INVESTIGATION OF BASIC YARN PARAMETERS INFLUENCING FORMABILITY BEHAVIOR OF COTTON SHIRTING FABRICS

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Abstract: Formability of the fabric is one of the cardinal parameter that determines the Total Appearance Value (TAV) of the fabrics; it is related to maximum compression sustainable by the fabric before the onset of buckling. Formability behavior of a fabric structures is determined by the low stress mechanical properties, viz. bending rigidity and in-plane compressional resistance. Poor formability leads to develop compression force that creates puckering at seams and affects the drape and shape retention characteristics of the finished garments. Extent of puckering is mostly determined by the fabric designed specifications and yarn the parameters. In woven fabric structure, apart from fibre properties and fabric specifications, yarn linear density influence bending rigidity of the fabric which in turn affects the fabric formability. Higher twist in yarn makes yarn stiffer and thereby increases the same. In-plane compression resistance of the fabric is also depending on the number plies in spurn yarn. The present paper discusses the effect of various yarn parameters, viz. count, twist, and doublings on formability characteristics of cotton woven shirting fabrics. 100% cotton woven fabrics of varying yarn linear densities and number of plies were produced. The formability characteristics were determined using KESF evaluation system. It was interesting to note that the formability is found to be higher for shirting fabrics produced from plied yarns than that of single yarns of same linear density.
Keywords: Formability, Total Appearance Value (TAV), Bending rigidity, In-plane compression resistance.

1. Introduction

Formability of the fabric is one of the important attribute that contributes towards the appearance value of apparel garment. Lindberg defined formability as its ability to cover surfaces of various curvatures that no wrinkles or folds are formed. It is usually defined as a product of bending rigidity and longitudinal compressibility sustained by fabric before it buckles [1, 2, 3, & 4].

$$F_{cr} = \frac{4\pi^2 \times b}{l^2} \tag{1}$$

Where F_{CR} = Critical Buckling Load, b = Bending Stiffness, l = Gauge Length,
Buckling occurs when $F > F_{CR}$

Bertil Olofsson and Noboru Oguchi worked on fabric buckling of woven fabric and revealed that the bending behavior of woven fabric exhibits an initial non-linearity produced by frictional restraint [5]. John Skelton's work on the bending behavior of the fabric exhibit that the suitability of a textile structure for a particular end-use is often determined by its bending behavior [6]. T. G. Clapp and H. Peng used theory of Timoshenko's elastica and studied the effect of the fabric weight on buckling behavior of the woven fabrics [7]. Several other models have been proposed to describe the basic fabric bending behavior includes, Peirce's model of constant bending rigidity [8], Grasberg's frictional couple theory [9] , and the theory of bilinear moment curvature relationship [10,11]. These models allow only analytical solutions for some basic fabric buckling problems neglecting effect of fabric weight.

Low stress mechanical properties of fabrics are measured using two most important methods Kawabata evaluation system (KES-FB) and Fabric assurance by simple testing (FAST) and determines fabric formability. Kawabata correlates mechanical properties of fabric viz. formability, drape and elastic behavior with the appearance of tailored garments and determined Total appearance value of men's suit fabric.

Consumer's choice for cotton shirting is mainly attributed to its unique comfort and appearance value. Low stress mechanical properties of cotton shirting fabrics determine its comfort and appearance.

2. Materials and Methods

Experimental specimens of 100% plain woven cotton shirting fabrics were used for study. Sample fabrics were composed of different yarn linear densities, viz. 50/1, 60/1, 70/1, 100/2 & 120/2. Kawabata evaluation system KES-FB was used for determination of fabric formability. Low stress mechanical properties of fabric samples were measured and their formability F_{KES} was calculated using following equation and the tested data was analyzed using one way ANOVA with replication method.

$$F_{KES} = \frac{EMT}{490\ LT} .B. \frac{G}{2HG5}$$

B - Bending Rigidity, LT- Linearity of Tensile Curve, EMT-Extension at 490 N/m load, G-Shear Modulus , 2HG5- Shear Hysteresis at an angle of 5^{o} in N/m.

