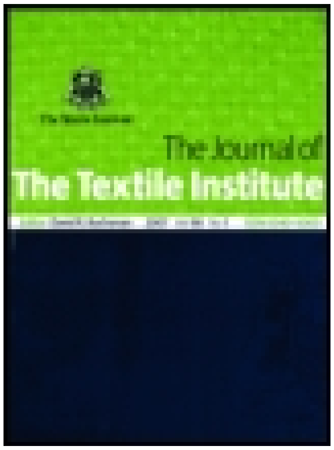

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Low-stress mechanical properties of pashmina shawls prepared from pure hand spun, machine spun and pashmina-wool blend yarn

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Low-stress mechanical properties of pashmina shawls prepared from pure hand spun, machine spun and pashmina-wool blend yarn

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The low-stress mechanical properties of the shawl made up of pashmina hand spun, machine spun and pashmina-wool blend yarns are determined by fabric assurance by simple testing system. The compression, extension and bending properties of shawls made by pashmina hand spun and machine spun yarns are comparable. However, the dimensional properties of pashmina hand spun shawl are superior to other two groups. A significant difference is observed between pure pashmina and pashmina blend shawls for majority of the low-stress mechanical properties. The thickness, weight, bending rigidity and hygral expansion in weft direction significantly differ among the three groups and they are influenced by a fibre mix as well as by the yarn-manufacturing method. It is attempted to define the control limits of different low-stress mechanical properties for different pashmina shawl qualities which may differentiate pure pashmina shawls from the others.

Keywords: pashmina; hand spun shawl; machine spun shawl; low stress mechanical properties; control limits

Introduction

Pashmina refers to a type of fine cashmere wool and the textiles made from it (Franck, 2001). The name comes from *Pashmineh*, made from Persian *pashm* (wool) and also referred as changthangi or pashmina goat. It is a down fibre or undercoat derived from domestic goat *Capra hircus* which is native to Asia and found in high altitudes of the Himalayas in Nepal, Pakistan and northern India (Yaqoob, Sofi, Wani, Sheikh, & Bumla, 2012). To survive in the freezing environment at high altitude, it grows a unique and incredibly soft pashm (inner coat) which is six times finer than human hair (Franck, 2001). The average pashmina fibre diameter ranges from 9 to 20 µm. It is non-medullated and lacks in crimp. On an equal weight basis, it has three times better insulating capacity than that of wool but because of its ultrafine structure it is weaker than wool and more susceptible to wetting (Bumla et al., 2012).

Pashmina is the most luxurious fibre and fetch higher price among all natural fibres. The cost-governing factors are fineness, softness, pureness, warmth, long life and no pile formation (Yaqoob et al., 2012). India produces the best quality of pashmina with an annual production of about 40 tonnes harvested from nearly two lakh goats (Ganai, Misra, & Sheikh, 2011; Shakyawar, Raja, Ajay, Pareek, & Wani, 2013). Pashmina has huge demand in international market and it is the prime source for the world-class shawl industry in Kashmir. Shawls are hand spun, woven and embroidered in the Kashmir itself. The traditional methods of processing, involving dusting, dehairing, combing and spinning have given them a special importance all over the world (Yaqoob et al., 2012). The hand spinning may be done on traditional charkha (Yander) or innovative pedal-operated charkha (Wani et al., 2013). Introduction of machines at different levels of processing (dehairing, spinning, weaving, etc.) reduces laborious work and consumes less time in product development. Efforts have been made by industries to spun 100% pashmina machine spun yarn by mixing with nylon fibre (Raja, Shakyawar, Pareek, & Wani, 2011). The nylon component is then dissolved by treating with commercial grade hydrochloric acid either after spinning or after manufacturing of shawl. However, there may be a compromise with the quality parameters (Bumla et al., 2012). Thus, the need of a time is to differentiate the quality of shawls made of hand-spun yarns from machine-spun yarns. The blending of Pashmina with Merino wool and rabbit hair is economical and viable alternative. In the absence of quality standards for pure pashmina shawl, low-cost blended shawl is being exploited by unscrupulous traders causing big loss to the pashmina industry. There is an urgent need to develop quality standards that differentiate pure pashmina and blended shawls.

