Comparative study of fabric comfort properties of different man-made cellulosic fibers

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Comfort is one of the most important aspects of clothing. Fabric hand and touch feel along with its warm and cool feeling are very important properties, as a result of which a human can feel comfort or discomfort in various activities and environmental conditions. In this paper, the comfort properties of fabrics made from different man-made cellulosic fibers (MMCF) produce by Birla Cellulose, Mumbai/India, such as viscose, modal and Excel lyocell in comparison to conventional fibers such as cotton and polyester were studied. In the experimental study the most common method, Kawabata evaluation system for fabric (KES-FB), was used to evaluate objective hand-feel of fabrics made from different fibers along with its air-permeability, fabric coolness/warmth (Q_{max}) and moisture management properties. Analysis of test data demonstrated that the content of fabric significantly influences the comfort properties. Excel fabric showing best total hand value (THV) among all 3 man-made cellulosic fabrics (Excel, modal and viscose) followed by cotton and polyester fabric.

Comfort is the most important property of any apparel. The comfort sensation of a fabric has multi-dimensional attributes and is impossible to quantify through a single physical property. The comfort characteristics of fabrics mainly depend on the structure, types of raw materials, weight, moisture absorption, heat transmission and skin perception. Although comfort is a highly subjective perception, researchers have developed various objective measurement methods to quantify the sensation when touching a fabric. In order to find a method for the comfort evaluation of textiles, the concept of "fabric hand" is commonly used to assess fabrics.

Basically, clothing comfort can be categorized under 2 broad components, i.e. sensorial comfort and non-sensorial comfort. The clothing comfort can be divided into 3 groups: psychological, tactile and thermal comfort.

- Psychological comfort is mainly related to the aesthetic appeal, which includes size, fit, color, luster, style, fashion compatibility, etc. psychological comfort is mainly related to the garment style, proper fit, fashion and suitability for the occasion and shown no relationship with the fabric properties.
- Tactile comfort is the feel of the fabric when it is touched, and it is directly related to fabric handle. The handle of a fabric is influenced by its mechanical and surface properties. The ease of body motion and the level of load generated in fabric during body movement are obviously related to the fabric handle properties, and therefore a study of clothing tactile comfort must take into account the fabric low-stress mechanical properties.
- Thermal comfort is related to the ability of fabric to maintain the temperature of skin through transfer of heat and perspiration, generated with the human body. Thermal comfort is the factor governed by the movement of heat, moisture and air through the fabric.

Fabric low-stress mechanical properties are most important from the tactile comfort standpoint. In this study, Kawabata evaluation system of fabrics (KES-FB) has been used to measure the low-stress properties. Also, the impact on comfort properties of MMCF (viscose, modal and Excel) in comparison with cotton and polyester fabric was studied.

Materials

5 plain woven fabric samples with fixed end and pick density were used for study. All 5 fabrics were prepared on Tsudakoma air-jet loom (ZAX N).

Methodology

Evaluation of fabric dimensional properties

Count of yarns used in warp and weft were measured as per IS1315 method. Thread density was measured by pick counting glass. The constructional parameters of the final finish fabric samples are given in Table 1.

Testing of fabric thermal comfort properties

- Air permeability of the fabric was evaluated by ISO-9237 using air permeability tester M021A SDL Atlas.
- Maximum energy transmitted during compression (Q_{max}) Measurement is the index of indicating the coldness and

Table 1
Constructional parameters of finish fabric

Sample	Fabric material	Warp yarn	Weft yarn	Weave	EPIXPPI	Weight [g/m^2]
T1	Cotton	30's cotton	30's cotton	Plain	74×66	120
T2	Viscose	30's viscose	30's viscose	Plain	74×66	120
T3	Modal	30's nodal	30's modal	Plain	74×66	120
T4	Excel	30's Excel	30's Excel	Plain	74×66	120
T5	Polyester	30's polyester	30's polyester	Plain	74×66	120

warmth feeling of skin touching fabric. It is determined by the heat loss from the skin to the fabric, measured by fabric touch tester (FTT) M-293 SDL Atlas.

