FIBRE ENGINEERING FOR ENGINEERED FABRIC

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Introduction

Fibres are the fundamental and the smallest elements constituting textile materials. The biomechanical functional performance of clothing material are very much dependent on the fibre mechanical and surface properties which are mainly determined by the constituting polymeric molecule's internal structural features and surface morphological characteristics of individual fibres. The morphology of fibres includes macrostructure, microstructure, submicroscopic and fine structure of fibres. Macrostructure constitutes the features of a textile fibre that are discernible to the human eye. Microstructure of fibres includes their surface contour and cross sectional shape. Cross sectional shapes vary a wide range particularly in case of man made fibres. To mimic different natural fibres, efforts are made to engineer fibres of a wide range of nonconventional cross sections and fabrics are developed to achieve both physical and physiological comfort.

Experimental Method

The broad objective of this study is to form a more scientific base to engineer the polyester filament to exploit the potential of polyester fibres to achieve maximum possible hand of the fabric produced from them. Therefore several trials are taken to explore how polyester fibre be best used in apparel sector as an alternative fibre to cotton and other natural fibres. Experiments are planned to study the effect of filament configuration on fabric hand using different type of filament yarns such as flat, twisted, textured and intermingled polyester yarns; to examine the effect of residual extensibility of fibre on low stress mechanical properties and hand behaviour of polyester fabrics; to study the effect of filament fineness on low stress mechanical properties and hand of fabric ; and finally to investigate the effect of fibre cross-sectional shape on fabric handle.

Results and Discussion

Effect of filament configuration on hand behaviour of polyester multifilament fabrics

The intermingled, twisted and flat yarns are used as warp threads with intermingled, textured, twisted and flat yarns as weft threads to get the twelve fabric samples of similar areal density and a comparative analysis of fabric hand is carried out . The THV for both winter and summer shirting in a scale of 1-5 are given in bar graphs (Fig. 1 and Fig2) for comparison purpose. The total hand value (winter) is highest for Intermingled/Intermingled combination in F1. The THV for F2 is also equally good, which is a combination of textured and intermingled yarns. The fabric F11, which is Flat Vs Flat combination, has offered minimum THV. This combination exhibited a negative fullness and softness value and having very high stiffness and surface smoothness. The THV (summer) of F10 sample comprising a combination of flat and twisted yarns showed a maximum summer THV because its crispy feel is better amongst all the fabric samples. The F-8 fabric made of both twisted warp and weft yarn has also got high THV for summer application. Although its fullness is poor and other primary hand values are moderate on the scale of 0-10. The

Intermingled/Intermingled combination is suitable for winter but not suitable for summer applications.

