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Low Stress Mechanical Properties & Total Hand Values of Silk Acrylic Knitted Fabrics

Abstract

Fabric hand has become indispensable property of fabric. It indicates that whether customer will prefer to purchase the fabric or not. This paper reports comparison of low stress mechanical properties (tensile, bending, shear, surface and compression properties) and Total hand Value of 100% silk, 100% acrylic, silk/ acrylic 50/50 blended knitted fabric to very common cotton knitted fabric of similar construction. It was found that comparatively lower values of elongation are observed for 100% acrylic and acrylic-silk 50/50 blend (A5S5) in comparison to 100% silk and cotton fabric. This is due to higher value of yarn diameter resulting in more area of contact within the threads and more resistance during tensile elongation resulting in lower value of EM in case of acrylic and A5S5 fabric. Slightly higher values of linearity of load-extension curve (LT) are observed in case of acrylic and A5S5 fabric. This is also due to more resistance offered by these yarns due to greater diameter. Mean bending stiffness (B) of acrylic fabric is maximum followed by A5S5, silk and cotton fabric. This is due to the fact that thickness of acrylic and A5S5 fabric is greater than silk and cotton fabric. Shear stiffness (G) is maximum for A5S5 fabric followed by acrylic, silk and cotton. Lower values of coefficient of friction (MIU) are observed for silk and acrylic-silk 50/50 blend. It indicates smoother surface of these fabrics. Linearity of compression (LC) for acrylic and A5S5 fabric is higher than silk and cotton fabric. This is due to higher resistance offered during shear deformation due to bulky nature of these fabrics. Koshi value (bending stiffness) is maximum in case of A5S5 fabric. Higher value of Numeri (smoothness) is observed for silk fabric in comparison to other fabrics. It indicates smoother nature of silk knitted fabrics. Fukurami values of acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics are better than cotton fabric. Total hand value of the acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics is better than cotton fabric. These results indicate that acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics are better than cotton fabric and customers may prefer to purchase acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics.

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Keywords: Silk Acrylic Blend, Knitted Fabrics, Low Stress Mechanical Properties, Kawabata Evaluation.

Introduction

Comfort is a complex term. Clothing comfort can be divided into three parts – Pschycological, tactile and thermal. Pshycological comfort is not related to fabric properties but is related to fashion, fit etc. Tactile comfort is related to hand value of the fabric. Customer is checking the hand value of the fabric with his own fingers and takes decision. Fabric Hand Value is very important these days for the fabrics intended for apparel use. It indicates that the customer will prefer to purchase the fabric or not. This is very important term for fabric manufacturers, product development and production planning. This term is directly related to fabric sale. Hence fabric hand is considered in the field of fabric selection, garment designing and merchandisers. Fabric hand is an important property of the fabric and helps the customer in selection of the fabric. It gives guideline for new product development to the manufacturer and gives a chance to study choice of the consumer.

Customer decides the selection of the fabric by touching. It is an objective measurement and many low stress mechanical tests are performed by the customer with the help of fingers. Tensile, bending, shear, compression and surface smoothness are estimated. After touching and sensing the customer takes the decision to purchase the fabric. The yarn parameters, yarn structure, fabric parameters, weave, type of finish affect the fabric hand value.

The same tests are done on Kawabata set of instruments (Tensile, bending, shear, compression and surface smoothness) and fabric hand value is calculated. This value helps in predicting that consumer will purchase this fabric or not.

Whenever yarn parameters, fabric parameters are changed, a new fibre is used or blend ratio is changed or new finish is applied then it becomes necessary to check fabric hand value so that an estimation can be done that customer will prefer that fabric or not,

Fabric low stress mechanical properties are most important if tactile comfort is considered. In case of new kind of knitted fabric 100% silk, it is necessary to find out hand value of this new fabric. In the present study, Kawabata evaluation system has been used to find out low stress mechanical properties of acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics. For comparison purpose cotton fabric of same construction was also manufactured so that low stress mechanical properties can be compared with very common and popular cotton knitted fabric.

