

Crimp % = (LxP)/P x 100 % …...(i)

Where, the straightened thread length = l

The length of thread in fabric or crimped length = p

2.1 Measurement of Warp Crimp:

2.1.1 Measurement of warp yarn crimp percentage by marking method:

On the loom, this measurement was taken. In order to obtain the correct information on the crimp percentage after the fabric has been manufactured, a set of warp threads were marked on the loom with marker pens spaced one meter apart. Figure 1 depicts where the markings A and B are located. The threads are entering the heald frame and flowing through the drop wire. It is employed to press the weft threads into position, to direct the shuttle's movement across the loom, and to divide and space the warp threads. Following the weaving of the referred input length of the warp thread in that location, the distance of the woven fabric between the two designated areas was measured once more, and the crimp percentage was determined using the formula in equation. (i). The crimp results are shown in Tables 1.

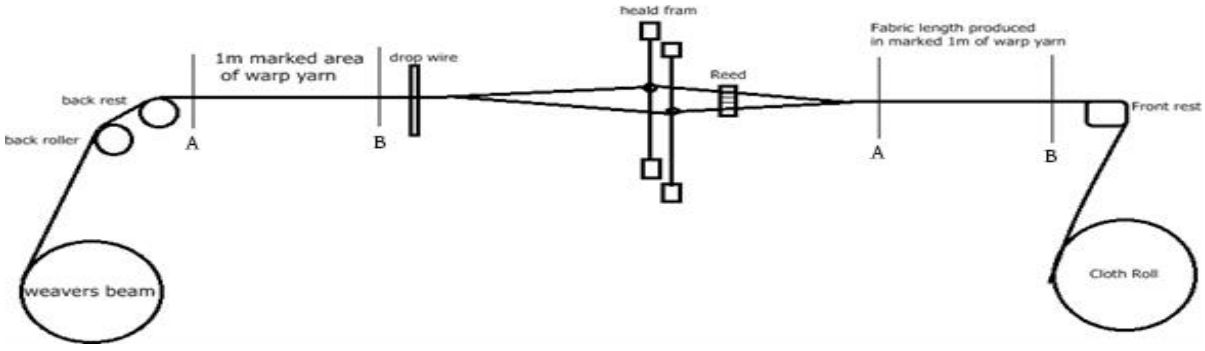

Fig-1: Warp crimp measurement by marking method

ISSN 1818-5878 (Print) 2408-8498 (Online)

2.1.2 Measurement of Warp Yarn Crimp Percentage by Set Length Method:

The length of the warp yarn twisted in the weaver's beam and the corresponding fabric made from that length were used in the procedures to indirectly determine the warp crimp percent. By using this method, the length of unwoven warp yarn that was wound on the weaver's beam was subtracted from the length that had been set up on the weaver's beam because we had to calculate the amount of fabric that was lost during production. It was discovered that a few yards had been wasted at the start of weaving a new beam and a few yards had been left unwoven at the end of that beam. After the fabric has been made, we have two lengths: one is the length of the specific warp yarn that was used to weave the cloth, and the other is the length of the woven fabric (including the length of waste yarn). The formula stated in equation was used to compute the crimp percentage using the two lengths. (i). The results have been shown on Table 1.

2.1.3 Measurement of Warp Crimp % by Using Crimp Tester:

This was done by the BSI method of crimp test. A fabric sample measuring 1 meter by 1 meter is first taken. After that, remove the entire length warp and weft yarns from the fabric sample. We have straightened the strands to their actual length and removed the crimp. Lastly, measure how long the warps and wefts are after being straightened. Assume that your warps are 1.05 meters in length and your weft yarn is 1.08 meters in length. A yarn tension prescribed by the BSI method of crimp test was maintained, which is shown below:

Table 1: Yarn tension prescribed by the BSI method of crimp test

Yarn Type	**Linear Density**	**Tension (cN)**
Woolen and Worsted	15 to 60 tex	(0.2 x tex) + 4
	61 to 300 tex	(0.07 x tex) + 12
Cotton	7 tex or finer	(0.75 x tex)
	Coarser than 7 tex	(0.2 x tex) + 4
All Man-made continuous filament yarn	All	(0.5 x tex)

Then crimp percentage was calculated by using same formula as above. Thus, data was taken from six different looms and average crimp percentage was calculated. The data is shown on Table 2.