- Overall moisture management capability (OMMC) of a textile material was evaluated by AATCC TM 195 using moisture management tester (MMT) M-290 SDL Atlas.

Testing of fabric tactile comfort properties

Handle properties of the fabrics were evaluated by measuring the fabric low-stress mechanical properties (tensile, shear, bending, compression, surface roughness and surface friction) on Kawabata evaluation system for fabrics (KES-FB). The tensile and shear properties were studied on KES-FB1 (tensile and shear tester). Bending properties were measured on KES-FB2 (bending tester). Compressional properties were studied on KES-FB3 (compression tester). The surface roughness and surface friction were measured on KES-FB4 (surface tester). The primary and total hand values were calculated from the 16 mechanical properties using the prescribed procedure by Kawabata and Niwa [3].

Result and discussion

Air permeability

Air permeability is defined as the volume of air in liters which allow to pass in 1 second through 1 m^2 area of fabric at a different pressure. From the result presented in Table 2, it can be stated that the highest air permeability value was obtained for viscose fabric, this was followed by Excel, modal, cotton and polyester fabric (viscose > Excel > modal > cotton > polyester).

Fabric touch testing

Maximum energy transmitted during compression (Q_{max}) can be directly determined by the machine, and the higher Q_{max} value means cooler initial touch feeling. It can be seen that MMCFs had the highest Q_{max} value followed by cotton and polyester fabrics (Excel > modal > viscose > cotton > polyester).

Moisture management testing

Moisture management is an essential feature of a textile material regarding its comfort appeal. Fabric content has a vital role in moisture related capability of a textile material. Overall moisture management capability (OMMC) of a fabric is estimated from its absorption, spreading and one-way transport property by applying a suggested equation.

Here from the result, although polyester fabric shows the highest OMMC value, this is because of its very good one-way transport

Fig. 1
Total hand value (THV)

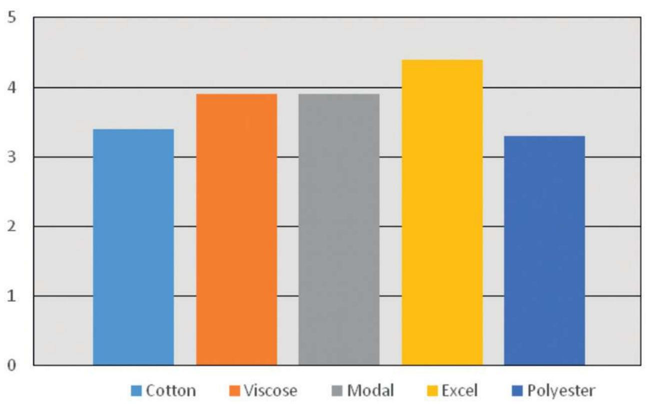

Table 2
Thermal comfort properties of comparative fabric samples

Sample	Fabric blend	Air permeability ($l/m^2/s$)	Q_{max} W/m^2	Moisture management testing – OMMC*
T1	Cotton	1156	1236.3	0.5791
T2	Viscose	1654	1269.4	0.6274
T3	Modal	1459	1270.2	0.6298
T4	Excel	1536	1275.2	0.6881
T5	Polyester	1044	1161.1	0.7240

* OMMC – Overall Moisture Management Capability

property only. MMCFs have very good absorption and spreading properties compared to polyester fabrics, and are better than cotton fabric in all 3 aspects.

Tensile properties

The linearity of tensile property (LT) is indicative of wearing comfort. Lower value of LT gives higher fabric extensibility in initial strain range, indicating better comfort. It can be seen that LT is highest in polyester fabric and lowest in viscose fabric (polyester > cotton > Excel > modal > viscose). Tensile resilience (RT) indicates recovery after tensile deformation. Value closer to 100 means better recoverability. It can be seen that RT is highest in polyester fabric and lowest in cotton fabric (polyester > Excel > modal > viscose > cotton). The EM (tensile strain) value indicates low-stress extensibility and is related to crimp removal process during tensile loading. It is the factor affecting fabric tailorability and seam slippage. Higher value of EM provides wearing comfort but creates problems during stitching and steam pressing. It can be seen that EM is highest for cotton fabric and lowest in polyester fabric (cotton > viscose > Excel > modal > polyester).

