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Comparison of characteristics of fabrics produced from singed and unsinged dyed yarns

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The effect of removal of different levels of comber noil, while preparing yarn, singeing and dyeing of yarn, on quality of fabric has been studied. The dyed yarns produced from singed and unsinged cone yarns, which, in turn, are produced with different levels of removal of comber noil have been converted into fabric. The pilling resistance, drape, and low-stress mechanical properties of fabric samples are studied. The fabrics produced from singed yarn possess higher pilling grades. The singeing of yarn increases the drapability of the fabric. The fabric produced from singed yarn shows a higher total hand value as compared to that of the fabrics produced from unsinged yarns. The results show that the removal of more amount of comber noil to produce yarn with lesser imperfection at the ring cop yarn stage does not necessarily result in the fabric with better pilling resistance and handle, whereas it can be achieved by the singeing process.

Keywords: Abrasion resistance, Cone winding, Cotton, Fabric handle, Fabric low-stress mechanical properties, Yarn hairiness, Kawabata fabric evaluation system, Pilling, Singeing

1 Introduction

The ring-spun yarn with lesser imperfections, hairiness and higher evenness can be produced by removing short fibres by combing process. The surface characteristics of woven fabric are mainly influenced by the evenness, imperfections and hairiness of yarn. Researchers produced cotton combed yarns by removing 14, 16 and 18% of noil at the comber[1]. These samples were dyed before and after singeing. It was found that an increase in comber noil caused a decrease in imperfections at the ring bobbin stage. The imperfections changed at different stages of post-spinning operations and dyeing, and finally, the difference was not appreciable. Removal of a higher level of comber noil or singeing did not make a significant difference at the dyed yarn stage, although there was a difference at the ring bobbin and cone stages. Hairs present in the yarn can be removed by singeing process also. Hairiness is an undesirable property of yarn; it leads to surface friction and geometric roughness, uneven dyeing and colour effect, interlocking of warp yarns during sizing and weaving, and a higher propensity to pill formation in the finished fabric[2, 3].

The effect of singeing treatment on the properties of combed ring-spun and compact-spun yarn was also studied[4]. Hairs were greatly removed by singeing, especially for short hairs with lengths less than 3 mm. Breaking force of yarn was stable after singeing treatment, while elongation, tenacity and breaking energy decreased slightly. Research was carried out to find the effect of singeing and heat setting on pilling properties of CVC (Chief Value Cotton) single jersey knit fabric[5]. It was found that both singeing and heat setting are most useful in the reduction of the pilling tendency of CVC knit fabric. The question arises whether (i) the removal of higher comber noil during the preparatory process of yarn production, or (ii) the singeing of the yarn, gives better quality at the final stage of fabric. Hence, a comparison of the properties of fabrics produced from these yarns is necessary to arrive at a conclusion.

In this work, the dyed yarns produced from singed and unsinged cone yarns, which, in turn, produced with different levels of removal of comber noil are converted into fabric. These fabrics are tested for pilling resistance, drape and low-stress mechanical properties to find the combined effect of removal of different levels of comber noil (14, 16 and 18%), while preparing yarn, singeing and dyeing of yarn on

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the pilling resistance, drape and low-stress mechanical properties of fabric.

2 Materials and Methods

2.1 Preparation of Fabric Samples

Combed cotton yarns of 40 Ne were produced from materials, combed at three different comber noil levels (14, 16 and 18%). These yarn samples were dyed before and after singeing. The singed and unsinged dyed yarns were warped and sized at a machine speed of 10 m/min at 90 °C with 15% size add-on and then converted into fabric using a sample rapier loom. The weaving parameters are: warp and weft count 40 Ne, ends per inch 88, picks per inch 70 and width 18 inch. The fabrics were then desized with enzyme 0.5% (owm), wetting oil 0.1% (owm) at 60°C for 5 min in a jigger dyeing machine by running four times and subsequently, one hot and cold wash was given. In total, six types of fabrics were produced, viz. fabric produced from unsinged dyed yarns (USDYF) and singed dyed yarns (SDYF), each produced from materials combed at three different comber noil levels. The experimental arrangement is given in Table 1.