Review of Literature

Lot of work has been done in the field of fabric hand values. References are available for estimation of hand value for woven fabrics, warp knitted fabrics and weft knitted fabrics on Kawabata set of instruments. Some researchers have tried to develop new alternative methods for calculating hand value of the fabrics also. Some researchers have tried new finishes on the cloth and found Total Hand Value of the fabric with new finish. Ni Xiaoyan et al[1] have studied effect of immobilized cellulase enzyme treatment on properties of ramie fabric. Low stress mechanical properties evaluated by Kawabata Evaluation System indicate that immobilized cellulase enzyme treatment improves the softness, flexibility and elastic recovery of the ramie fabrics. Stankovic S.B.[2] has studied effect of yarn folding on comfort properties of Hemp knitted fabrics. This study focused on the effect of yarn folding on both thermal and tactile comfort of plain knitted fabric. In addition to structural characteristics of the yarn and knitted fabrics, the transport properties, deformation behavior and surface properties of the knitted fabrics were investigated. Das A. et al[3] have tried to predict fabric hand characteristics using extraction principle. In this paper, prediction of fabric handle characteristics using extraction principle has been studied. An instrument for objective measurement of the fabric handle characteristics has been developed using nozzle extraction method. This instrument measures the force exerted on the periphery of the nozzle by the fabric being drawn out of the nozzle on the periphery of the nozzle. This force, called the radial force, is a measure of the certain low stress mechanical characteristics of the fabric that determine handle. Shyr T.W.[4] has taken new approaches to establishing Translation equations for the Total Hand Value of fabric. The aim of the study is to take new approaches using a one step transformation process to establish translation equations for total hand evaluations of fabrics by employing a stepwise regression method and an artificial neural network. Radhalakshmi Y.C.[5] has studied suitability of modified method for evaluating low- stress mechanical properties of silk fabrics. Modifications have been made to the simple conventional method of determining low- stress mechanical properties of fabrics to make it applicable for finished silk fabrics. The bending rigidity of the fabric has been obtained from tensile stress- strain curves and shear rigidity by bias extension. The correlation between the parameters obtained by modified method and that obtained by Kawabata evaluation test method is found to be good for a series of finished silk fabrics. Gong R.H.[6] has investigated quality measurement of knitted apparel fabrics. In this study the possibility of objective measurement and controlling the quality of knitted garments during finishing has been studied. The association of the hand of knitted garments with KES-FB parameters is discussed, along with the requirements for an objective testing technique suitable for routine quality control in the finishing factory.

Many researchers have studied comfort properties of woven fabrics. Nayak R.K. et al[7] has studied comfort properties of suiting fabrics. The effects of polyester content, pick density and weave on the thermal comfort and tactile properties of polyester/ viscose blended yarn fabrics have been studied by measuring the low stress mechanical properties on Kawabata evaluation system. Behera B.K.[8] has studied comfort properties of non- conventional light weight worsted suiting fabrics. Mechanical and thermal comfort aspects of fabrics produced from some non- conventional blends and lightweight constructions have been examined. Among various natural fibre based worsted suiting fabrics, the linen blend proves to be most suitable with respect to mechanical comfort. Wool and wool:silk blend provide very good transmission properties. Natarajan V.[9] has studied low stress mechanical properties of polyester/ cotton suiting fabrics. The effects of different stages of finishing such as scouring, mercerization, heat setting, polyester dyeing, cotton dyeing and finishing on low stress mechanical properties of polyester cotton suiting fabrics have been studied. Behera B.K.[10] has made an attempt to review the work done so far in understanding the influence of wool fibre, yarn and fabric structure and their properties on low stress mechanical properties and hand value of fabric. Gulrajani M.L.[11] has analysed Kawabata evaluation of enzyme treated cotton knitted fabric. Industrial trail of enzymatic treatment of cotton knitted fabric with cellulase enzyme Denifade has been carried out under optimized conditions and the various low stress mechanical properties of the treated fabrics have been assessed in the Kawabata system.