Table: 1 Specification of Experimental 100% Cotton Fabric Samples

Sr. No.	Warp Count (Ne)	Weft Count (Ne)	E.P.I.	P.P.I.	Warp T.P.I.	Weft T.P.I.	G.S.M (gm/m^2)
1	50/1	50/1	144	77	28.99	27.64	117
2	60/1	60/1	180	88	34.07	32.75	119
3	70/1	70/1	190	90	34.4	37.06	100
4	100/2	100/2	148	77	29.29	31.23	123
5	120/2	120/2	188	88	36.34	35.51	120.5

3. Result and Discussion

3.1 Yarn Linear Density and Fabric Formability in Case of Single Yarn

In general designing of dense fabrics is accomplished by using finer yarns. The higher number of threads per unit length in fabric reduces buckling force shared per unit thread, which in turn reduces the formability value of the fabrics. Results obtained in case of single yarns indicated a good correlation of fabric formability with of yarn linear densities.

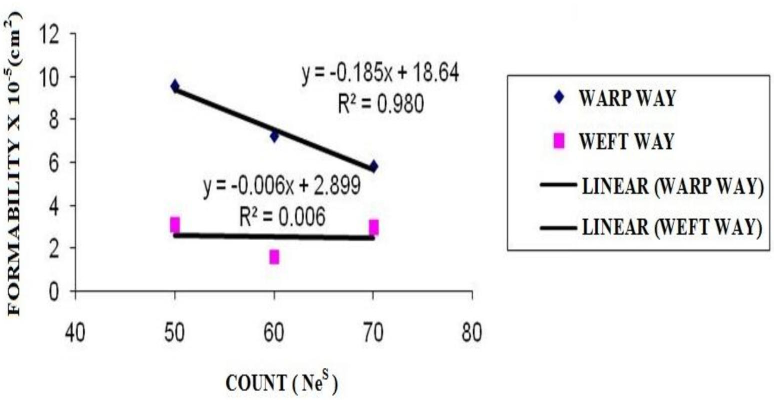


Figure 1: *Effect of Yarn Linear Density on Formability Single Yarn*

On the other hand, fabrics constituting coarser yarns have less thread density means force per unit thread for buckling the yarn is more, so the formability is more in coarse yarn.

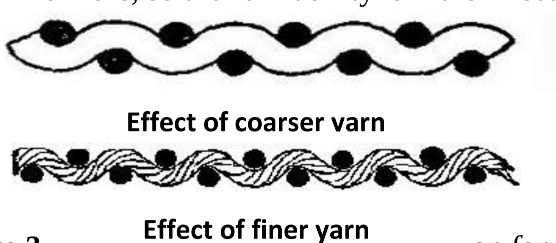


Figure 2 *on formability*

In figure 1,it shows that, in 50/1, 60/1 & 70/1 fabric has formability in warp way $9.542X10^{-5}$, $7.234\ X10^{-5}$ & $5.839X10^{-5}$ & in weft way $3.033\ X10^{-5}$, $1.609\ X10^{-5}$ & $2.905X10^{-5}$ respectively, which shows that as yarn count goes finer the formability is going down.

3.2 Effect of Count on Formability (For Plied Yarn)

In plied yarn two single threads are twisted together in opposite direction to the twist in the single yarn. In finer plied yarn the rate of twist insertion per unit length is more than that of the coarser plied yarn. Due to this in finer plied yarn the cross over points within the twisted yarn will be more which resist the compressive force to buckle the fabric. Because of this, it shows higher formability. Whereas in coarser plied yarn the cross over points within the twisted yarn are less hence requires less compressive force for buckling which leads to lower formability.