2.2 Testing

The fabrics were tested for pilling and draping. The fabric samples were subjected to rubbing for 100, 250, 500, 1000, 1500, 2000, 2500 and 3000 cycles and the pills present in the fabrics were compared with the Standard ASTM Rating Scale. The low-stress mechanical properties of fabrics were measured using the Kawabata Evaluation System.

Table 1 — Experimental arrangement for production of fabric samples

Fabric code	Singed / unsinged	Yarn (Comber noil), %
USDYF1	Unsinged	14
USDYF2	Unsinged	16
USDYF3	Unsinged	18
SDYF1	Singed	14
SDYF2	Singed	16
SDYF3	Singed	18

3 Results and Discussion

3.1 Pilling and Draping

The pilling grade of fabrics after different cycles of abrasion is given in Table 2.

The pilling grade rating scale: grade 5 – no pilling; grade 4 – slight pilling; grade 3 – moderate pilling; grade 2 – severe pilling; and grade 1 – very severe pilling.

It is evident from Table 2 that the pilling grade of SDYF is higher than the pilling grade of USDYF fabrics for all the levels of comber noil levels. This is due to the removal of hairy fibres by singeing process and hence, less chance of formation of balls during rubbing. But in the case of USDYF fabrics, the hairy fibres present on the surface of the fabric entangle themselves and form balls during rubbing of fabric. Amount of comber noil extracted does not significantly influence the pill formation in the fabrics produced from singed dyed yarns as well as unsinged dyed yarns.

Drape coefficient of fabrics produced from dyed yarn is given in Table 2. Fabric that possesses a lower drape coefficient value drapes well. The drape coefficient is less for SDYF and the difference is significant (p=0.0221) between SDYF and USDYF. The singeing of yarn decreases the drape coefficient and increases the drapability of the fabrics. There is no trend seen due to change in comber noil level.

3.2 Fabric Low-stress Mechanical Properties

3.2.1 Compression Properties

Linearity of compression (LC), compression energy (WC), thickness at 0.5 gf /cm^2 (T_o) and thickness at 5 gf /cm^2 (T_m) pressure are the indicators of softness of material. Lower values of LC and WC, and higher values of difference in T_o and T_m indicate softness. The compression properties of fabrics are

Table 2 — Pilling grade and drape coefficient of fabrics

Fabric code	Pilling grade								Drape
	100 cycles	250 cycles	500 cycles	1000 cycles	1500 cycles	2000 cycles	2500 cycles	3000 cycles	coefficient
USDYF1	4	4	3	3	2	2	1 / 2*	1 / 2*	0.6529
USDYF2	4	4	3	3	2	2	2	2	0.6372
USDYF3	4	4	4	4	3	3	3	2	0.6614
SDYF1	5	4	4	4	4	4	4	3	0.5979
SDYF2	5	5	4	4	4	4	4	3	0.6159
SDYF3	5	5	5	4	4	4	4	3	0.5751

* Between the grades mentioned.

given in Table 3. Compression resilience (RC) is the ability of the fabric to recover from compression. Higher the resilience, lower will be the energy loss. There is no trend found in LC, WC, RC and difference in *To* and *Tm* values between USDYF and SDYF fabrics. This shows that the compressional properties of fabrics are not much influenced by singeing of yarn. Similarly, there is no trend followed for different comber noil levels.

3.2.2 Tensile Properties

The tensile properties of fabrics are given in Table 4. The fabrics produced from dyed yarn do not show any significant difference due to singeing in warp (p=0.4675) as well as weft directions (p= 0.9851) in the case of linearity of load-extension curve. It depicts that singeing does not affect the dimensional stability of the fabric. No trend is observed due to a change in comber noil level in both warp and weft directions.

