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RESEARCH ARTICLE

Thermal Characteristics of Hospital Bed Linens–A Sensitive Science

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Abstract

Understanding the thermal performance of fabrics in final product provides valuable inputs for the manufacturing of hospital bed linens. Primarily, hospital bed linens are used as a protection barrier in between human body and the place where the human body take rest (sleep) against cooling environment. However, the comfort of the fabric during sleeping depends on various factors. In this work, an attempt has been made to study one of the prime comfort parameter 'Thermal behaviors'. Measurement of thermal behavior under stimulated conditions has been carried out for advance technical finish applied on the fabric. The chemical compositions of advance technical finish on the fabrics were optimized using quality evaluation like heat of fusion, heat of crystallization and transition temperature etc.

Keywords: Hospital bed linens, human body, comfort parameter, thermal behaviors, heat of fusion.

Introduction

Clothing is comfortable when humans feel physical, physiological and mental satisfaction as heat and moisture transfer efficiently from the body to the environment through clothing. Therefore, development of intelligent fabrics, including thermal storage/release ones, which can adjust and maintain thermal comfort as circumstances change are very important and necessary (Keyoun and Gilsoo, 2004). When a patient lies for a long duration on the bed, unbearable heat is generated on the patient's body. This excessive heat creates restlessness to patients (Kandavadivu *et al.,* 2011) and the patient's body temperature raises from 39 to 40°C on the rexin covered hospital bed. The thermal comfort of fabrics is associated with the thermal balance of the human body and its thermal responses to the dynamic interactions with the clothing and environment systems.

Both heat and moisture transmission behavior of a fabric plays a very important role in maintaining thermo physiological comfort. The fabrics should allow moisture in the form of sensible and insensible perspiration to be transmitted from the body to the environment in order to cool the body and reduce the degradation of the thermal insulation of the fabric caused by moisture build-up. The fabric which is in contact with the skin should be dry to the touch; otherwise heat, which flow from the body will increase, causing unwanted loss in body heat and a clammy (sweaty) feeling (Das *et al.,* 2007). Wong *et al.* (2002) studied perception of thermal and moisture sensations of fabrics using mathematical models and showed that coolness to touch of fabrics can be predicted with reasonable accuracy using heat and moisture transfer within the fabric.

Bendkowska and Wrzosek (2009) stated that a phase change is the process of going from one physical state to another. Phase change materials (PCMs) are those that can absorb, store and release large amounts of energy, in the form of latent heat, over a narrowly defined phase change range, during which the material changes state. PCMs use chemical bonds to store and release heat. When the melting temperature is reached during the heating process, a phase change from solid to liquid occurs, in which the PCM absorbs a large amount of latent heat from the surrounding environment. Energy is absorbed by the material and is used to break down the bonding responsible for the solid structure. This heat is then stored in the PCM and subsequently released in a cooling process starting at the PCM's crystallization temperature. The latent heat is released to the surroundings when the material cools down. During the entire phase change process, the temperature of the PCM as well as the surrounding substrate remains constant. When the phase change is complete, continued heating/cooling results in a further temperature increase/decrease (Bendkowska and Wrzosek, 2009). The potential application of PCM micro-capsulation are in surgical apparels, patient bedding, bandages and the products related to regulate patient temperature in intensive care units (Faisal *et al.,* 2010). Hence, SITRA would like to develop hospital bed linens with following objectives:

1. To develop hospital bed linen for immobile patients with improved comfort properties, an important factor in the hygiene sector.
2. To develop hospital bed linen using best possible combination of yarns and chemical processing.

Materials and methods

In general, the hospital bed linens are made using either cotton yarns or blends of polyester and cotton yarns. SITRA has developed four plain weave hospital bed linens with the fabric width of 48 inches. They are:

1. 14 Ne Cotton fabric samples.
2. 14 Ne P/C (Polyester/Cotton) fabric samples.
3. 2/20 Ne Cotton fabric samples and
4. 2/20 Ne P/C fabric samples.