Table 2: Summery of warp crimp percentages obtained by various methods

SL. No	Construction				Crimp% by Marking Method			Crimp % by Set Length Method		Crimp % by Using Crimp Tester	
	EPI	Warp Count	PPI	Weft Count	On loom	Relaxed	Finished	Grey	Finished	Grey	Finished
A	60	7.2 RS	48	16L-40D + 300L-40D	7.61	10.38	26.92	11.04	28.02	11.50	27.47
B	66	7.5 RS	40	6 OE	9.57	12.38	25.94	13.12	27.25	13.52	26.71
C	62	7 RS	40	10L-40D	10.38	12.69	28.98	13.32	30.14	13.37	27.79
D	68	8.5 OESL + 7 OE + 10 OE	39	7OESL + 10L-40D	9.74	12.21	26.87	12.58	28.31	8.5 0ESL: 11.92 7 OE: 12.38 10 OE: 12.01	8.5 0ESL: 27.89 7 OE: 28.92 10 OE: 27.20
E	54	7 RS	44	10L-40D	9.99	13.20	27.65	13.49	28.01	13.26	27.72
F	65	7.5 RSL + 8 R + 11 R	45	8 RS + 10L-40D	10.85	12.21	28.57	13.38	30.90	7.5 RS: 12.13 8 R: 11.87 11 R: 11.60	7.5 RS: 28.62 8 R: 28.32 11 R: 28.39

[Here, R= Ring, OE= Open End, RS= Ring Slub, OESL= Open End Slub]

2.2 Measurement of Weft Yarn Crimp Percentage:

2.2.1 Measurement of Weft Yarn Crimp Percentage by crimp tester:

The same method and formula (Warp Crimp % by Using Crimp Tester) had been done for weft crimp percentage and that was calculated by using formula according to BSI method of crimp test. In the same way crimp percentage was calculated from the grey and finished fabric. Thus, readings from seven different looms were taken and average crimp percentage was calculated. The data is shown on Table 3.

2.2.2 Measurement of Weft Yarn Crimp:

At first a running machine was stopped and then fabric width (in cm) from selvedge to selvedge was taken by measuring tape at fell of the cloth position. The last weft yarn from selvedge to selvedge was removed. The straightened length of this weft yarn was measured. Then the crimp percentage was calculated by equation (i). Secondly, this measured position was marked and let the loom run for weaving 10 inch of fabric. After production of 10 inch of the fabric, width (in cm) from selvedge to selvedge was taken by measuring tape in that marking point. Then crimp percentage was calculated by equation (i). Thus, readings from seven different looms were taken and average crimp percentage was calculated. The data is shown on Table 3.

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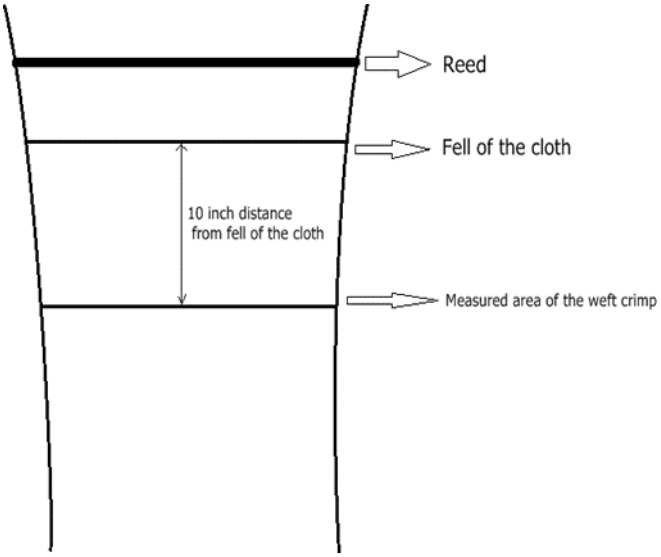