Tensile energy (WT) is measured by the area under the load-elongation curve. It is strongly related to the fabric handle and movement of the body parts in the garment. Lower value of WT means that the lower energy is required for deformation, indicating that the fabric will bend easily and drape better. Hence, lower WT value is preferred for the fabrics used for apparel[6]. With the increase of fabric tensile strain (EMT), WT also increases. The fabrics produced from dyed yarn have higher WT and the difference is significant (p=0.0009) due to singeing, but not due to different comber noil levels in the warp direction. In the weft direction, the difference between singed and unsinged fabric (p=0.7868) is not significant and no trend is observed due to change in comber noil%. It is noticed that tensile energy measured in warp direction is about one and half times of tensile energy measured in weft direction. This is due to a higher number of ends per inch than picks per inch.

The ability of textile fabrics to restore their original shape after removing the external loading is known as fabric resilience. Higher tensile resilience (RT) results in higher dimensional stability after deformation. The p values of warp way direction (p=0.1170) and weft way direction (p=0.7332) show that there is no significant difference in tensile resilience due to singeing and no trend is followed due to change in noil %. Majority of the fabrics have low RT, which indicates that the fabrics are less elastic.

The larger the tensile strain (EMT), the greater will be the wearing comfort[7]. Higher values of EMT provide wearing comfort but creates problem during stitching and steam pressing. Very high values of EMT in warp direction generate problems in sewing and pressing due to distortion of fabric[8]. EMT% is higher for SDYF and the difference in EMT% is significant (p=0.000138) between USDYF and SDYF fabrics in warp direction. But the difference in EMT%

Table 3 — Compression properties of fabrics

Fabric code	LC	WC g.cm/cm^2	RC %
USDYF	1.285	0.182	53.00
USDYF	1.406	0.209	42.96
USDYF	1.397	0.210	44.01
SDYF1	1.461	0.237	41.05
SDYF2	1.342	0.239	41.70
SDYF3	1.355	0.231	44.79

LC - linearity of compression-thickness curve, WC - compression energy, and RC - compression resilience.

Table 4 — Tensile and bending properties of fabrics

Direction of testing	Fabric type	LT	WT gf.cm/cm^2	RT %	EMT %	B gf.cm^2/cm	2HB gf.cm/cm
Warp way	USDYF1	0.916	0.33	45.50	1.44	0.0614	0.1008
	USDYF2	0.859	0.31	52.75	1.42	0.0555	0.1170
	USDYF3	0.795	0.26	52.95	1.35	0.0631	0.1213
	SDYF1	0.932	0.38	48.08	1.61	0.0468	0.0743
	SDYF2	0.857	0.37	44.59	1.73	0.0488	0.0818
	SDYF3	0.890	0.38	46.66	1.68	0.0409	0.0770
Weft way	USDYF1	0.840	0.22	53.46	1.03	0.0428	0.0756
	USDYF2	0.760	0.19	50.84	1.00	0.0536	0.0933
	USDYF3	0.799	0.22	51.41	1.08	0.0499	0.0828
	SDYF1	0.774	0.19	55.56	0.99	0.0461	0.0694
	SDYF2	0.800	0.22	45.76	1.10	0.0371	0.0736
	SDYF3	0.827	0.20	50.00	0.98	0.0416	0.0711

LT - linearity of load-extension curve, WT - tensile energy, RT - tensile resilience, EMT - tensile strain, B - Bending rigidity, and 2HB - bending hysteresis.

Table 5 — Shear and surface properties of fabrics

Direction of testing	Fabric type	G gf/cm.deg	2HG gf/cm	2HG5 gf/cm	MIU	MMD	SMD µm
Warp way	USDYF1	1.46	4.68	7.30	0.162	0.0134	5.46
	USDYF2	1.52	5.10	7.88	0.149	0.0165	6.16
	USDYF3	1.55	4.74	7.93	0.154	0.0139	5.37
	SDYF1	1.07	4.18	6.16	0.160	0.0134	5.66
	SDYF2	1.23	4.43	6.61	0.157	0.0145	6.07
	SDYF3	1.16	4.45	6.44	0.155	0.0139	6.30
Weft way	USDYF1	1.45	4.10	7.09	0.160	0.0141	5.36
	USDYF2	1.63	4.39	8.05	0.154	0.0159	5.69
	USDYF3	1.56	4.20	7.81	0.156	0.0140	5.73
	SDYF1	1.06	3.53	5.73	0.162	0.0131	5.70
	SDYF2	1.21	3.69	6.16	0.160	0.0147	5.62
	SDYF3	1.12	3.60	5.91	0.159	0.0125	6.22