Shear rigidity

Shear rigidity of a fabric mainly depends upon the mobility of warp and weft thread within the fabric. The high value of shear rigidity causes difficulty in tailoring and discomfort during wearing. It can be seen that shear rigidity (G) is highest for polyester fabric and lowest in Excel fabric (polyester > cotton > viscose > modal > Excel). 2HG and 2HG5 indicate the hysteresis of shear force at 0.5° and 5° respectively. Elasticity for minor and large

Table 3
Characteristic values in KES-F system

Low-stress mechanical properties		Description	UOM
Tensile	EMT	Extensibility	%
	LT	Linearity of tensile curve	-
	WT	Tensile energy	$gf.cm/cm^2$
	RT	Tensile resilience	%
Shearing	G	Shear rigidity	gf/cm. degree
	2HG	Hysteresis at 0.5° shear angle	gf/cm
	2HG5	Hysteresis at 5° shear angle	gf/cm
Bending	B	Bending rigidity	$gf.cm^2/cm$
	2HB	Hysteresis of bending moment	gf.cm/cm
Compresssion	LC	Linearity of compression-thickness curve	-
	WC	Compressional energy	$gf.cm/cm^2$
	RC	Compressional resilience	%
Surface	MIU	Coefficient of friction	-
	MMD	Mean deviation of MIU	-
	SMD	Geometrical roughness	µm

shear (2HG and 2HG5), higher value indicated poor recoverability. It can be seen that recoverability of Excel fabric is best and least in polyester fabric (Excel > modal > viscose > cotton > polyester).

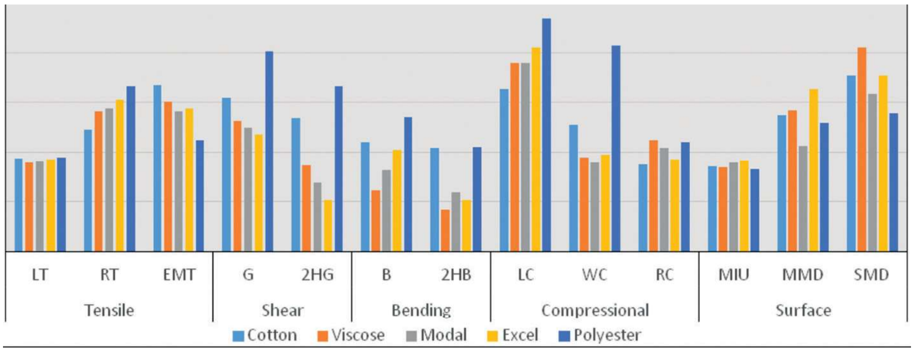

Fig. 2
Low-stress mechanical properties of comparative fabric samples

Bending properties

Bending rigidity (B) is one of the important mechanical properties influencing the tailorability of the fabric. Bending rigidity of a fabric depends upon the bending rigidity of the thread and the mobility of warp and weft thread within the fabric. It can be seen that bending rigidity (B) is highest for polyester fabric and lowest in viscose fabric (polyester > cotton > Excel > modal > viscose). Hysteresis of bending moment (2HB), indicates recovery from bending moment. Bending hysteresis (2HB) higher values mean poor recoverability. It can be seen that polyester fabric has poor recovery and viscose fabric shows the lowest value (polyester > cotton > modal > Excel > viscose).