It is difficult to evaluate light-weight clothing like pashmina and requires special handling skills make-up

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during processing. Fabric assurance by simple testing (FAST) is as useful set of instruments for light-weight fabrics (Ly & De Boos, 1990). FAST is a set of instruments and test methods for measuring mechanical and dimensional properties of wool fabrics at low stress. These measurements allow the prediction of fabric performance and the appearance during wear (Ly et al., 1988). FAST is robust and simple to use whereas KES-F test system is costly, complex and difficult to interpret (Ly et al., 1991). However, the results obtained from KES-F and FAST are comparable and there is very good correlation coefficient (more than 0.9) (Ly et al., 1991; Naujokaityte, Strazdiene, & Domskiene, 2008; Yick, Cheng, Dhingra, & How 1996).

The low-stress mechanical properties of various pashmina shawls evaluated by FAST are reported in the present paper. The shawls prepared with different existing techniques and classified into three different groups i.e. shawls made by hand spun, machine spun and pashmina-wool blend yarns. Comparative analysis done and quality control limits for each manufacturing technique prepared. It is also attempted to validate the control limits for pashmina shawl made from different techniques.

Experimental

Pashmina shawls were prepared using various pashmina yarn manufacturing techniques and categorized into three different groups, namely hand spun (PHS), machine spun (PMS) and pashmina-wool and pashmina-rabbit hair blend (PBS). Eight pashmina shawls were prepared in each group. In case of hand-spun shawl, pashmina yarn was produced on traditional charkha and shawl was manufactured on hand loom. Pashmina machine-spun yarn was produced using a carrier-spinning technique using fibres like nylon/PVA. The yarn was then used to produce shawl. The carrier fibres were then removed from the shawl by subjecting it to acid or hot-water treatment (Raja et al., 2011). In the third group, pashmina was blended with wool, rabbit hair and silk/silk filament hair to make the processing easier and also to reduce cost of manufacturing. The yarn count (Nm), ends/inch, picks/inch and weight of fabric in g/m^2 were determined for each group.

The low-stress mechanical properties were evaluated on *siro*-FAST set of instrument. Compression, tensile and bending properties were measured on FAST-1, FAST-2 and FAST-3 instrument, respectively. In compression, thickness was measured at 2 g/cm² load (T2) and 100 g/cm² (T100), and the difference was expressed in terms of surface thickness (ST). All these measures durability of the surface layer (Taieb, Msahil, & Sakli, 2010). Similarly, thickness recovery after the steam press was also determined at same loads, i.e. 2 g/cm² load (T2-R) and 100 g/cm² (T100-R). The relative difference between thickness recoveries at two different loads is expressed as surface thickness recovery (STR). The warp and weft extensibility of a fabric was measured under three different loads (5, 20 and 100 g/cm width). The bias extensibility (at 45° to the warp direction) of the fabric was measured under a low load of 5 g/cm width. The bending properties measured were bending length in mm (warp way – C1 and weft way – C2), bending rigidity in μN m (warp way – B1 and weft way B2), shear rigidity (G) in N/m.

The dimensional properties, relaxation shrinkage (RS) and hygral expansion (HE), were measured, both warp and weft way using a formula according to Sirofast-4 test procedure. With SiroFAST-4, the fabric is dried in a convection oven at 105 °C and its dry dimensions measured (L1). The fabric is then relaxed by wetting water and its wet dimensions measured (L2). Lastly, the fabric is dried against 105 °C and its final dry dimensions are measured (L3) (De Boos & Tester, 1994).

$$\mathrm{RS}\% = ((L1 - L3)/L1) \times 100$$

$$\mathrm{HE}\% = ((L2 - L3)/L3) \times 100$$

Statistical ANOVA analysis was carried out using SPSS software to test the significance among the different manufacturing techniques of pashmina shawls, control limits were worked out based upon the standard error of the mean, using two and three times of standard error as the inner (warning) and outer (action) limits, respectively.

Results and discussion

Yarn and fabric parameters

The PMS yarn obtained is finer as compared to that of PHS and PBS yarn (Table 1). It is attributed to throughout positive control on fibres and higher draft during machine spinning. Pashmina fibres prone to abrasion and causes end breaks during weaving hence, warp density was kept less. It leads to increase the weft density as higher inter space was available. There is a significant difference found in the weight of PHS, PMS and PBS shawls ($p < 0.01$). In case of PMS shawl, the chemical treatment which is used to remove carrier fibre reduces its weight considerably. While in case of PBS, relatively coarse nature of the wool and rabbit hair than pure pashmina resulted into heavy yarn and thus high mass per unit area of the fabric in comparison to pure pashmina shawls.