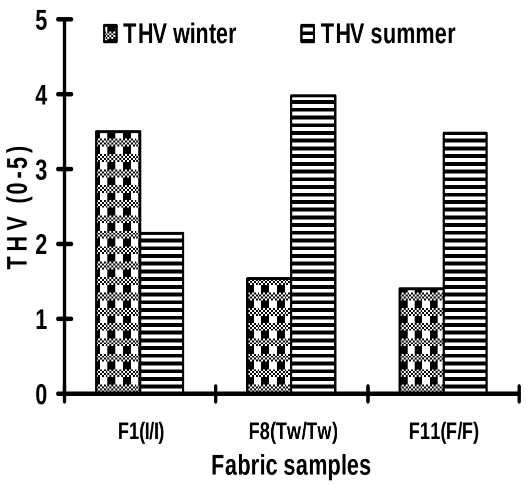

Fig.1 THV of fabric produced from pure combinations

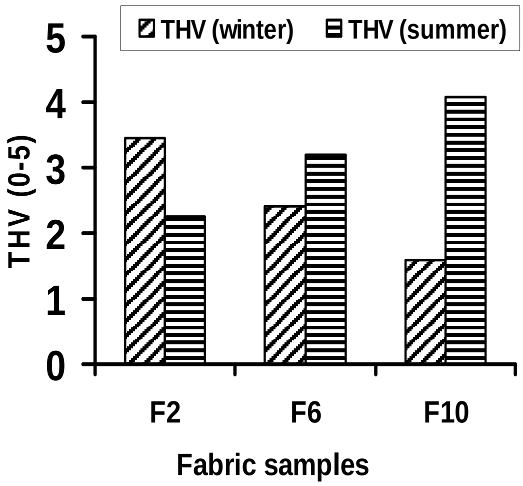

Fig.2 Effect of Textured filling yarn on THV of pure combinations

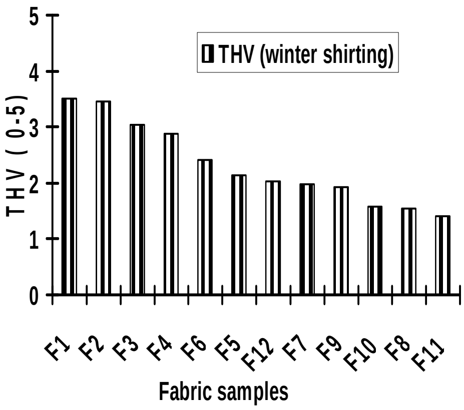

Fig.3 THV (winter) for all fabric samples

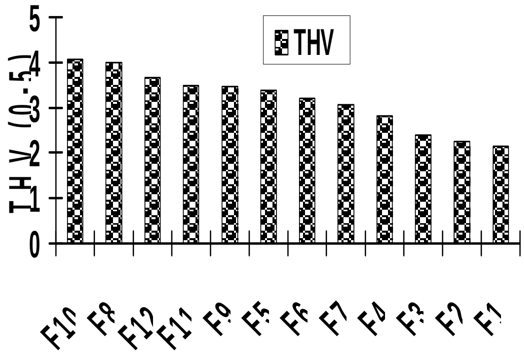

Fig.4 THV (summer) for all fabric samples

The pure yarn combination is defined as both warp and weft yarns having the same constituent filament conformations. By comparing the THV winter shirting fabric for pure combination the F1 (intermingled/intermingled) offers highest THV. The twisted and flat yarn combinations offer a poor THV (winter) and this can be explained on the basis that twisted and flat yarns exhibit less filament flexibility due to higher compactness of constituent filaments. The THV for summer application has exhibited a nearly opposite trend. The F8 (Tw/Tw) combination has offered highest THV among the three combinations (Fig.1) as crispy feel is important for summer wear which is extracted by twisted Vs twisted combinations while the F1 showed the lowest THV summer due to high softness and very low scroopy or high soft shuffle feel.

As the textured yarn filled with intermingled, twisted and flat warp, the F2 showed the nearly same THV winter but the presence of textured filling yarn improved the THV with twisted and flat warp combinations as presented in Fig. 2. This can be explained that the presence of textured weft is contributing for enhanced softness mainly in weft way which is an important criterion for winter wears. The presence of textured weft has registered a positive impulse on THV summer in all three combinations with intermingled, twisted and flat warp. From these results it may be inferred that combination of intermingled with textured yarn offer a moderate properties which are suitable for both winter and summer applications and similar trend is encountered with flat warp. The overview of THV winter and THV summer is shown in Fig 3 and Fig 4 in ascending order. It may be clearly observed from Fig 3 that combination of intermingled yarn with intermingled and textured yarn is best suitable for winter application while the twisted weft filled fabric with twisted and flat warp (F8 &F10) are best suitable for summer application.

Effect of DPF on Hand Behaviour of Fabric Samples

In order to observe the effect of filament fineness, poly(ethylene terephthalate) filament yarns from same batch of polymer were produced to keep the molecular weight same. Different yarns having dpf 0.6, 0.7, 0.9. 1.0, 1.1, 1.4, 2.1 were produced. The filament yarns are converted to fabrics of similar areal density at identical fabric formation conditions. For evaluation of total hand value of winter shirting, three primary hand values such as stiffness, smoothness and fullness are estimated by KES system and given in Table 1.

The results show that microdenier filaments have produced fabrics with lower stiffness. Stiffness increases with increase in DPF. The fabric D41, indicates that these fabrics are very stiff in comparison of D6 and D7 microdenier fabrics. This is due to the large diameter of the coarser filament which gives high stiffness for winter applications. The smoothness is also highly contributing primary hand value for winter applications. The fine denier filaments produce fabric with higher surface smoothness. The texturing registered a negative effect on surface smoothness as indicated by D7text. and D11text fabrics. The coarse mix denier (with heavy yarn denier) fabric D234 offered a low fabric smoothness.