Compressional properties

The compressional properties of fabrics are measured by placing the sample between 2 plates and monitoring its thickness with increasing pressure. The linearity of compression (LC) mainly depends on the fabric thickness and compressional characteristics of yarn. It has been observed that the LC value is highest for polyester fabric and lowest for cotton fabric (polyester > Excel > modal > viscose > cotton). The compressional energy (WC) depends upon LC and the amount of compression, with the increase in fiber to fiber slippage the energy required to compress the fabric decreases. It has been observed that polyester fabric required highest compressional energy (WC) and lowest for modal fabric (polyester > cotton > Excel > viscose > modal). Compression resilience (RC) indicates recovery after compression. Values closer to 100 mean better recoverability. It has been observed that RC value is highest for viscose fabric and lowest for cotton fabric (viscose > polyester > modal > Excel > cotton). Fabric thickness (T0) is highest for polyester and followed by viscose, cotton, modal and Excel fabric.

Surface properties

The coefficient of friction (MIU) increases with increase in contact area with contactor. Higher value means less tendency to slip. It has been observed that Excel fabric is the least slippery and polyester is the most (Excel > modal > cotton > viscose > polyester). The mean deviation of coefficient of friction (MMD) indicates the variation in MIU. Higher value the mean, the less smoothness and more roughness. The geometrical roughness (SMD) indicates surface variation in a unit surface area. The higher the value mean, the more surface unevenness. It has been observed that polyester fabric is the most even, followed by modal, cotton, Excel and viscose fabric (polyester > modal > cotton > Excel > viscose).

Fabric hand value

The total hand value (THV) of the fabric is estimated from the primary hand values using Kawabata system of equation. It has been observed that THV value is highest for Excel fabric followed by modal, viscose, cotton and polyester fabric (Excel > modal > viscose > cotton > polyester).

Table 4
Low-stress mechanical properties of comparative fabric samples

Sample		T1	T2	T3	T4	T5
Material		100 % cotton	100 % viscose	100 % modal	100 % Excel	100 % polyester
Low-stress mechanical properties		Warp + weft (average)	Warp + weft (average)	Warp + weft (average)	Warp + weft (average)	Warp + weft (average)
Tensile test	LT	0.375	0.358	0.364	0.371	0.378
	WT	0.61	0.54	0.5	0.5	0.43
	RT	49.14	56.66	57.48	61.1	66.61
	EMT	6.71	6.04	5.66	5.77	4.48
Surface test	MIU	0.171	0.169	0.179	0.184	0.166
	MMD	0.011	0.0114	0.0085	0.0131	0.0104
	SMD	7.094	8.195	6.328	7.095	5.577
Bending test	B	0.0442	0.0245	0.0326	0.0408	0.054
	2HB	0.0416	0.0169	0.024	0.0206	0.042
Shear test	G	1.24	1.05	1	0.94	1.61
	2HG	3.33	2.4	1.9	1.29	3.54
	2HG5	4.29	2.78	2.21	1.66	5.34
Compression test	LC	1.31	1.519	1.521	1.643	1.875
	WC	0.051	0.038	0.036	0.039	0.083
	RC	35.12	45.01	41.77	37.2	44.07
	T0	0.207	0.225	0.172	0.17	0.25
	TM	0.128	0.175	0.126	0.124	0.162
Total hand value	THV	3.4	3.9	3.9	4.4	3.3

Conclusion

Comfort of apparel has not been objectively expressed so far, although it can be recognized through the experience of a person. Comfort is purely a subjective criterion. However, it can be quantified in an objective manner in terms of the properties of non-sensorial comfort characteristics.

Satisfactory thermal equilibrium and efficient moisture management are the most important comfort criteria in apparel. Compared to polyester and cotton fabric, man-made cellulosic fabrics (MMCF) shows very good air permeability and cooler initial touch feeling (Q_{max}).

Moisture management property (OMMC) of man-made cellulosic fabrics (MMCF) is better compared to cotton fabric and comparable with polyester fabric.

The linearity of tensile property, tensile energy, shear rigidity, bending rigidity, compressional energy is highest in polyester and cotton fabric compared to man-made cellulosic fabrics (MMCF). This means that man-made cellulosic fabrics (MMCF) shows better wearing comfort compared to polyester and cotton fabric.
Excel lyocell fabric shows the highest total hand value (THV) among all 3 man-made cellulosic fabrics (Excel, modal and viscose) followed by cotton and polyester fabric. Due to very good comfort properties of man-made cellulosic fabric (MMCF), it can be used as comfort apparel for all season.

