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RESEARCH ARTICLE

Studies on Thermally Conductive Filament Incorporated Hospital Bed Linens and its Thermal Comfort

K.P. Chellamani*, D. Veerasubramanian and G. Panner Selvam
The South India Textile Research Association, Coimbatore, TN, India
spg@sitra.org.in, kpc@sitra.org.in*; 0422-4215347

Abstract

Thermal conductivity is an intrinsic property of a material that indicates its ability to conduct heat. Uncomfortable matters cause people to restless sleep. Hundred percent cotton yarns or blends of polyester and cotton yarns are used to manufacture the commercial hospital bed linens. Thermal sensations between clothing and human body decides the comfort of the fabrics. Thermo-physiological comfort is affected by fibre type, yarn properties, fabric structure, finishing treatments and clothing conditions. Fabrics made using straight filament yarns remove heat rapidly by conduction method. When the fabric thickness is increased, the thermal conductivity is increased. Hospital bed linen incorporated with advanced thermally conductive filament has better thermal conductive values and has better washing durability. This study was aimed to develop hospital bed linen for immobile patients with improved thermal comfort using thermally conductive filaments. From the study, it was clear that Luxicool incorporated fabric samples, both 14 Ne and 2/20 Ne fabric samples showed lower weft way tensile strength to the tune of 30-35% in the case of 100% cotton fabrics and about 15% in the case of P/C fabrics as compared to that of control fabric samples. As compared to control sample, the thermal conductivity of Luxicool incorporated cotton and P/C fabrics did not get affected much even after 50 washes.

Keywords: Thermal conductivity, hospital bed linens, luxicool, conductive filaments, tensile strength.

Introduction

The commercial hospital bed linens are made using either 100% cotton fibres or blend of polyester and cotton fibres (Sharabaty *et al.,* 2008). The comfort and discomfort is decided by interaction between clothing and human body in terms of thermal sensations. Thermal comfort to the patient is important for medical apparels like hospital beddings, curtains and apparels due to the effect of diseases and miscellaneous therapies given in hospitals (Uzun *et al.,* 2012). Thermal conductivity is an intrinsic property of a material that indicates its ability to conduct heat. Prakash *et al.* (2012) found that the 100% cotton fabrics have higher air permeability and higher thermal resistance values compared with cotton blended fabrics. Some peoples are suffered by sleep disorders. If people continuously lack the amount of sleep, they are caused by daytime sleepiness, trouble in concentration, irritability, increased risk of falls, accidents and lower productivity. Sleep problems can be related to an uncomfortable mattress or bedclothes. Hence, bed cloths should be as comfortable as possible (Hoerr *et al.,* 2011). Thermal comfort is primarily related to the efficiency heat dissipation from a human body to fabric (Das *et al.,* 2013). Thermo-physiological comfort is affected by fibre type, yarn properties, fabric structure, finishing treatments and clothing conditions.

Fabrics made using straight filament yarns remove heat rapidly by conduction method. These kinds of fabric make the wearer to cool feel or handle. When the fabric thickness is increased, the thermal conductivity is increased (Bivainyte *et al.,* 2012). Hence, SITRA would like to develop hospital bed linens with following objectives in this study:

1. To develop hospital bed linen for immobile patients with improved thermal comfort, an important factor in the hygiene sector.
2. To develop hospital bed linen using thermally conductive filaments.

Materials and methods

Luxicool is a light elastic monofilament which can be used in weaving, knitting and braiding. This filament conducts heat and cools the surface of the fabric. It can be used to manufacture sportswear, work wear, military wear, protective clothing, medical bandages, sports bandages, burn wound treatments, linen and pillows (hospitals), shoes, spacer fabrics etc. Plain weave fabrics were produced using these yarns with six different weft combinations. A total of 24 fabric samples were produced with different combinations of fiber, yarn linear density and pick arrangement (Table 1).

Table 1. Fabric samples produced using luxicool filament.