Table 1 Primary Hand and Total Hand Value (THV) Winter Shirting

Denier Per Filament (DPF)	Fabric Code	Primary hand values			THV (W)
		Koshi **Y1** (Stiffness)	Numeri **Y2** (Smoothness)	Fukurami **Y3** (Fullness)	
0.60	D6	3.65	6.65	3.71	3.46
0.70	D7	3.72	6.05	3.37	3.21
0.70	D7 text.	4.90	4.64	4.35	2.95
0.90	D9	3.97	4.98	2.53	2.38
1.00	D10	4.19	4.54	1.99	2.05
1.10	D11	4.35	4.22	1.76	1.97
1.10	D11 text.	3.14	3.49	4.12	1.36
1.40	D14	4.93	3.07	0.86	1.23
2.10	D21	5.30	2.84	0.47	0.92
4.10	D41	6.15	2.16	0.22	0.85
2,3,4	D234	4.56	2.82	1.58	1.42

Fullness of fabric by using fine to coarse DPF multifilament yarns by keeping constant fabric areal density, the fabric fullness decreases as DPF increases. The mix denier yarn offered a better fullness than its equivalent D41 fabric. The smoothness of microdenier fabric made of 0.6 DPF(D6) is 6.5 on the scale of 0-10 which is decreasing continuously with increasing DPF to 2.16 in case of 4.1 DPF(D41).

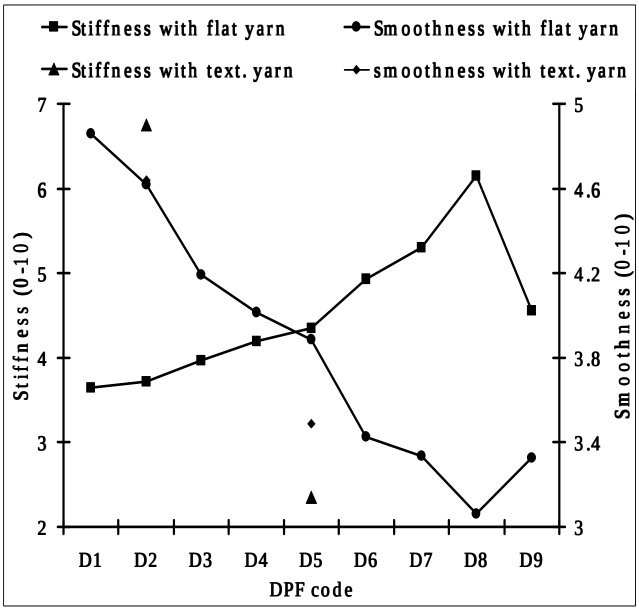

Fig. 5 Relation between Smoothness & Stiffness with DPF

The fullness of polyester fabrics is not very satisfactory in polyester fabrics which are again decreasing by increasing DPF and close to zero in case of DPF 4.1(D41). The stiffness of fine denier fibre is always less than coarse denier fibre and trend is verified at fabric stage also. The stiffness is 3.65 for D6 and that increases to 6.15 for D41. In case of textured filament the stiffness is less than the corresponding flat filament. This can be explained that textured form consists micro-loops and crimps to break the continuity of filament. It can be safely concluded that textured microdenier filament are suitable to offer very soft touch fabric.

In order to evaluate total hand values (THV) for men's summer and winter shirting applications only three primary hand values such as stiffness, smoothness and fullness are considered. The results reveal that the stiffness increases as filament DPF increases. The fullness of fabrics decreases as filament fineness decreases. Effect of texturing gives a small slit to understand the impact of texturing on hand behaviour due to lack of broad range of data. The texturing shows a negative effect on smoothness but significant positive impact shows on fullness values. The microdenier multifilament yarns improve the softness and fullness as compared to coarse denier multi-filament PET fabrics. The THV of 0.6 DPF fabrics (D6) is highest and it decreases by increase in DPF. However, textured and mixed denier filament fabrics improve the THV. The total hand value (THV) of winter suit for 0.6 DPF (D6) multi filament fabrics is 3.46 which are very good on the scale of 0-5 but it continuously decreases with rise in DPF. The mix denier yarn has offered a higher THV than its corresponding normal yarn. The fabric production with zero twist fine denier filament as warp yarn is difficult and therefore, sizing is inevitable. Sizing enhances the cost of weaving and left some environmental issues. However microdenier multi-filaments fabric gives comparatively high THV. The sizing of microdenier yarn is tricky and requires skill and proper care because they are prone to filamentation and stretching. Twisting may be another option but it deteriorates the novelty of filament fineness completely.