In the previous study, Kumar R.[12], the effect of steaming on acrylic/ silk blended yarn was studied. It was found that after steaming the increase in yarn diameter is maximum for acrylic- silk 50/50 blend.

Aim of the Study

The aim of the study is

1. To evaluate the low stress mechanical properties of 100% shrinkable acrylic A10, acrylic/ silk 50/50 blend, 100% silk S10 and 100% cotton single jersey weft knitted fabrics.
2. To compare tensile, bending, shear, surface and compression properties of 100% shrinkable acrylic A10, acrylic/ silk 50/50 blend, 100% silk S10 and 100% cotton single jersey weft knitted fabrics on Kawabata set of instruments.
3. To compare Koshi, Numeri and Fukurami values of 100% shrinkable acrylic A10, acrylic/ silk 50/50 blend, 100% silk S10 and 100% cotton single jersey weft knitted fabrics.
4. To compare Total Hand value (THV) of 100% shrinkable acrylic A10, acrylic/ silk 50/50 blend, 100% silk S10 and 100% cotton single jersey weft knitted fabrics.

Material and Methods

Acrylic-silk yarns in following blend proportions such as 100% shrinkable acrylic A10, acrylic/ silk 50/50 blend, 100% silk S10 were prepared. The process parameters were chosen in such a way that after steaming the hanks of the yarn should be of 30^s N_e and Twist multiplier 2.7 (T.p.i 14.8). For comparison of acrylic-silk blended yarns and fabrics with equivalent cotton yarn and fabric, 100% cotton yarn of 30^s N_e and Twist multiplier 2.7 (T.p.i 14.8) was also prepared. All acrylic silk blended fabrics, 100% silk and 100% cotton fabrics were knitted on single jersey, 24 feeder circular knitting machine having 12 inches diameter, total numbers of needles 886 and 24 gauge. All the fabric samples were knitted at the same time one by one with same cam setting.

Fabrics knitted in tubular form were laid free from constraints for 24 hours on a flat surface to facilitate recovery from the stresses imposed during knitting. Prior to testing all the fabric samples were conditioned to moisture equilibrium and the fabrics were tested in standard atmospheric condition of 65% $\pm$ 2% RH and 27^0C $\pm$ 2^0C temperature.

The tensile and shear behavior of all fabrics were studied on a KES-FB1 (tensile, shear tester) and the bending properties were measured by using a KES-FB 2 (pure bending tester). Compression properties and fabric thickness were measured with a KES-FB 3 (compression tester) , surface roughness and friction were measured using the KES-FB 4 (surface tester).These four instruments are used to test fabrics at low stress levels simulating the day to day handling of the fabrics and garments.

Results & Discussion

Low Stress Mechanical Properties can be divided into tensile, bending, shear, surface and compression properties. Due to limited financial resources, only four samples (100% acrylic, acrylic-silk 50/50, 100% silk and cotton) were evaluated on Kawabata system. The results of low stress mechanical properties and primary hand expressions are as follows.

Tensile Properties

Table 1 shows comparatively lower values of elongation for 100% acrylic and acrylic-silk 50/50 blend (A5S5) in comparison to 100% silk and cotton fabric. This elongation represents mobility of the threads within the knitted fabric. Yarn diameter was found to be greater in case of A5S5 yarn and 100% acrylic yarn in comparison to silk and cotton yarn as observed in previous publication. Due to higher value of yarn diameter, area of contact within the threads is higher which offers more resistance during tensile elongation resulting in lower value of EM in case of acrylic and A5S5 fabric.