The fabric construction parameters are shown in Table 1. The fabric construction parameters were chosen from the data provided by AIIMS (All India Institute of Medical Science), New Delhi and commercially available bed linens used in hospitals in and around coimbatore. The above 4 fabric samples were desized, scoured, mercerized, bleached and dyed. From the 4 dyed fabric samples, 28 fabric samples were produced using cotton and P/C single and doubled yarns and by varying the concentration of PCM (Phase Change Material) finish applied on the fabrics.

Table 1. Construction parameters for hospital bed linen fabric.

Fabric type	EPI (Ends per inch)	PPI (Pick per inch)	Fabric weight (gsm)
14 Ne Cotton fabric	66	56	230
14 Ne P/C fabric			
2/20 Ne Cotton fabric	36	36	160
2/20 Ne P/C fabric			

Pad dry cure method: The PCM finishes were applied on the fabric samples using pad dry cure method. They were applied on the fabric using padding mangle with 2 dip and 2 nip methods. It gave a wet pick up of about 70% (Chakraborty *et al.,* 2010). The wet pick up of fabric samples is varied depending upon the type of raw materials used in the fabric samples. The PCM finish applied fabric samples were dried using stenter at the temperature of 100°C for 2 min. The dried fabric samples were cured at high temperature of 150°C for 1 min. Schematic diagram of processing setup for pad dry cure method is shown in Fig. 1.

Fig. 1. Schematic diagram of processing setup for padding mangle and hot air stenter (Dhall group, 2013).

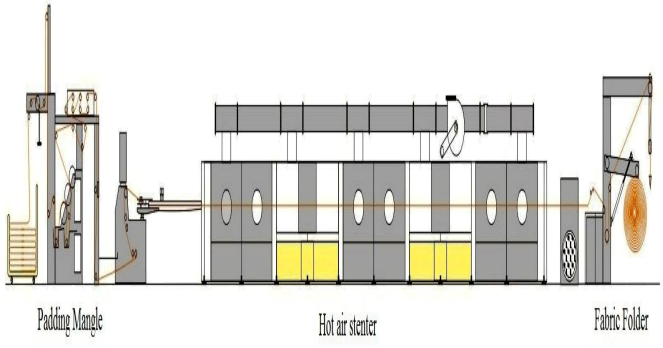
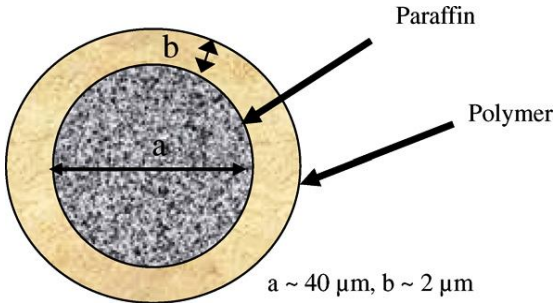


Fig. 2. Paraffin PCM core material individually with a hard polymeric shell.



The PCM finish was applied onto the fabric by soaking the fabric in the mixture of PCM and binder. The fabric was then passed through a padding mangle to squeeze the excess liquor (PCM finish) present in the fabric and ensures uniform finish applied in the fabric samples (Prasad, 2011). The padded fabric was passed through the hot air stenter where the moisture present in the fabric is evaporated. The dried padded fabric was fed to the curing chamber, (that is not shown in Fig. 1) where the PCM finish firmly fixed on the fabric surface with the help of binder by means of high temperature hot air. The relevant details of PCM finishing concentrations are given in Table 2.

PCM finish: PCM finish used in this study contains two basic chemicals. They are i) PCM microcapsules and ii) Binder. PCM microcapsule contains paraffin either in liquid or in solid state. The paraffin is enclosed into the small plastic spheres with diameter of only a few micrometers. The schematic diagram of the PCM microcapsule materials are shown in Fig. 2 (Mondal, 2008). Binders play a crucial role in microcapsule coating formulation for various textile materials, as they are required to fix microcapsules on textile supports permanently. To a large extend, binders determine the quality, durability and washability of textile materials with microencapsulated ingredients. Some of the most frequently used binders in textile are water-soluble polymers, such as starch, modified starches, carboxymethyl cellulose, synthetic latexes such as styrene-butadiene, polyvinylacetate or acrylate latexes and aminoaldehyde resins (Luz *et al.,* 2011).