G - Shear rigidity, 2HG - hysteresis of shear force at 0.5^o shear angle, 2HG5 - hysteresis of shear force at 5^o shear angle, MIU - Coefficient of friction, MMD - Deviation in the coefficient of friction, and SMD - Geometrical roughness.

is not significant (p=0.8583) between USDYF and SDYF fabrics in weft way direction. There is no consistent trend noticed due to different noil %, both in warp and weft directions.

3.2.3 Bending Properties

Bending properties of fabrics are given in Table 4. Bending rigidity (B) is the resistance of fabric to bend. It depends on the bending rigidity of the yarns and the mobility of yarns within the fabric. Higher bending rigidity (B) indicates that the fabric is stiff and possesses a lower drape. Bending hysteresis (2HB) is a measure of fabric's ability to recover from bending.

Bending rigidity is less for SDYF and the difference is significant (p=0.0031) in warp direction but is not significant (p=0.1674) in weft direction. Change in comber noil level does not show trend both in warp and weft directions. It can be seen that bending hysteresis (2HB) is less for SDYF and the difference with USDYF is significant in warp (p=0.00075) as well as weft direction (p=0.007193). Change in comber noil level does not have trend both in warp and weft directions.

It is inferred from these results that the singeing process decreases the bending rigidity (B) and bending moment (2HB) of the fabrics which makes the fabric more pliable and drapeable when produced from singed dyed yarn as compared to that of fabrics produced from unsinged dyed yarns.

3.2.4 Shear Properties

The shear properties of fabrics are given in Table 5. Shear modulus or modulus of rigidity (G) is defined as the ratio of shear stress to shear strain. Shear rigidity (G) of a fabric depends mainly on the mobility of warp and weft yarns within the fabric. The mobility depends on the type of weave, yarn diameter and surface properties of yarn. The lower value of G is preferred for better handle of the fabric.

USDYF fabric possesses higher shear rigidity than SDYF fabric and the difference is significant both in warp-way (p=5.984E-06) and weft-way (p=2.73016E-05) directions. This is due to the hindrance in the movement of interlaced yarns by the hairy fibres which are projecting on unsinged yarn surface in the course of shearing of the fabric. The removal of hairy fibres by singeing of yarn makes the yarn slippery which reduces the shear rigidity of fabric. There is no consistent trend noticed due to changes in comber noil level both in warp and weft directions.

It is observed from Table 5 that the singeing process decreases both 2HG and 2HG5 values of the fabrics. In the case of hysteresis of shear force at 0.5^o shear angle (2HG), there is a significant difference between USDYF and SDYF fabrics both in warp-way (p=0.01276) and weft-way (p=0.00325) directions. No trend is observed due to comber noil levels in both warp and weft directions. 2HG and 2HG5 represent the inelastic components of the properties. The higher the values of 2HG and 2HG5, the lesser will be the recovery from shear deformation and this will create problems in tailoring and form wrinkles during usage of fabric. In the case of hysteresis of shear force at 5^o shear angle (2HG5), a similar trend is found as in the case of 2HG. The level of significance in warp direction is p=9.3E-05 and weft direction is p=0.00015 and no trend exists due to comber noil levels in both directions.

3.2.5 Surface Properties

The friction and roughness properties of fabrics are given in Table 5. Frictional characteristics of woven fabric determine the smoothness of the fabric. Protruding fibres on the fabric surface have an effect on the fabric surface's smoothness and frictional properties. The geometrical roughness is a measure of the variation of fabric thickness around the central point[9]. Fabric roughness depends on yarn spacing, irregularity, weave design and other fabric geometrical factors. An increase in geometrical roughness (SMD) reflects an increase in the surface variation of a fabric.