Compression properties

The compression properties, viz. thickness (T), ST and STR of the PHS, PMS and PBS are shown in Figure 1. The thickness of PBS is significantly higher ($p < 0.01$)

Table 1. Yarn and fabric parameters of Pashmina shawls.

	Yarn count (Nm)	Ends (inch)	Picks (inch)	Weight (g/m^2)
Hand spun	2/70	42	64	97.50
Machine Spun	2/90	50	44	58.60
Pashmina blends	2/55	42	68	130.65

than PHS and PMS shawls, whereas the STR of PBS is significant at 5% significance level as compared to PHS and PMS (Table 2). It is attributed to coarser and voluminous nature of pashmina-blended yarns. The blending of wool and rabbit hair with pashmina make it rough and increases the interspaces between fibre and yarn. The high interspace between fibres and yarns increases fabric thickness and compressibility (Goud, 2012).

It is reported that increase in the ST (less than 0.1 mm) can be perceived subjectively in fabric handle. For very thin and light-weight fabrics, a smaller increase in ST could produce a perceptible change in handle (Ly et al., 1991). However, difference in ST is found non-significant ($p > 0.05$) for all groups of the shawl (Table 2). It may be due to very light weight and delicate nature of pashmina shawls as compared to contemporary light-weight wool fabrics.

Extension properties

Spinning technique, fibre type and blending of synthetic fibres with wool have small, medium and large effects, respectively, on the warp extensibility of formal wear fabrics (Mori, 1983). The extensibility of various pashmina shawls is shown in Figure 2. It reveals that there is no significant difference ($p > 0.05$) in the warp and weft extensibility at the load of 100 g/cm^2 (Table 2), among all three groups. It may be concluded that the pashmina fabric manufacturing technique does not have any effect on fabric extensibility. The higher values of

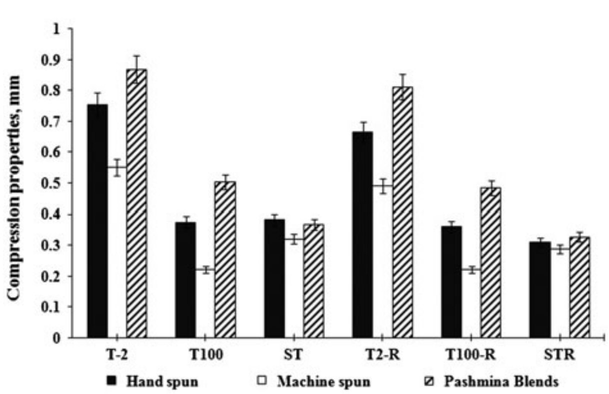

Figure 1. Compression properties of pashmina shawls.

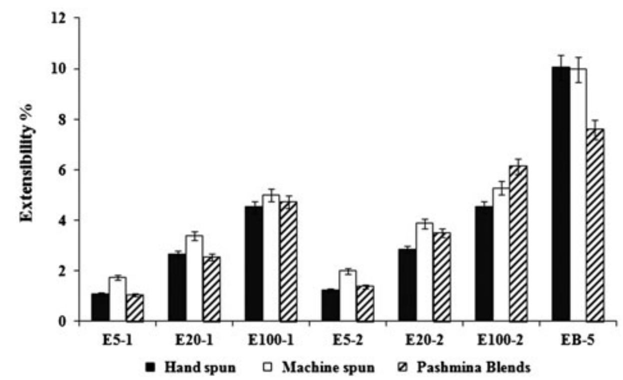

Figure 2. Extensibility of shawls in warp, weft and bias direction at different loads.

warp extensibility in PBS is attributed to the low cover factor of the fabric which is due to removal of carrier fibres after fabric manufacturing. In another study, it is reported that the highest formability is obtained for the fabric with lowest thickness and the lowest formability is obtained with the highest mass per unit area (Taieb et al., 2010). The lower thickness and mass per unit of PBS may be indirectly correlated with the extensibility results since the formability is governed by bending rigidity and fabric extension.

Bending properties

Bending length is related to the ability of a fabric to drape and bending rigidity is associated with stiffness when the fabric is touched or handled (Taieb et al., 2010). The bending rigidities of PHS and PMS shawls are significantly lower than PBS ($p < 0.01$) (Figure 3). It is attributed to coarser fibres used in pashmina blends. They have a relatively higher density than the pure pashmina. The higher thickness and mass per unit area in pashmina blends resulted in high bending stiffness. It is in agreement with previous study reported by Taieb et al. (2010).