S.No	Fabric Code	Yarn count	Warp yarn	Weft yarn(s)	Pick arrangement
1.	14 Ne Cotton (control sample)	14 Ne	cotton	cotton	Picks/Inch = 56; All picks are Cotton
2.	14 Ne–1 CL*	14 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 2 picks cotton – 2 picks
3.	14 Ne–2 CL	14 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 2 picks cotton – 4 picks
4.	14 Ne–3 CL	14 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 2 picks cotton – 8 picks
5.	14 Ne–4 CL	14 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 4 picks cotton – 8 picks
6.	14 Ne–5 CL	14 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 4 picks cotton – 16 picks
7.	14 Ne P/C (Control sample)	14 Ne	Polyester/Cotton	Polyester/Cotton	Picks/Inch = 56; All picks are Polyester/Cotton
8.	14 Ne–1 P/CL**	14 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 2 picks Polyester/Cotton – 2 picks
9.	14 Ne–2 P/CL	14 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 2 picks Polyester/Cotton – 4 picks
10.	14 Ne–3 P/CL	14 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 2 picks Polyester/Cotton – 8 picks
11.	14 Ne–4 P/CL	14 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 4 picks Polyester/Cotton – 8 picks
12.	14 Ne–5 P/CL	14 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 4 picks Polyester/Cotton – 16 picks
13.	2/20 Ne Cotton (Control sample)	2/20 Ne	cotton	cotton	Picks/Inch = 36; All picks are Cotton
14.	2/20 Ne–1 CL*	2/20 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 2 picks cotton – 2 picks
15.	2/20 Ne–2 CL	2/20 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 2 picks cotton – 4 picks
16.	2/20 Ne–3 CL	2/20 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 2 picks cotton – 8 picks
17.	2/20 Ne–4 CL	2/20 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 4 picks cotton – 8 picks
18.	2/20 Ne–5 CL	2/20 Ne	cotton	Luxicool filament and cotton	Luxicool filament – 4 picks cotton – 16 picks
19.	2/20 Ne P/C (Control sample)	2/20 Ne	Polyester/Cotton	Polyester/Cotton	Picks/Inch = 36; All picks are Cotton
20.	2/20 Ne–1 P/CL**	2/20 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 2 picks Polyester/Cotton – 2 picks
21.	2/20 Ne–2 P/CL	2/20 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 2 picks Polyester/Cotton – 4 picks
22.	2/20 Ne–3 P/CL	2/20 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 2 picks Polyester/Cotton – 8 picks
23.	2/20 Ne–4 P/CL	2/20 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 4 picks Polyester/Cotton – 8 picks
24.	2/20 Ne–5 P/CL	2/20 Ne	Polyester/Cotton	Luxicool filament and Polyester/Cotton	Luxicool filament – 4 picks Polyester/Cotton – 16 picks

* CL – Cotton with luxicool filament; ** P/CL – P/C fabric with luxicool filament.

The 24 fabric samples were desized, scoured, mercerized and bleached. The hospital bed linens woven using luxicool filament was evaluated for thermal conductivity. The optimum combination of Luxicool filament incorporated hospital bed linens were evaluated for physical properties like

a. Tensile strength test was carried out using universal testing machine (UTM) Instron tensile strength tester.
b. Tear strength test was carried out using Elmendrof tear strength tester.

Chemical properties like pH and durability for repeated launderings was also evaluated.

Results and discussion

Thermal conductivity: The thermal conductivity values of Luxicool incorporated hospital bed linen fabrics are shown in Table 2. Thermal conductivity is better by 20% as compared to existing commercial hospital bed linens.

Table 2. Thermal conductivity of luxicool incorporated hospital bed linen fabrics.

S.No	Fabric code	Thermal conductivity (x 10^{-3} W/(m.K))
1.	14 Ne Cotton (Control sample)	36.30
2.	14 Ne–1 CL*	42.90
3.	14 Ne–2 CL	42.48
4.	14 Ne–3 CL	38.56
5.	14 Ne–4 CL	40.83
6.	14 Ne–5 CL	37.48
7.	14 Ne P/C (Control sample)	27.14
8.	14 Ne–1 P/CL**	31.01
9.	14–2 P/CL	29.25
10.	14–3 P/CL	27.86
11.	14–4 P/CL	30.23
12.	14–5 P/CL	28.27
13.	2/20 Cotton (Control sample)	38.95
14.	2/20–1 CL	45.95
15.	2/20–2 CL	43.59
16.	2/20–3 CL	42.87
17.	2/20–4 CL	44.70
18.	2/20–5 CL	43.20
19.	2/20 P/C (Control sample)	32.87
20.	2/20–1 P/CL	35.31
21.	2/20–2 P/CL	34.31
22.	2/20–3 P/CL	33.14
23.	2/20–4 P/CL	35.07
24.	2/20–5 P/CL	34.17

*Cotton with luxicool filament, **P/C with luxicool filament.

Table 3. Tensile strength of control and luxicool incorporated fabric samples.