Effect of residual extensibility of polyester multifilament yarn on low-stress mechanical properties and hand value of fabric

PET multifilament yarns having residual extensibility 6, 12, 18, 24 and 30 percent were manufactured with nearly identical filament and yarn linear density. All filament yarns were converted to fabrics of similar areal density to examine the influence of residual extensibility of multifilament yarn on fabric handle. The hand behaviour of fabric samples for ladies thin dress material is shown in Table 2. The antidrape stiffness (Hari) and crispness (shari) show a decreasing trend with rise in residual extensibility of filament yarns. It indicates that the yarn having very low residual extensibility is suitable to offer higher crispy feel in fabric due to its high toughness.

Table 2 Hand Behaviour for Ladies Thin Dress Material

Sam. code	Primary hand value						THV for ladies thin dress material
	Stiffness Y1 koshi	Antidrape stiffness Y2 hari	Fullness Y3 fukurami	Crispness Y4 shari	Scrrooping feeling Y5 kishimi	Flexibility With soft feeling Y6 shinyakasa	
TF54	7.08	8.35	2.69	4.25	4.23	3.70	3.90
TF51	7.00	8.06	3.12	3.81	4.15	3.90	3.97
TF48	7.99	8.00	3.25	3.57	1.97	2.18	4.54
TF45	6.91	7.61	3.54	3.32	4.67	4.30	4.33
TF42	6.73	7.14	2.77	3.73	4.75	4.53	4.14

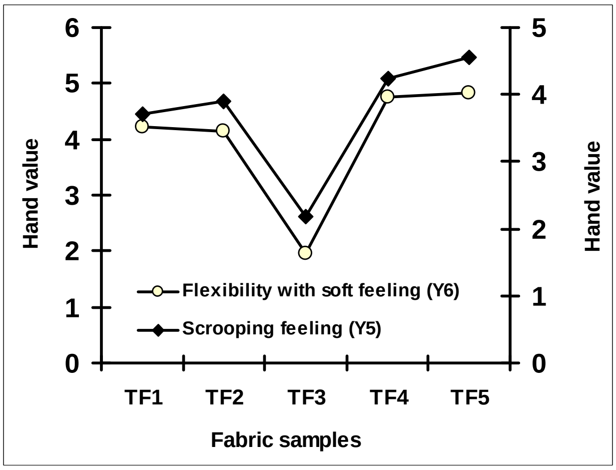

Fig. 6 Relationship of Residual Extensibility with Primary Hand Values

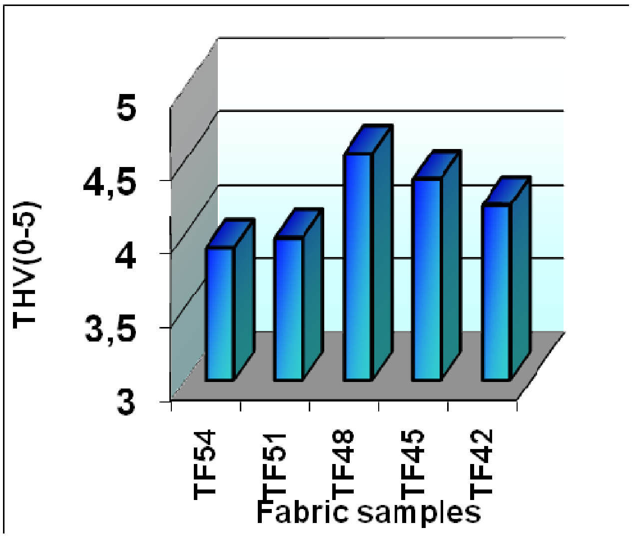

Fig.7 Relationship of Residual Extensibility with THV Ladies Thin Dress Material

The THVs of fabric samples indicate that the optimization of residual extensibility is required. The TF48 fabric shows the maximum THV of 4.54 which is excellent for ladies thin dress application point of view as shown in Fig.7. Both too high and too low residual extensibility have found the lower THV.