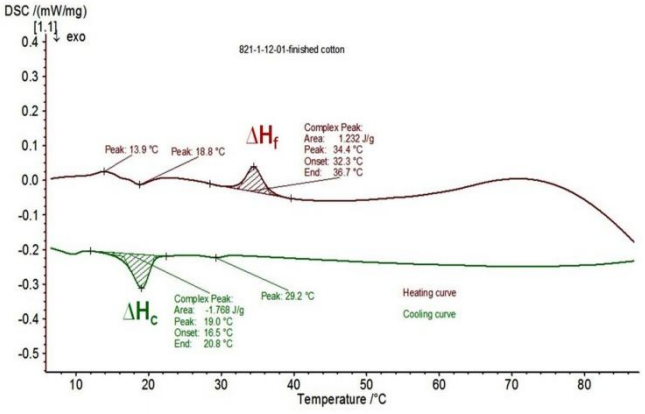
Method to evaluate PCM finish: The PCM finished fabric samples were tested for its thermal storage and release properties using differential scanning colorimeter (DSC). The heat storage property was determined by measuring the melting temperature (Tm) and heat of fusion (ΔHf) at 10-50°C. Thermal release properties were determined by measuring crystallization temperatures (Tc) and heat of crystallization (ΔHc) at 50 to -10°C. The heating and cooling rates of the DSC run were both 10°C/min.

Table 2. Fabric code for PCM finished fabric samples produced.

S. No	Fabric code	Yarn count	Warp yarn	Weft yarn	PCM conc. (gpl)	Binder conc. (gpl)
1)	14–1C	14 Ne	Cotton	Cotton	50	20
2)	14–2C	14 Ne	Cotton	Cotton	75	25
3)	14–3C	14 Ne	Cotton	Cotton	100	30
4)	14–4C	14 Ne	Cotton	Cotton	125	35
5)	14–5C	14 Ne	Cotton	Cotton	150	40
6)	14–6C	14 Ne	Cotton	Cotton	175	45
7)	14–7C	14 Ne	Cotton	Cotton	200	50
8)	14–1PC	14 Ne	Polyester/Cotton	Polyester/Cotton	50	20
9)	14–2PC	14 Ne	Polyester/Cotton	Polyester/Cotton	75	25
10)	14–3PC	14 Ne	Polyester/Cotton	Polyester/Cotton	100	30
11)	14–4PC	14 Ne	Polyester/Cotton	Polyester/Cotton	125	35
12)	14–5PC	14 Ne	Polyester/Cotton	Polyester/Cotton	150	40
13)	14–6PC	14 Ne	Polyester/Cotton	Polyester/Cotton	175	45
14)	14–7PC	14 Ne	Polyester/Cotton	Polyester/Cotton	200	50
15)	20–1C	2/20 Ne	Cotton	Cotton	50	20
16)	20–2C	2/20 Ne	Cotton	Cotton	75	25
17)	20–3C	2/20 Ne	Cotton	Cotton	100	30
18)	20–4C	2/20 Ne	Cotton	Cotton	125	35
19)	20–5C	2/20 Ne	Cotton	Cotton	150	40
20)	20–6C	2/20 Ne	Cotton	Cotton	175	45
21)	20–7C	2/20 Ne	Cotton	Cotton	200	50
22)	20–1PC	2/20 Ne	Polyester/Cotton	Polyester/Cotton	50	20
23)	20–2PC	2/20 Ne	Polyester/Cotton	Polyester/Cotton	75	25
24)	20–3PC	2/20 Ne	Polyester/Cotton	Polyester/Cotton	100	30
25)	20–4PC	2/20 Ne	Polyester/Cotton	Polyester/Cotton	125	35
26)	20–5PC	2/20 Ne	Polyester/Cotton	Polyester/Cotton	150	40
27)	20–6PC	2/20 Ne	Polyester/Cotton	Polyester/Cotton	175	45
28)	20–7PC	2/20 Ne	Polyester/Cotton	Polyester/Cotton	200	50

Heat of fusion and heat of crystallization were obtained by calculating the peak area of the DSC curve (Keyoun and Gilsoo, 2004). The result of heat of fusion is taken from heating curve and heat of crystallization is taken from cooling curve from the DSC curve. The DSC curve is shown in Fig. 3.