Table 1 Tensile Properties

Sample	Strain at 500 gf/cm of Tensile Load (EM)			Linearity of Load-Extension Curve (LT)			Tensile Energy gfcm/cm^2 (WT)			Tensile Resilience (RT) %		
	Wale	Course	Mean	Wale	Course	Mean	Wale	Course	Mean	Wale	Course	Mean
Acrylic	18.4	22.4	20.4	0.73	0.66	0.69	16.8	18.5	17.6	25.7	22.2	24.0
A5S5	15.7	28.7	22.2	0.85	0.69	0.77	16.7	24.7	20.7	39.4	45.0	42.2
Silk	21.5	33.8	27.6	0.67	0.64	0.66	18.0	27.2	22.6	23.7	41.3	32.5
Cotton	30.9	45.8	38.3	0.67	0.63	0.65	26.0	36.0	31.0	23.9	27.2	25.6

Slightly higher values of linearity of load-extension curve (LT) are observed in case of acrylic and A5S5 fabric. This may be ascribed to more resistance offered by these yarns due to greater diameter. Linearity of load-extension curve LT represents fabric extensibility in initial strain region. It depends upon slope of the load-extension curve of the fabric and resistance offered by the threads during elongation. Lower values of tensile energy (WT) are observed in case of acrylic and A5S5 fabric. Maximum value of tensile resilience (RT) is observed in case of A5S5 fabric. It implies that recovery from tensile deformation of acrylic/silk 50/50 fabric is maximum among the fabrics studied.

Bending Properties

Table 2 shows that mean bending stiffness (B) of acrylic fabric is maximum followed by A5S5, silk and cotton fabric. This is due to the fact that thickness of acrylic and A5S5 fabric is greater than silk and cotton fabric. Hence a higher value of bending stiffness is observed for acrylic and A5S5 fabric. The hysteresis of bending moment (2HB) is also maximum for acrylic fabric.

Table 2 – Bending Properties

Sample	Bending rigidity (B) $gfcm^2/cm$			Hysteresis of bending moment (2HB) gf/cm		
	Wale	Course	Mean	Wale	Course	Mean
Acrylic	0.1372	0.1122	0.1247	0.3509	0.1815	0.2662
A5S5	0.1434	0.0369	0.0902	0.3410	0.0642	0.2026
Silk	0.0693	0.0967	0.0830	0.2377	0.1697	0.2037
Cotton	0.0998	0.0214	0.0606	0.1802	0.0471	0.1137

Shear Properties

Table 3 – Shear properties

Sample	Shear stiffness (G) gfcm/deg			Hysteresis of shear force at 0.5^0 shear angle(2HG), gf/cm			Hysteresis of shear force at 5^0 shear angle(2HG5), gf/cm		
	Wale	Course	Mean	Wale	Course	Mean	Wale	Course	Mean
Acrylic	1.0070	0.9726	0.9898	5.5174	5.6840	5.6007	5.9437	6.0760	6.0099
A5S5	1.2471	1.1956	1.2214	5.8653	6.1691	6.0172	6.3014	6.6444	6.4729
Silk	0.6003	0.6934	0.6468	3.6652	4.6550	4.1601	3.9445	4.9196	4.4321
Cotton	0.6542	0.6174	0.6358	2.2589	2.2540	2.2565	2.4892	2.4255	2.4573

Table 3 shows that shear stifness (G) is maximum for A5S5 fabric followed by acrylic, silk and cotton. This may be due to more resistance offered by A5S5 fabric during shear deformation. The same trend is observed for hysteresis of shear force (at 0.5^0 angle and 5^0 angle). The hystersis is higher in case of acrylic and A5S5 fabric.

Surface Properties

From Table 4 lower values of coefficient of friction (MIU) are observed for silk and acrylic-silk 50/50 blend. It indicates smoother surface of these fabrics. Mean deviation of MIU (MMD) is also lowest for A5S5 and silk fabric. Geometrical roughness of acrylic and A5S5 fabric (SMD) is also lower than other fabrics studied.

Table 4 – Surface Properties

Sample	Coefficient of friction (MIU)			Mean deviation of MIU (MMD)			Geometrical roughness (SMD), μm		
	Wale	Course	Mean	Wale	Course	Mean	Wale	Course	Mean
Acrylic	0.2367	0.2847	0.2607	0.0200	0.0166	0.0183	4.234	5.307	4.771
A5S5	0.2352	0.2577	0.2465	0.0133	0.0183	0.0158	3.357	8.070	5.713
Silk	0.2220	0.2509	0.2364	0.0166	0.0154	0.0160	4.268	7.360	5.814
Cotton	0.3685	0.2862	0.3274	0.0155	0.0174	0.0164	4.145	7.938	6.041