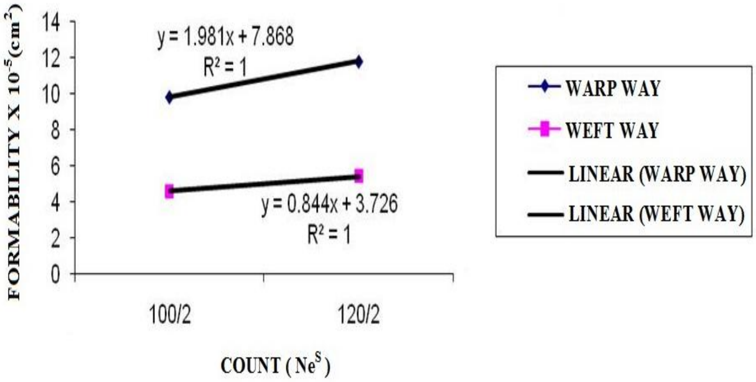


Figure 3: *Effect of Count on Formability (For Plied Yarn)*

In figure 3, In 100/2 fabric has less formability in warp way & in weft way i.e., 9.849X10^{-5} & 4.57X10^{-5} respectively whereas in 120/2 fabric has more formability in warp way & in weft way i.e., 11.83X10^{-5} & 5.414X10^{-5} respectively.

3.3 Effect of Yarn Doubling on Formability

In the fabric of single yarn, the longitudinal compression sustained by the fabric in axial direction before the fabric buckles is less as compared to the fabric of plied yarn. As the force is applied in axial direction on single yarn, the resistance offered by the single yarn is less as compared to the plied yarn. Because in case of plied yarn the cross over points resists the buckling.

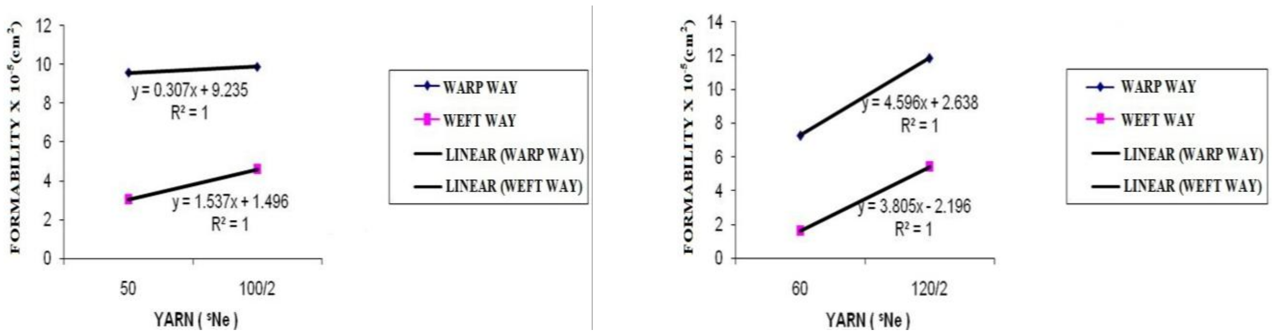


Figure 4: *Effect of Yarn Doubling on Formability*

Plied yarn of 100/2 count has more twists. So, it becomes stiffer & hence increased bending rigidity. In case of single yarn of 50/1 count, it posses less twist, as doubling is eliminated. Hence it is less stiff & offers less resistance to bending. Another reason for less formability in 50/1 & 60/1 single yarn fabric is less number of threads which forms less compact structure and hence require less compressive force to buckle. On other hand in 100/2 & 120/2 plied yarn fabric, number of threads are more which forms more compact structure and hence requires more compressive force to buckle which leads to higher formability.

From figure 4, In case of fabric of single yarn the formability is less is proved from the graph. In 50/1 and in 60/1 fabric the formability in warp way is 9.542X10^{-5} & 7.234X10^{-5} and in weft way 3.033X10^{-5} & 1.609X10^{-5} respectively. Whereas in fabric of plied yarn the formability is more. In 100/2 and in 120/2 fabric the formability in warp way $9.849X10^{-5}$ & $11.83X10^{-5}$ and in weft way $4.57X10^{-5}$ & $5.514X10^{-5}$ respectively.

3.4 Effect of Twist Per Inch on Formability (For Single Yarn)

The effect of twist per inch depends on the density of the fiber in yarn. Usually in finer yarn, fiber density is higher. The density is changing according to the number of twist in the yarn. Higher the twist more finner will be the yarn. Further, a greater number of the twist in yarn means that fibers are more rigid because the fibers are close together. That means no freedom for movement of fiber so the formability is less.