Fig. 3. DSC diagram of PCM finished cotton fabric sample.



Results and discussion

The results of both heat of fusion and heat of crystallization of PCM finished samples are shown in Table 3. From Table 3, the negative value of ΔHc (heat of crystallization) indicates that the heat is transferred from the PCM microcapsules to the fabric sample. It is also called as 'exothermic processes'.

The positive value of ΔHf (heat of fusion) indicates that the heat is absorbed by PCM microcapsules from the fabric. It is also called as 'endothermic processes. In case of 14 Ne PCM finished cotton sample, heat contents varied from 0.09722 J/g to 1.0640 J/g for heat of fusion and 0.07359 J/g to 0.4390 J/g for heat of crystallization. The maximum heat content value is observed at fabric code 14-6C (PCM concentration of 175 gpl and binder concentration of 45 gpl). The heat content of the fabric code 14-7C (PCM concentration of 200 gpl and binder concentration of 50 gpl) became smaller than fabric code 14-6C, because the finish applied on the fabric became too thick to handle the heat content.

It is discernible from Table 3 that the heat of fusion as well as heat of crystallization is higher for fabric code 14-6C, 14-6P/C, 20-6C and 20-6P/C than that of other PCM finished fabric samples. Both 14 Ne PCM finished cotton sample and 14 Ne PCM finished blend of polyester cotton sample can be used for the temperature range of 28.5°C. In case of 2/20 Ne, PCM finished cotton sample as well as 2/20 Ne PCM finished blend of polyester cotton sample can be used for the temperature range of 35°C. Hence, the study suggests that, SITRA developed hospital bed linen provides improved heat absorption capability as compared to currently available conventional hospital bed linen.

Table 3. Heat of fusion and heat of crystallization of PCM finished fabric samples.

S. No	Fabric code	Tm (°C)	ΔHf (J/g)	Tc (°C)	ΔHc (J/g)
1)	14–1C	28.4	0.09722	25.8	-0.07359
2)	14–2C	28.5	0.1738	25.6	-0.1357
3)	14–3C	28.6	0.3706	25.6	-0.1537
4)	14–4C	28.7	0.4348	25.6	-0.1877
5)	14–5C	28.6	0.5187	25.7	-0.2288
6)	14–6C	28.8	1.0640	25.4	-0.4390
7)	14–7C	28.7	0.7090	25.4	-0.1152
8)	14–1PC	28.5	0.2206	25.6	-0.1139
9)	14–2PC	28.7	0.2985	25.5	-0.1371
10)	14–3PC	28.5	0.3733	25.5	-0.1416
11)	14–4PC	28.5	0.6171	25.6	-0.1768
12)	14–5PC	28.5	0.6231	25.6	-0.2030
13)	14–6PC	28.8	1.5900	25.0	-0.5618
14)	14–7PC	28.7	0.8342	25.0	-0.2494
15)	20–1C	35.0	0.5381	20.2	-0.3887
16)	20–2C	33.9	0.5863	20.2	-0.6296
17)	20–3C	34.3	0.6483	19.8	-0.7972
18)	20–4C	34.8	0.9843	20.4	-0.9744
19)	20–5C	34.8	1.2010	20.0	-1.0060
20)	20–6C	34.9	1.7740	19.0	-1.7680
21)	20–7C	34.4	1.2320	20.3	-0.4854
22)	20–1PC	34.8	0.8237	20.6	0.5309
23)	20–2PC	34.7	0.9203	19.8	-0.5683
24)	20–3PC	34.5	0.9568	20.2	-0.5734
25)	20–4PC	34.7	1.1950	20.5	-0.5992
26)	20–5PC	35.1	1.3640	20.4	-0.8492
27)	20–6PC	34.1	1.8020	19.7	-1.0445
28)	20–7PC	35.0	1.7150	20.1	-0.7608

Conclusion

SITRA has developed the hospital bed linen with enhanced thermal characteristics for immobile patients. The optimum combination of paraffin wax based PCM microcapsule finish applied on both cotton and blend of polyester cotton sample is PCM concentration of 175 gpl and binder concentration of 25 gpl. SITRA developed PCM finished hospital bed linen provides improved heat absorption capability as compared to currently available conventional hospital bed linen.

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