Shear rigidity is characterized by the ability of a two dimensional piece of fabric to deform into a three dimensional shape (Kilby, 1963). It is found non-significant among all groups of shawl (Figure 3). It means the manufacturing techniques do not have any influence on shear rigidity property. Similarly, the

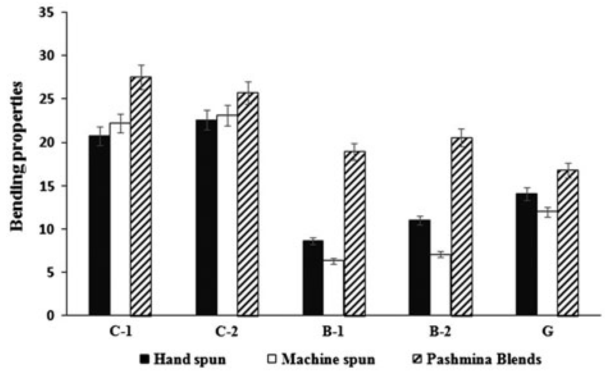

Figure 3. Bending properties of pashmina shawls.

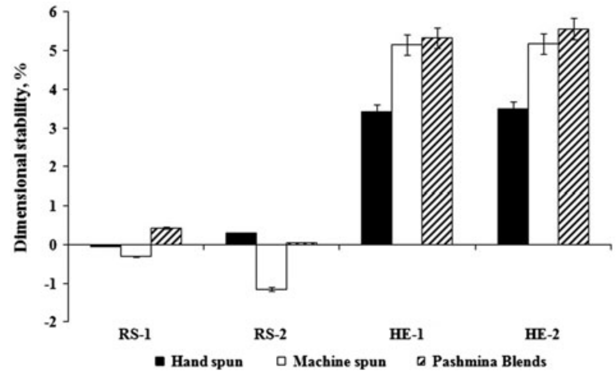

Figure 4. Dimensional properties of pashmina shawls.

bending length in weft direction has non-significant difference among the groups. On the other hand, the bending length in the warp direction of PBS is significantly higher at 5% level (Table 2). The bending rigidity of PBS in the warp and weft direction is highly significant ($p < 0.01$) over PHS and PMS. It is attributed to higher stress on the warp during weaving of PBS as compared to pure pashmina shawls and higher weft density in PBS, respectively. It is in agreement with previously reported studies that bending rigidities of the fabrics in the warp directions increased as warp tension increased and higher fabric bending rigidities with higher weft densities and thicker weft yarns (Süle, 2012).

Dimensional stability

The dimensional stability of wool fabrics is governed by RS and HE. The RS is caused by the recovery of fibres strained during manufacturing (Ly et al., 1991). It is the irreversible change in dimensions that occurs when a fabric is relaxed in steam or water (Shaw, 1978). The results for dimensional stability are shown in Figure 4. The PHS is found dimensionally more stable as compared to PMS and PBS. It is attributed to lower stress on fibres during hand spinning and finer yarn linear density.

The higher warp shrinkage of PBS, compared to the other two groups (Figure 4), is attributed to coarse count of blend yarn in comparison to pure pashmina. The residual shrinkage in both warp and weft directions is statistically different at the 5% significance level (Table 2). However, no significant difference in shrinkage was found in shawls made by hand- and machine-spun yarns in the earlier reported study (Bumla et al., 2012). The higher weft yarn RS of PHS than the other two groups is attributed to the relatively lower warp density in the fabric. The lower warp density ensures minimum abrasion and stress during weaving, thus minimum end breaks occur in delicate and smooth pashmina yarn. The shrinkage values of pure pashmina shawls are lower as compared to blended shawl. It is due to the absence of felting characteristics in pashmina, unlike wool fibre.

Although RS and HE would appear to be fundamentally quite different, they are closely related to each other (Cookson, 1992). The HE or contraction is caused by the swelling or de-swelling of hygroscopic fibres (Ly et al., 1991) and it is the reversible change in fabric dimensions. The difference in HE in warp direction is highly significant ($p < 0.01$) while weft way HE is significant at 5% significance level (Table 2). The lower HE of the PHS shawl in comparison to PMS and PBS shawl is mainly because of its stable structure.

The quality of hand-spun pashmina shawl is significantly better than machine-spun shawl. Long life of shawls attributed to less damage caused to the

Table 2. ANOVA test results for pashmina hand spun, machine spun and blend shawl.