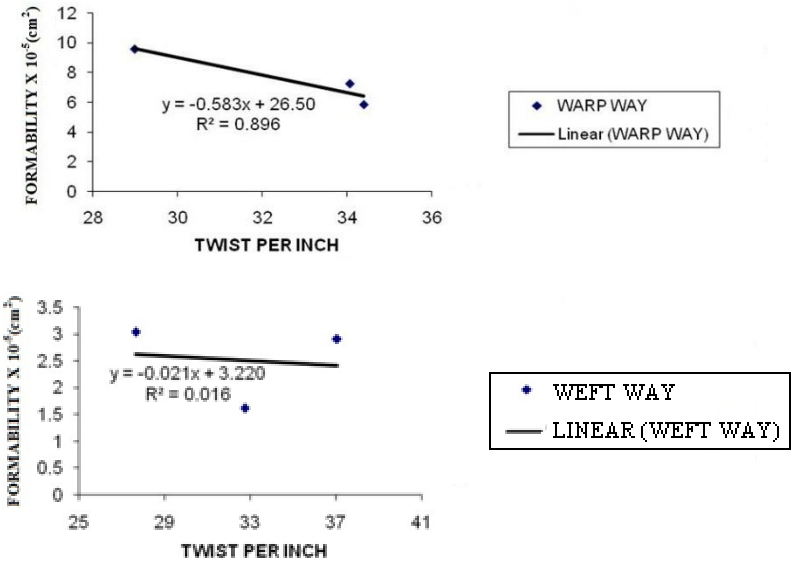
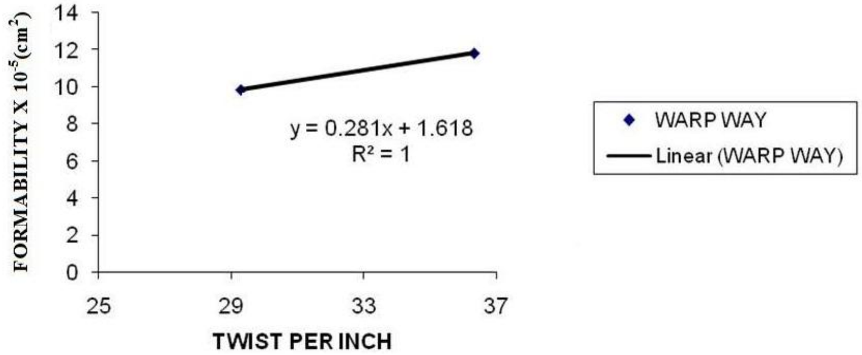


Figure5: *Effect of Twist per Inch on Formability (For Single Yarn)*

On the other hand, the fibers in yarn with fewer twists per inch have some freedom of movement; therefore these fibers are less rigid and have higher degree of formability. From the above figure 5, Fabric of twist per inch in warp 28.99, 34.09 & 34.4 has formability $9.542X10^{-5}$, $7.234X10^{-5}$ & $5.839X10^{-5}$ and twist per inch in weft 27.64, 32.75 & 37.06 has formability 3.033 $X10^{-5}$, 1.609 $X10^{-5}$ & 2.905 $X10^{-5}$. Both ways it is clear that as twist per inch increases, the formability decreases. As per one way ANOVA with replication, twist per inch value of cotton shirting fabric of single yarn is significantly differing in both warp and weft direction.

3.5 Effect of Doubling Twist Per Inch Formability (For Plied Yarn)

The coarse plied yarn is having less twist per inch than finer. Due to less twist per inch the crossover points in coarse plied yarn are less. The less crossover points offer less resistance to compressive force which leads to easier buckling of fabric. Whereas, in finer plied yarn the twist per inch is more which forms more crossover points which leads to more formability.