Fig-2(a): Weft crimp measurement by Set Loom Method

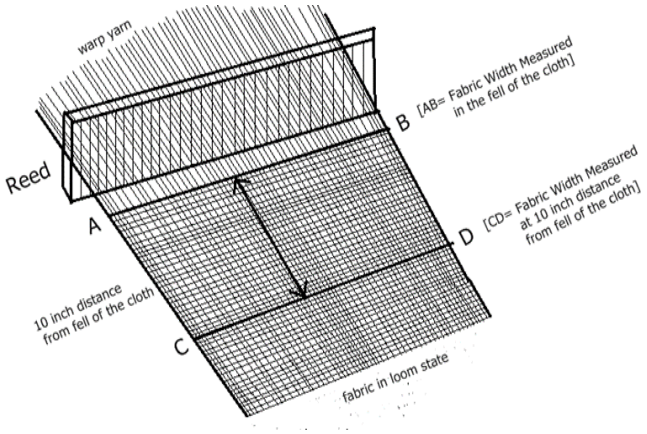

Fig-2(b): Weft crimp measurement by Set Loom Method

2.2.3 Measurement of Weft Yarn Crimp Percentage by off loom (Relaxed Method):

Two days later, the fabric samples were recovered after they had been unwound from the cloth roller and given enough time to relax. In this technique, the fabric was marked on the loom beforehand. Then a relaxed fabric width was chosen in accordance with this marked place. Seven readings were therefore taken. Each of these test textiles had a weft yarn taken out of it. Following that, the length of these yarns after being straightened was measured, and the crimp % was computed using the formula in equation. (i). The data is shown on Table 2.

Table 3: Summery of weft crimp% obtained by various methods

Sample no	Fabric Construction				Crimp% at fell of the cloth position	Crimp% at 10 inches production on loom	Crimp% at relaxed Width	Crimp% Finished Width	Crimp % by Using Crimp Tester	
	EPI	Count	PPI	Count					Grey	Finished
A	66	7.5 RS	40	6 OE	1.31	2.34	3.93	6.34	3.93	6.18
B	64	7.2 RS	42	6 OE	1.58	2.76	3.22	7.39	3.27	7.53
C	72	10 RS	50	12L-40D	1.47	3.12	6.34	14.77	6.54	15.27
D	62	7RS + 7R	44	6.25 OE	1.43	2.26	6.5	7.16	6.12	8.11
E	62	7RSL	40	8L-40D	2.34	3.48	6.2	11.52	6.27	11.67
F	60	7.2 RSL	48	16L-40D	1.54	2.41	9.31	14.74	8.8	17.67
				300L-40D	0.76	1.63	8.47	13.86	6.5	14.027
G	68	8.5 OESL + 7OE + 10 OE	39	7OESL	1.25	2.08	3.98	9.68	4.20	10.60
				10L-40D	3.19	4.06	5.98	11.81	5.86	11.66

[Here, R= Ring, RS= Ring Slub, OE= Open End, OESL= Open End Slub]

3. Results and Discussion:

3.1 Discussion on the Findings of Warp Crimp:

Table 1along with the figures 3-5 shows the warp crimp results obtained by various methods which have been discussed here.

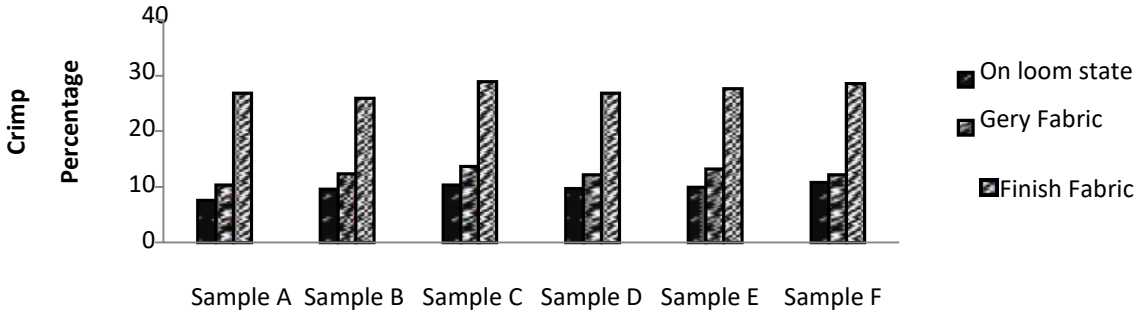

Fig-3: Measurement of warp crimp% in marking method for different fabric constructions

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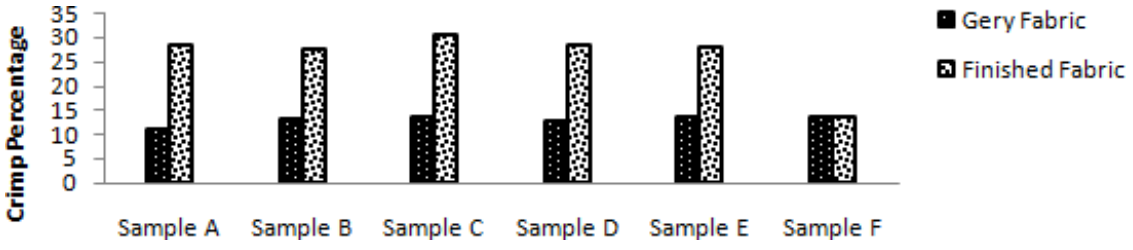

Fig-4: Measurement of warp crimp% in set length method for different fabric constructions