	Sum of squares*	*F*	Significance
T2	0.72	24.74	0.00
ST	0.10	2.68	0.09
STR	0.13	4.67	0.02
E 1001	62.79	0.31	0.733
E 1002	96.83	0.28	0.763
B (warp way)	1553.03	62.84	0
B (weft way)	1106.00	9.46	0.00
G	1480.65	0.62	0.55
W	61980.26	8.72	0.00
RS (warp way)	19.64	3.90	0.036
RS (weft way)	34.03	3.76	0.04
HE (warp way)	46.63	8.41	0.002
HE (weft way)	75.49	4.39	0.026
F (warp way)	23.15	5.80	0.01
F (weft way)	42.35	2.05	0.153

Note: *The total sum of squares is addition of sum of squares between and within groups for 2 and 21 degree of freedom, respectively.

delicate fibres during traditional processes which do not involve the harsh chemical and mechanical treatments unlike machine-made shawls (Bumla et al., 2012; Yaqoob et al., 2012).

The FAST system measures the mechanical, dimensional and pressing performance of fabrics which are critical to the assessment of not only fabric tailorability, appearance and handle properties, but also stability and durability of a finishing process (Fan & Hunter, 2009; Ly et al., 1991). The instrument provides a chart which defines tailorability of the fabric. The gray zone of the chart indicates potential problems that can be anticipated during garment manufacture and hence useful for garments. However, as such the chart may not be applicable for pashmina shawls. Therefore, warning and action limits based on standard error of mean are prepared for three different kinds of pashmina shawls (Table 3). The control charts may be drawn from the values obtained. Control chart is a convenient method of presenting test results into a readily digested form (Booth, 1968).

The quality of shawls can be determined from the limit values presented in Table 3. The value of any property within the range of warning limits indicates acceptable quality whereas, the value in between warning and action limits considered as reasonably acceptable quality. In case, the value beyond the action limits, the purity of pashmina and its blend, if any, need to be checked. These charts could be used as an effective tool to set the standard norms for pashmina shawls. They could also be helpful in classifying the shawl into different categories viz. hand spun, machine spun and blended shawl. These shawls may be marked for marketing purpose on the basis of the classification. The marking system of the shawl can facilitate the customer to select their choice and ensure about the quality and purity of pashmina.

In order to confirm and validate defined control limits, a separate set of pashmina shawls was prepared and evaluated by FAST system. The results were compared with the defined limits. Pearson's correlation coefficient of 0.97, 0.94 and 0.87 was observed in PHS, PMS and PBS shawl, respectively (Figure 5(a)–(c)). The good correlation between the standard norm and sample values indicates the reliability of the norms developed.

Table 3. Control limits of pashmina shawls prepared from different techniques based on standard error.

	PHS			PMS			PBS		
	Mean	Warning limit	Action limit	Mean	Warning limit	Action limit	Mean	Warning limit	Action limit
T-2	0.76	±0.05	±0.07	0.55	±0.05	±0.08	0.91	±0.10	±0.16
T-100	0.37	±0.02	±0.03	0.22	±0.02	±0.04	0.51	±0.08	±0.13
ST	0.38	±0.03	±0.05	0.33	±0.05	±0.08	0.39	±0.04	±0.07
T2R	0.67	±0.03	±0.05	0.5	±0.04	±0.06	0.89	±0.03	±0.05
T100R	0.36	±0.02	±0.02	0.22	±0.02	±0.03	0.51	±0.07	±0.11
STR	0.31	±0.02	±0.03	0.29	±0.05	±0.08	0.38	±0.06	±0.09
E5-1	1.1	±0.42	±0.67	1.75	±0.60	±0.95	0.70	±0.23	±0.36
E20-1	2.67	±0.88	±1.39	3.4	±1.00	±1.58	2.07	±0.52	±0.82
E100-1	4.53	±1.26	±1.99	5	±1.24	±1.96	4.35	±1.02	±1.61
E5-2	1.24	±0.48	±0.75	1.99	±0.54	±0.85	1.11	±0.60	±0.94
E20-2	2.86	±1.00	±1.58	3.87	±1.06	±1.67	2.81	±1.06	±1.66
E100-2	4.52	±1.21	±1.91	5.28	±1.74	±2.74	5.09	±1.41	±2.22
EB-5	10.05	±2.78	±4.38	9.99	±3.24	±5.10	5.20	±2.78	±4.38
C1	20.75	±0.84	±1.32	22.23	±1.25	±1.98	28.88	±4.93	±7.77
C2	22.61	±0.79	±1.25	23.11	±0.80	±1.26	23.52	±1.17	±1.85
B-1	8.66	±1.43	±2.25	6.33	±0.94	±1.49	23.16	±3.51	±5.53
B-2	11.04	±0.90	±1.41	7.07	±1.06	±1.67	18.35	±6.16	±9.72
G	14.09	±3.71	±5.86	12.41	±2.65	±4.18	16.90	±8.66	±13.66
W	97.5	±5.51	±8.68	58.6	±4.52	±7.13	142.38	±47.67	±75.15
RS-1	0.05	±0.62	±0.98	−0.30	±0.60	±0.94	0.80	±0.49	±0.77
RS-2	0.3	±0.59	±0.93	−1.15	±0.99	±1.56	−0.10	±0.62	±0.98
HE-1	3.43	±0.54	±0.85	5.15	±1.18	±1.87	5.58	±0.30	±0.47
HE-2	3.5	±1.08	±1.71	5.18	±1.33	±2.10	5.78	±0.83	±1.31
F-1	0.5	±0.37	±0.58	0.7	±0.17	±0.27	2.01	±0.99	±1.56
F-2	0.91	±0.67	±1.06	0.9	±0.36	±0.56	2.17	±1.45	±2.29