Compression Properties

Table 5 – Compressional Properties

Sample	Linearity of compression (LC)	Compressional energy (WC) $gfcm/cm^2$	Compressional resilience (RC) %	Fabric thickness (T) mm	Fabric weight (W) mg/cm^2
Acrylic	0.394	0.559	54.33	1.30	14.85
A5S5	0.326	0.476	54.07	1.40	15.09
Silk	0.259	0.376	66.34	1.13	13.82
Cotton	0.291	0.466	52.75	1.31	14.32

Table 5 shows that linearity of compression (LC) for acrylic and A5S5 fabric is higher than silk and cotton fabric. This may be ascribed to higher resistance offered during shear deformation due to bulky nature of these fabrics. The same trend is also observed for compressional energy (WC). Compressional resilience (RC) is found to be highest in case of silk fabrics.

Thickness and Weight

From Table 5 thickness of A5S5 fabric is found to be maximum among all fabrics. This may be due to highest value of yarn diameter and yarn bulk observed in case of A5S5 yarn. The variation in weight/sq.m may be due to count variation.

Fabric Hand Values

Primary hand expressions for knitted outerwear fabrics of acrylic, acrylic- silk 50/50 A5S5, silk and cotton are shown in Table 6.

Table 6 Total Hand Value of Single Jersey Knitted Outerwear Fabrics

Material	Koshi (Stiffness)	Numeri (Smoothness)	Fukurami (Fullness and softness)	Total Hand Value
Acrylic	3.21	6.64	6.27	3.66
A5S5	3.57	6.31	6.04	3.58
Silk	1.56	7.37	6.22	3.47
Cotton	0.14	7.23	5.33	2.61

Table 6 shows that Koshi value (bending stiffness) is maximum in case of A5S5 fabric. This may be due to maximum bulk and thickness observed in case of A5S5 fabric. Koshi depends upon bending properties of fabric. It is a stiff feeling promoted by springiness in the fabric. Higher value of Numeri (smoothness) is observed for silk fabric in comparison to other fabrics. It indicates smoother nature of silk knitted fabrics. Fukurami value represents fullness and softness of the fabric. It is observed from Table 6 that fukurami values of acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics are better than cotton fabric.

Toal Hand Value of the fabrics is shown in Table 6. It is observed that total hand value of the acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics is better than cotton fabric. These results indicate that acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics are better than cotton fabric and customers may prefer to purchase acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics.

Conclusion

The results of the study are as follows,

1. It was found that comparatively lower values of elongation are observed for 100% acrylic and acrylic-silk 50/50 blend (A5S5) in comparison to 100% silk and cotton fabric. This is due to higher value of yarn diameter resulting in more area of contact within the threads and more resistance during tensile elongation resulting in lower value of EM in case of acrylic and A5S5 fabric
2. Slightly higher values of linearity of load-extension curve (LT) are observed in case of acrylic and A5S5 fabric. This is also due to more resistance offered by these yarns due to greater diameter. Mean bending stiffness (B) of acrylic fabric is maximum due to the fact that thickness of acrylic is greater than silk and cotton fabric.
3. Shear stiffness (G) is maximum for A5S5 fabric followed by acrylic, silk and cotton. Lower values of coefficient of friction (MIU) are observed for silk and acrylic-silk 50/50 blend. Linearity of compression (LC) for acrylic and A5S5 fabric is higher than silk and cotton fabric. This is due to higher resistance offered during shear deformation due to bulky nature of these fabrics.
4. Koshi value (bending stiffness) is maximum in case of A5S5 fabric. Higher value of Numeri (smoothness) is observed for silk fabric in comparison to other fabrics. It indicates smoother nature of silk knitted fabrics. Fukurami values of acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics are better than cotton fabric.
5. Total hand value of the acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics is better than cotton fabric. These results indicate that customers may prefer to purchase acrylic, A5S5 acrylic/silk 50/50 and silk knitted fabrics.

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