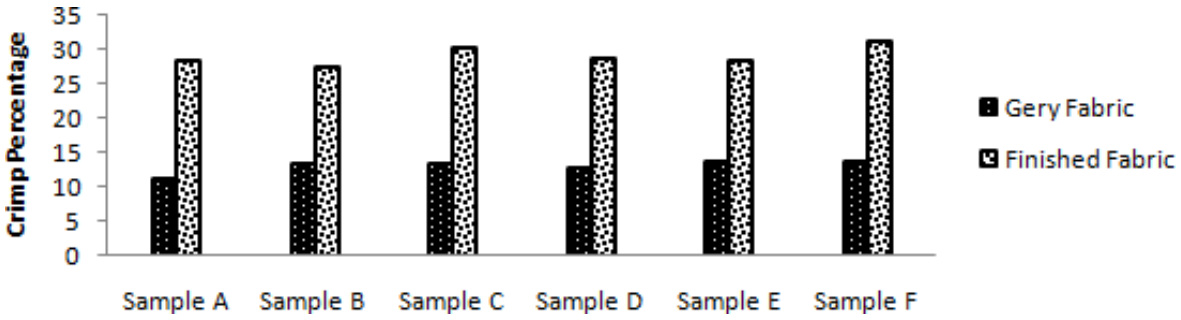

Fig-5: Measurement of warp crimp% by crimp tester for different fabric constructions

An important point need to be noted is that the warp yarns were under relatively heavily stretched on the loom. Therefore the crimp percentages on the loom and relaxed fabric were somewhat lower. The reason that the final crimp% are much higher than usual crimp percentages is that during finishing stage a process is carried out called compressive shrinkage where the fabric is allowed to shrink warp-way deliberately. This is done to avoid any shrinkage after making garment i.e. during use. It seems that the marking method is the most authentic method than the other two methods.

As was previously mentioned, the technique for measuring crimp by set length method is based on the length of warp wound on the experimental weaver's beams being recorded. During and after weaving, a certain length of warp is wasted as yarn form; this length has been subtracted from the initial length, and after deduction, the length was used as the actual length of warp yarns used in the fabric. These two fabric lengths, along with the previously determined warp yarn lengths, were utilized to calculate the crimp percentages at the relaxed and finished phases from the lengths of fabric that were acquired from each beam (after being taken out, relaxed, and also after finishing). The tables show that both the grey and finished crimp percentages were almost same as were obtained from the marking method, however the crimp percentages obtained from the set length methods were slightly higher in all cases of both grey and finished stage. This may had happened due to the fact that in case of marking method the warp yarns were under stretch so that the length before weaving were actually less than that were used for set length method, because the set lengths were taken with nominal stretch used in the sizing machine.

It was observed that in most cases the grey crimp results obtained by the crimp tester are slightly higher than those obtained from the set length method while the finished crimp obtained from the crimp tester is slightly lower than those obtained from the set length method. It was not possible to comment about the differences but the differences are insignificant.

3.2 Discussion on the Findings of Weft Crimp:

Table 2 along with the figures 6-8 shows the weft crimp results obtained by various methods which have been discussed here.

The grey weft crimp percentage obtained by the crimp tester lies between 3.27% and 8.8% whereas the finished crimp% lies between 6.18 and 17.67.

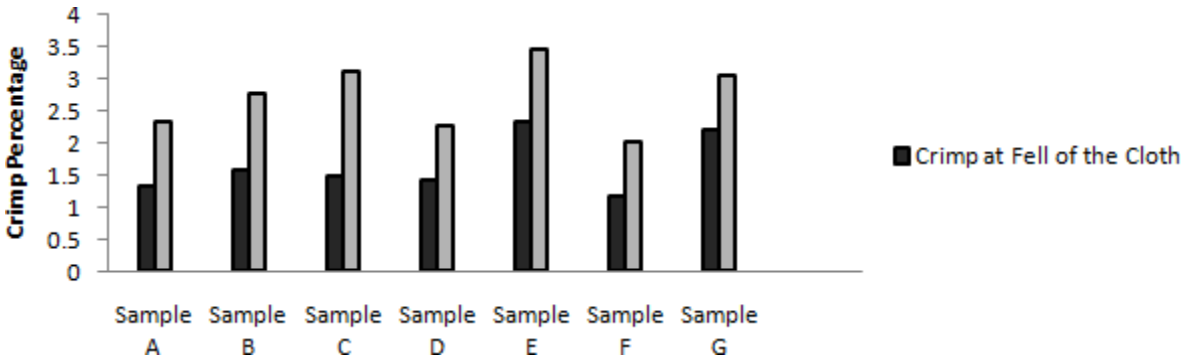

Fig-6: Weft Crimp% measured in set length method for different fabric constructions