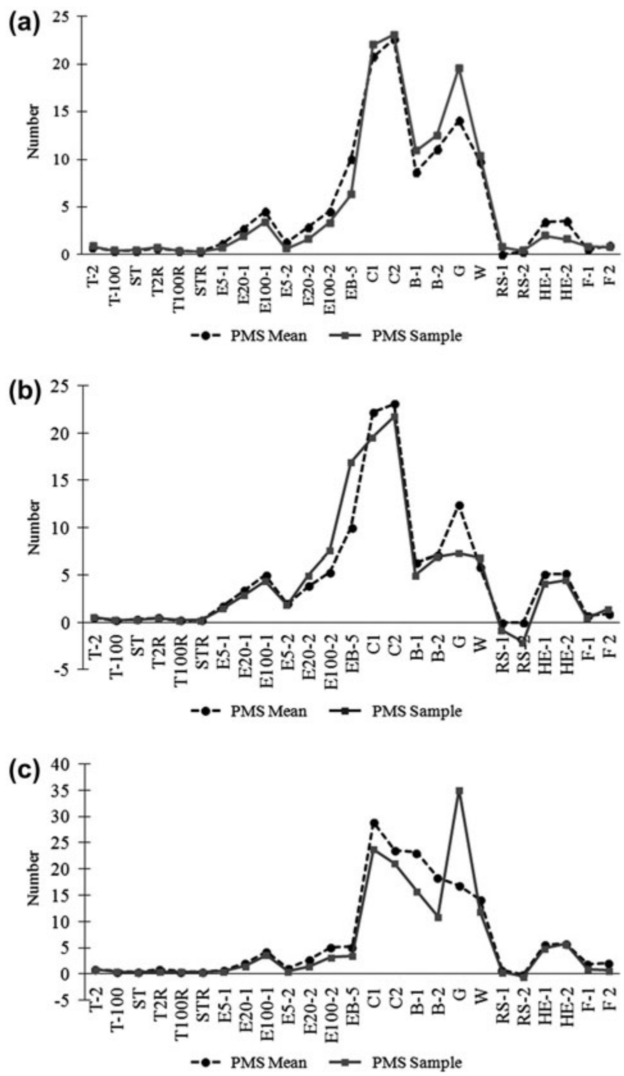

Figure 5. Co-relation between defined control limits and sample pashmina shawls for (a) pashmina hand spun, (b) pashmina machine spun and (c) pashmina blend shawls.

Conclusion

The hand-spun shawl is found dimensionally stable and superior in quality as compared to machine-spun and blended shawls. However, the compression, extension and bending properties of hand-spun shawl are comparable with machine-spun shawls. The pashmina-wool-blend shawl significantly differs from pure pashmina shawls in majority of the low-stress properties. The pashmina shawl manufacturing technique has significant influence on the properties like thickness, warp and weft bending rigidity, warp way HE and weight whereas the extension and shear rigidity are least affected. The change in low-stress properties of different qualities of shawl may be utilized to define control limits and thus the type of shawl. The control limits may help to set standard norms for pure pashmina shawls.

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