S.No	Sample Particulars	Warp way		Weft way	
		Strength (Kgf)	Elongation (%)	Strength (Kgf)	Elongation (%)
1.	14 Ne Cotton fabric (Control sample)	102.34	10.93	61.77	23.76
2.	14 Ne Luxicool incorporated cotton fabric	98.72	21.46	48.38	27.61
3.	14 Ne P/C fabric (Control sample)	107.09	17.93	62.04	23.09
4.	14 Ne Luxicool incorporated P/C fabric	105.46	19.42	52.34	29.12
5.	2/20 Ne Cotton fabric (Control sample)	77.16	8.12	51.74	17.57
6.	2/20 Ne Luxicool incorporated cotton fabric	75.86	13.79	34.21	25.08
7.	2/20 Ne P/C fabric (Control sample)	99.59	18.78	82.16	23.85
8.	2/20 Ne Luxicool incorporated P/C fabric	105.37	20.67	68.82	31.49

Table 4. Tear strength of control and luxicool incorporated fabric samples.

S. No	Sample particulars	Tear strength (gf)	
		Warp way	Weft way
1.	14 Ne Cotton fabric (Control sample)	2944.0	2483.2
2.	14 Ne Luxicool incorporated cotton fabric	3278.3	2706.5
3.	14 Ne P/C fabric (Control sample)	2777.6	2022.4
4.	14 Ne Luxicool incorporated P/C fabric	4368.9	3192.7
5.	2/20 Ne Cotton fabric (Control sample)	5593.6	4684.8
6.	2/20 Ne Luxicool incorporated cotton fabric	5068.7	4826.1
7.	2/20 Ne P/C fabric (Control sample)	4044.8	3878.4
8.	2/20 Ne Luxicool incorporated P/C fabric	6218.5	6008.6

Higher values of thermal conductivity are better for fabrics meant for hospital bed linens. Higher values of thermal conductivity were observed for

i. 14 Ne cotton fabrics incorporated with luxicool filament (Pick arrangement: Cotton–2 picks, Polyester–2 picks).
ii. 14 Ne P/C fabrics incorporated with luxicool filament (Pick arrangement: Cotton–2 picks, Polyester–2 picks).
iii. 2/20 Ne cotton fabrics incorporated with luxicool filament (Pick arrangement: Cotton–2 picks, Polyester–2 picks).
iv. 2/20 Ne P/C fabrics incorporated with luxicool filament (Pick arrangement: Cotton–2 picks, Polyester–2 picks)

Bulk samples of fabrics (Both cotton as well as P/C with luxicool filament) were produced and evaluated for physical and comfort properties.

Tensile strength: Tensile strength of luxicool incorporated hospital bed linens are given in Table 3. From Table 3, it is clear that the luxicool incorporated fabric samples, both 14 Ne and 2/20 Ne fabric samples showed lower weft way tensile strength to the tune of 30 to 35% in the case of 100% cotton fabrics and by about 15% in the case of P/C fabrics as compared to that of control fabric samples. However, there is no significant difference in warp way tensile strength. From Table 4, it is clear that the tear strength of luxicool incorporated fabric samples is higher than that of control fabric samples. The presence of the higher elasticity luxicool filament helps to increase the fabric tear strength.

pH of fabric samples: pH of luxicool incorporated fabric samples are given in Table 5. This test is essential to know about the skin friendliness property of the produced fabric samples. From Table 5, it is clear that the pH value of control and luxicool incorporated fabric sample do not differ significantly.

Durability of luxicool incorporated fabric samples: In order to assess the durability of luxicool incorporated cotton and P/C fabrics. The thermal conductivity of those fabrics was evaluated and the results are given in Table 6. It is clear from Table 6 that the thermal conductivity of luxicool incorporated cotton and P/C fabrics did not get affected much even after 50 washes.

Conclusion

SITRA had developed hospital bed linen fabrics with enhanced thermal characteristics for immobile patients. Both 14 Ne and 2/20 Ne luxicool incorporated fabric samples showed lower weft way tensile strength to the tune of 30 to 35% in the case of 100% cotton fabrics and by about 15% in the case of P/C fabrics as compared to that of control fabric samples. However, there is no significant difference in warp way tensile strength. The tear strength of luxicool incorporated fabric samples is higher than that of control fabric samples. pH value of control and luxicool incorporated fabric sample do not differ significantly. As compared to control sample, the thermal conductivity of luxicool incorporated cotton and P/C fabrics did not get affected much even after 50 washes.

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