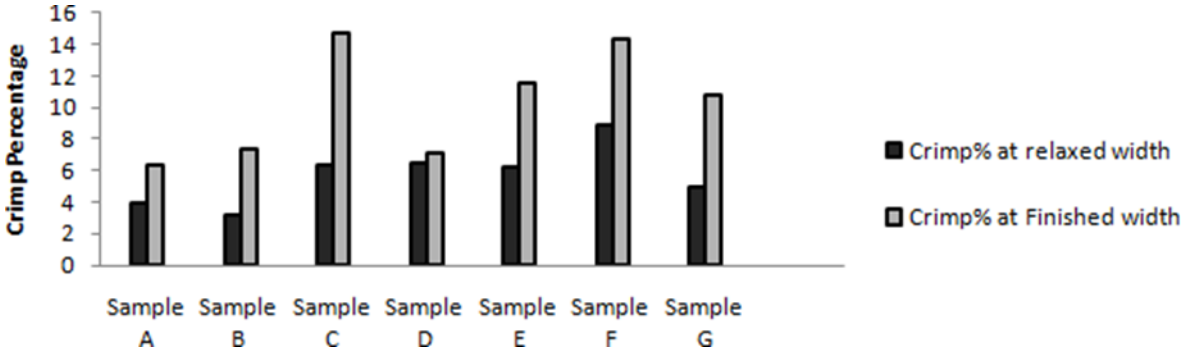

Fig-7: Weft Crimp percentage measured in relax method for different fabric constructions

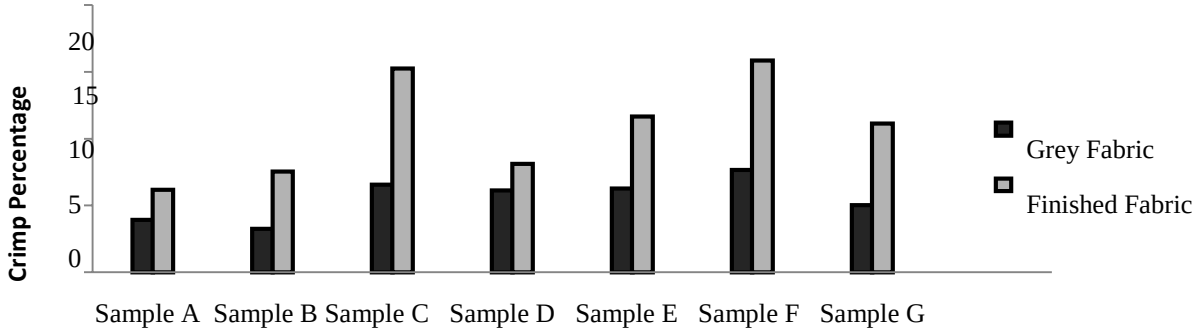

Fig-8: Crimp percentage measured by crimp tester for different fabric construction

The weft crimp percentage at the cloth fell position on the loom was between 0.76 to 3.19%, and the crimp% at 10 inch distance was between 1.63 to 4.06%. When taken of the loom and relaxed, the weft crimp% was

ISSN 1818-5878 (Print) 2408-8498 (Online)

found to be in the range of 3.98 to 9.31. The crimp% of the finished fabric was found to be in the range of 6.34 to as high as 14.77.

4. Conclusion:

Three alternative methods, such as the marking method, the set length method, and the conventional crimp tester method, have been used to determine the crimp percentages of the warp and weft of various types of denim fabrics. The marking technique appears to be the most authentic, however because the length before weaving was measured under tension, the crimp percentage is believed to be a little less than true crimp. The fixed length method was also discovered to be highly accurate after marking procedures. The marking and set length approach and the crimp tester method are not all that dissimilar. It was found that at the grey stage, 10 to 13% of crimp is formed depending on the construction, but after finishing, the crimp% increases to 27 to 30%. It seems that deliberate shrinkage during finishing (after weaving) is responsible for this high crimp% of the finished denim fabrics.

When it comes to the weft crimp percentage, it can be noted that grey crimp is between 3 and 5%, but for textiles that utilized lycra as the weft, crimp was between 6 and 8%, and the completed crimp was found to be between 6 and 8% (without lycra), but with fabrics the crimp% was as high as 15%. Weft crimp was also measured using a novel technique using a crimp tester, however there was no discernible difference between the two approaches.

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