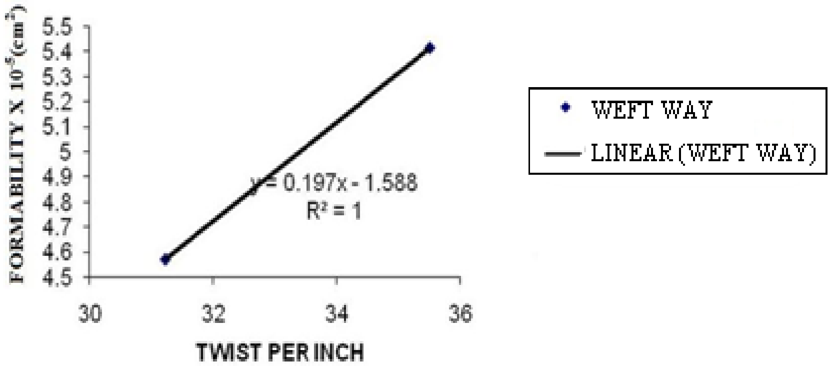


Figure 6: *Effect of Doubling Twist per Inch Formability (For Plied Yarn)*

Another factor affecting formability is direction of twist in warp and weft thread. The fabric for which the warp and weft plying twist direction is same (S & S or Z & Z) gives more formability.

From the above graphs, Fabric of twist per inch in warp 29.29 & 36.34 has formability $9.849X10^{-5}$ & $11.83X10^{-5}$ and twist per inch in weft 31.23 & 35.51 has formability $4.57X10^{-5}$ & $5.414X10^{-5}$. Both ways it is clear that as doubling twist per inch increases, the formability increases. As per one way ANOVA with replication, twist per inch value of cotton shirting fabric of plied yarn is significantly differing in both warp and weft direction.

3.6 CONCLUSION

In case of cotton shirting fabric composed of single yarn, with increase in linear density of yarn formability decreases, whereas cotton shirting fabric composed of plied yarn there is direct relation in between yarn linear density and formability. Formability is more for fabric sample of plied yarn than that of fabric sample of single yarn of same linear density.

Cotton shirting fabric composed of single yarn, twist per inches have inverse relation with formability i.e. with increase in twist per inches formability decreases. The relation was same for warp and weft twist per inch. Cotton shirting fabric composed of plied yarn it shows direct relationship with formability i.e. as twist per inches increases formability increases in both the warp & weft direction.

References:

[1] Alamdar-Yazdi, A. & Gheblah, F.: The Effect of Yarn Twist Direction on The Formability of The Woven Fabrics, 6th International Conference-TEXSCI 2007, pp.5-7.

[2] Lindberg, J.; Behre, B. & Dahlberg, B.: *Textile Research Journal*, Vol. **(**31) No.,99, (1961).

[3] Lindberg, J.; Westerberg, L. & Svenson, Ft.: *Journal of Textile Institute* Vol. (51T) No., 1475, (1960).

[4] Lindberg, J.: "Fabric Engineering and Clothing Technology"; Proc. 2nd World Congress of Man-Made Fibres, London (1962).

[5] Grosberg P.; & Swani, N.M. The Mechanical Properties of Woven Fabrics: Part III: The Buckling of Woven *Textile Research Journal,* (1966) pp.332-338.

[6] Skelton John.; The Bending Behavior of Fabrics at High Curvatures, *Textile Research Journal,* (1971), pp. 174 -181.

[7] Clapp T. G.; & Peng H.: Buckling of Woven Fabrics Part I: Effect of Fabric Weight, *Textile Research Journal,* (1990), pp. 228 -234.

[8] Peirce, F. T.: The Geometry of Cloth Structure, J. Textile Inst. T45-T97 (1937).

Grosberg, P.: The Mechanical Properties of Woven Fabrics, Part II: The Bending of Woven [1] Fabrics, *Textile Research Journal*, Vol. (36), pp. 205-211, (1966).

[9] Ghosh, T.: Computational Model of the Bending Behavior of Plain Woven Fabrics, Doctoral Thesis, College of Textiles, North Carolina State University (1987).

[10] Leaf, G. A. V. & Anandjiwala, R. D.: A Generalized Model of Plain Woven Fabrics, *Textile Research Journal,* Vol. (55), pp. 92-99, (1985).

[11] Konopasek, M., & Hearle, J. W. S., Computational Theory of Bending Curves, Part I, The Initial Value Problem for 3-Dimensional Elastic Bending Curves, Fibre Science Tech, pp.1-28 (1972).

[12] Behera, B.K. & Mishra, Rajesh: Effect of Crease Behavior, Drape and Formability on Appearance of Light Weight Worsted Suiting Fabrics, Dept. of Textile Technology, IIT Delhi, *Indian Journal of Fibre & Textile Research,* Vol.(32), pp 319-325, (2007)