References

[1] Yoon, H.N.; Buckley, A.: Improved comfort polyester: Part I: Transport properties and thermal comfort of polyester/cotton blend fabrics, Textile Research Journal 54 (1984) 289

[2] Nayak, R.K.; Punj, S.K.; Chatterjee, K.N.: Comfort properties of suiting fabrics, Indian journal of fiber & textile research 34 (2009) 122-128

[3] Kawabata, S.; Niwa, M.: Objective measurement of fabric mechanical property and quality: Its application to textile and clothing manufacturing, Int. J clothing science technology 3 (1991) 7

Excel = registered trademark

TTRI

PA fiber helps to keep cool

AquaBreath is the name of a modified polyamide (PA) fiber that can actively respond to the moisture of skin microclimate. Mixed with polymers, AquaBreath is intrinsically equipped with high hydrophilicity and moisture exhaustion function to quickly absorb and evaporate sweat. Moreover, the fiber can sense human microclimate at any time and activates its deformation mechanism to provide good comfort for wearers. The fabric demonstrates visual changes with the structure design and creates deformation called air chambers. When the wearer exercises and sweats, the fabric absorbs the sweat from the human skin surface and elongates to form air chambers, which helps increase convection. The stickiness can quickly be reduced because of the high air permeability, generating a cool feeling. After exercising, the fiber shrinks to reduce the air permeability, and the air chamber, in turn, keeps the warm air, providing a warming effect and preventing chills after exercise. With the combination of the fiber property of high hydrophilicity, moisture exhaustion, and deformation, AquaBreath delivers quick-drying and high air permeability effects, providing coolness and comfort. AquaBreath was developed by the Taiwan Textile Research Institute (TTRI), Taipei/Taiwan, and is supported by the Department of Industrial Technology, Ministry of Economic Affairs, Taiwan. It comprises 100 % single modified PA. Unlike other products using PET and other materials in the market to achieve the stretching and deformation effect, AquaBreath uses single material, which is conducive to the next step of recycling after consumption. For the end-of-life of product recycling process, the product of AquaBreath can save a lot of processing time, without the need to separate the blended textiles. The fiber can be easily recycled, and it is in line with the trend of zero carbon emission and a circular economy.

Carbios

Consortium to advance circularity in the textile industry

Carbios, a pioneer in the development of enzymatic solutions, dedicated to the end-of-life of plastic and textile polymers, has signed an agreement with On AG, Zurich/Switzerland, Patagonia, Ventura, CA/USA, Puma AG, Herzogenaurach/Germany, and Salomon SAS, Epangy Metz-Tessy/France, to develop solutions that will enhance the recyclability and circularity of their products.
An important element of the 2-year deal will be to speed up the introduction of Carbios' unique bio-recycling technology, which constitutes a very important step for the textile industry. Carbios SA, Clermont-Ferrand/France, and the other 4 companies will also research how products can be recycled, develop solutions to take-back worn polyester items, including sorting and dismantling technologies, and gather data on fiber-to-fiber recycling as well as circularity models.
Carbios' innovative process constitutes a very interesting development for the recycling of polyester (PET) fibers, which are widely used in apparel, footwear and sportswear, on their own or together with other fibers. PET is the most important fiber for the textile industry with 52 million tons produced, even surpassing cotton at 23 million tons. The bio-recycling process uses an enzyme capable of selectively extracting the polyester, recovering it to recreate a virgin fiber. This new technology makes it possible to recover the PET present in all textile waste that cannot be recycled using traditional technologies.
PET plastics and fibers are used to make everyday consumer goods such as bottles, packaging and textiles. Today, most PET is produced from fossil resources, then used and discarded according to a wasteful linear model. By creating a circular economy from used plastics and fibers. Carbios' bio-recycling technology offers a sustainable and more responsible solution.