In the case of geometrical roughness (SMD), the difference is not significant between USDYF and SDYF fabrics both in warp (p=0.1176) and weft (p=0.1401) directions. This indicates that singeing of yarn has not altered the fabric thickness. The difference due to different comber noil levels does not follow any trend both in the warp and weft directions. In the case of coefficient of friction (MIU), there is no significant difference between USDYF and SDYF fabrics in warp direction (p=0.2535). But, in weft direction, SDYF possesses higher MIU values and a difference (p=0.0204) between SDYF and USDYF exists.

This is due to the difference in warp and weft thread densities, viz. 88 ends per inch and 70 picks per inch, which is in line with the findings of other researchers[10]. They observed that the fabric surface roughness is significantly affected by the fabric warp and weft yarn densities. At low yarn density, the loose structure of the weave causes the surface roughness to gradually increase, and the increase in weft setting causes a decrease in fabric friction.

The increase in fabric sett decreases the projection of yarn knuckles above the plane of the fabric surface (crown height)[11]. This results in a more regular, compact, and smoother fabric surface. A large area of contact between fabric and abradent would permit better distribution of abrasive stresses, thus decreasing the localized load at any one fibre point[12]. This would lessen frictional wear, surface cutting, fibre plucking, slippage and tensile fatigue. No trend is noticed due to a change in comber noil in both directions.

Table 6 — Primary and total hand values of fabrics

Fabric code	Koshi (Stiffness)	Numeri (Smoothness)	Fukurami (Fullness & softness)	THV KN-203-LDY
USDYF1	6.71	4.87	6.06	3.02
USDYF2	6.85	4.22	5.50	2.72
USDYF3	6.89	4.54	5.76	2.80
SDYF1	6.38	4.56	5.63	3.01
SDYF2	6.33	4.79	6.02	3.14
SDYF3	6.27	4.90	6.03	3.18

3.2.6 Primary and Total Hand Values

Table 6 shows the primary and total hand values of fabrics. The primary hand values, such as Koshi, Numeri, and Fukurami of the fabrics are estimated and the total hand value (THV) for KN-203-LDY is calculated from primary hand values. The total hand value provides the information as per the standard rating scale: THV5-Excellent, THV4-Good, THV3-Average, THV2- Below average, THV1-Poor and THV0-Out of use.

The SDYF fabrics possess a higher total hand value than that of the USDYF fabrics. It shows that the total hand value increases due to singeing of the yarn. Total hand value of USDYF and SDYF fabrics of about three is graded as an average handle. THV of the fabrics does not show any trend due to different comber noil levels. It can be inferred that the removal of higher noils at comber does not affect the handle of fabric, though less imperfections could be found at ring yarn stage. However, the effect is appreciable due to singeing of the yarn.

4 Conclusion

The fabrics are produced from dyed yarns, which, in turn, are produced from singed and unsinged yarns. The pilling resistance, drape, and low-stress mechanical properties of fabrics have been measured. The effect of removal of different levels of comber noil while preparing yarn, singeing and dyeing of yarn on quality of fabric has been analysed. The following conclusions are drawn from the results:

4.1 Singeing of yarn increases the pilling grade of fabrics. Amount of comber noil extracted does not show significant influence on pilling.

4.2 Singeing process decreases the bending rigidity (B) and bending moment (2HB) of the fabrics, which makes the fabric more pliable and drapeable. Change in comber noil level does not have trend both in warp and weft directions.

4.3 Compressional properties of fabrics are not much influenced by singeing of yarn.

4.4 The fabric produced from unsinged dyed yarn possesses higher shear rigidity than that of the fabric produced from singed dyed yarn.

4.5 The fabrics produced from singed yarn show a higher THV than that of the fabrics produced from unsinged yarns. There is no trend seen on THV due to different comber noil levels.

4.6 It is concluded that the removal of more amount of comber noil to produce yarn with lesser imperfections at ring cop yarn stage does not necessarily result in the fabric with better pilling resistance and handle, whereas the effect is significant due to singeing of yarn.

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