Effect of fibre cross-sectional shapes on fabric hand

The effect of fibre cross-sectional shapes on low stress mechanical property of fabrics are investigated to determine fabric hand. To produce a ideal fabric, the stiffness should remain in between 4.5 to 6.5 as stated by Kawabata et al. (1999). The circular cross-section has a stiffness value of 4.77 which is in ideal fabric range. Trilobal (CS2), octagonal (CS3) and square (CS4) cross-section fabrics show lower stiffness than reference fabric, CS1. The TBL-plus (CS5) exhibit stiffness in lower part of ideal fabric range. In this way this fabric will give ideal stiffness with relatively better softness. The plus cross-section in textured form offers highest stiffness i.e. 7.41 which is out side of the ideal fabric stiffness range.The second primary hand expression is crispness which is quite important from summer application view point. Crispness is a feeling comes from crisp and rough surface of fabric. This feeling becomes stronger by the use of hard and twisted yarns in fabric manufacturing. Higher crispness is required for summer application particularly in humid conditions. The split micro cross-section revealed lowest crispness. This can be explained on the basis of its denier per filament (DPF) after splitting (i.e 0.1 denier) followed by sea-island having DPF 0.14. The plus shape cross-section (CS8) offered highest crispness in non-textured form which is reduced to 3.57 after texturing. The octagonal, square, trilobal, double flange and rectangular cross-section exhibited crispness in ideal fabric range which is higher than circular cross-section (i.e. 2.67).

Table 3 Primary Hand and Total Hand Value for Summer Suit Applications

Sample Code	Primary hand values				THV (summer)
	Koshi (Stiffness)	Shari	Fukurami	Hari	
CS1	4.77	2.67	4.83	5.22	2.17
CS2	3.11	5.96	2.76	4.34	3.41
CS3	3.25	5.49	3.65	4.44	3.50
CS4	3.72	4.22	4.91	4.41	3.25
CS5	4.43	3.79	3.44	5.49	2.65
CS6	4.48	4.13	3.03	5.76	2.65
CS7	3.61	4.26	4.35	4.31	3.18
CS8	7.35	5.96	4.65	8.41	3.11
CS9	4.4	2.25	3.59	1.71	1.84
CS10	7.05	3.74	6.38	8.18	2.49
CS11	1.81	0.85	5.03	1.89	1.27
CS12	0.57	0.13	5.33	0.25	0.17
CS13	5.14	3.57	4.10	5.88	2.64

Fullness for summer wears is another primary hand expression essential for all three summer; winter and ladies dress application view point. The fullness feeling comes from bulky rich and well formed fabrics. The fullness is also associated with springy property in compression and thickness. A good warm feeling accompanied with higher fullness. For ideal fabric, the fullness value must be in the range of 5-8.

The fullness of circular cross-section (CS1) is 4.83 which reduce in trilobal (CS2), octagonal (CS3) and TBL-plus (CS5) fabric samples. This can be explained on the basis of that these shapes are more prone for close packing in ideal geometry. The multilobal (CS10) revealed fullness of 6.38 which is highest among the cross-section considered. It can be explained on the basis of possibilities of close packing and which may be less in multilobal cross-section (CS10)

Antidrape stiffness is essential for summer application view point. Antidrape stiffness is very low in split –micro and sea-island cross-section. The circular cross-section showed antidrape stiffness 5.22 which is raised slightly in TBL-PLUS but higher in plus & multilobal cross-section (CS10) i.e. 8.41 and 8.18 respectively. This may be attributed to the specific lobes and edges present in typical multilobal and plus shape cross-section which may restrict any relative movement for drape the fabric to get any contour. The total hand value for summer application showed a mixed trend which is not comparable with shape factor. The circular cross-section is exhibited a THV of 2.17 which is increased above three in case of trilobal, octagonal, square, double flange and rectangular cross-section. The THV of plus shape (CS8) is lowered after texturing (CS13) from 3.11 to 2.64. This is attributed to fall in crispness and stiffness.

CONCLUSIONS

The fibre properties are most important basis for handle behaviour of fabrics. Tensile strain for fabric sample contain intermingle warp with textured filling yarn is maximum (fabric with intermingled warp and textured weft). The intermingled warp with textured weft combination of flat with twisted yarn offer highest resiliency i.e. most inelastic fabric. The presence of intermingled warp with all four type of weft threads offer good THV for winter application while the presence of twisted warp is most suitable for summer applications. To produce a soft touch ladies thin dress material higher extensibility is better but in most of the samples under study, optimum extensibility is preferred and in this case we found the residual extensibility 20% in unsized and 24 % in sized yarn offered the highest THV for ladies thin dress application. The fibre fineness is an important parameter that not only influences the bending stiffness of fibre, yarn and fabric but also the primary hand and total hand values. The shape factor of cross section can be considered as the focused and guiding parameter for deciding fabric properties. The shape factor is related with some low stress mechanical properties and hand behaviour but the trend is not very clear because packing of constituent fibres in fibre strand is also another decisive parameter. Change in cross-sectional shape of filaments influences the low stress mechanical behaviour and hand expression in multifold.