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Influence of sewing thread fineness and seam type on thermal properties of seams

M Maanvizhi[1,a], C Prakash[2] & V Ramesh Babu[3]

[1]VIT Fashion Institute of Technology, Vellore Institute of Technology, Chennai 600 127, India

[2]Department of Handloom and Textile Technology, Indian Institute of Handloom Technology, Nadia 741 402, India

[3]Department of Textile Technology, Kumaraguru College of Technology, Coimbatore 641 049, India

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This research is aimed at studying the impact of micro-denier polyester filament on seam thermal comfort properties. Sewing threads of 150 deniers have been proposed from textured micro-denier polyester filaments with five different filament numbers (3.94 dpf, 3.1 dpf, 1.38 dpf, 1.04 dpf, and 0.52 dpf), calculated based on the number of the filament within the specified fibre diameter. The stitch density (10 stitches per inch) has been used. It is observed that the air permeability and water vapour permeability increase with an increase in sewing thread filament fineness on the seam line. The thermal properties of the seamed fabric are highly influenced by the sewing thread filament fineness. Micro filaments of the sewing thread improve the thermal conductivity of the seams. Air permeability and moisture vapor transmission rate increase as the fineness decreases in the micro-denier range. All the results are statistically analyzed using ANOVA at 0.05 significance levels. The statistically analyzed results show that the sewing thread filament fineness is significantly affecting the thermal properties of the seamed fabric.

Keywords: Micro-denier filament, Polyester filaments, Seam comfort, Sewing thread fineness, Thermal comfort

1 Introduction

High textile performance capabilities of the utilized materials are required for work wear, whereas comfort and skin sensory features are given less consideration. The seam is a significant concern for a garment like sportswear. To avoid skin injuries, the seam line should be soft and smooth enough, especially for action fit garments and form-fitting garments. Thermal conductivity and thermal insulation through the fabric have gained a lot of importance in the textile industry, whereas thermal properties on the seam line have scored less.

The clothing industry uses many varieties of sewing threads. Cotton and polyester threads are the most often used sewing threads[1]. Some other varieties of sewing threads, such as nylon, acrylic, and viscose, are also used by the garment manufacturing industries. They are available as spun yarn, continuous filaments, or core-spun yarns. Seam quality is affected by the fibre type and the manufacturing methods of yarns. Sewing threads are exposed under continuous loads (kinematic and dynamic) during high-speed sewing conditions, which are due to many forces applied on threads, such as frictional force, shear, bending, compression, and tensile stress[2]. Friction and bending are the most essential loads occurring on the thread for seam quality, which makes the sewing thread to lose its early strengths by 60%, and as a result the efficiency of the seam reduces. Hence, understanding the characteristics of sewing threads is critical for enhancing seam aesthetics and reliability. The quality and behaviour of sewing threads have an impact on seam performance. The sort of threads used in sewing, as well as their structure, size, and finishing, have an impact on the garment's seam strength. The incorrect selection of any of the components can lead to the failure of the stitched seam and, eventually, the finished product. Flexural rigidity of the sewing threads also plays a crucial role in seam flexural rigidity[3]. Flexural rigidity of nylon thread is 2.5 – 3.6 kN/mm^2, polyester thread is 7.7 kN/mm^2, and viscose thread is 10 kN/mm^2. The flexibility of the sewing threads increases the seam performance. It gives excellent stability in terms of its dimensions and good stitch retention properties to the seam.

Textile materials are available with various surface characteristics. The most commonly used concept for the evaluation of tactile properties, of the textile material is “Fabric hand”. The hand of a textile material refers to the total sense experience when the

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[a]Corresponding author.
E-mail: maan252ft@gmail.com

fabric is touched by a finger[4]. The sense may be pleasant or unpleasant. The most common unpleasant feeling or discomfort occurred to the skin is due to continuous rubbing with clothing. Fabrics with poor sensorial comfort cause prickly, tickling, rough, craggy, scratchy, itchy, picky, and sticky skin[5]. This discomfort may arouse to all the parts of the garments, particularly on the seam line. Sensorial comfort is mainly influenced by friction between the skin and the surface roughness or smoothness. There is scope for reducing the surface roughness on the seam line, thereby improving the tactile properties of the seams.

Tactile comfort is associated with smoothness, stiffness, and clinginess. It also deals with low-stress mechanical properties, such as bending, tensile strength, shear, and compression behaviour majorly[6]. It is also termed as sensorial comfort, hand feel property or handle, and tactile comfort in the textile field. Tactile comfort is the interaction between the human skin and the surface of the cloth, which includes the combination of itchiness, smoothness, softness, roughness, prickliness, and warmth or coolness feelings[7,8]. There are many research findings on the influence of fibres, blend ratio, yarn characteristics (morphology, yarn modified pathways), fabric structure, fabric surface finishes on the tactile comfort properties of textiles[9-12]. These findings state that the yarn and its areal density significantly influence the sensorial comfort properties of fabrics. In addition to visual observation, the textile material was tested for touching, squeezing, and pulling for analyzing the quality of tactile comfort of textile materials. This subjective analysis was effective only for a group of different materials rather than a specific cloth type[13]. It is majorly associated with mechanical sensations induced by the clothing when it is worn next to the skin. Feeling associated with wetness and clinginess is the crucial parameter of sensorial comfort, especially when there is enormous sweat in the body. It creates a sort of discomfort and unpleasant feeling when there is a lack of moisture transport and the fabric next to the skin will stick to the body[14]. Sensorial comfort can be improved by controlling the odour and use of UV resistance on the material to a smaller extent. In sportswear, sensorial comfort, such as surface friction, roughness, compression, and softness, are the utmost determining factors. The most common problem that causes injuries owing to continuous rubbing of the cloth against the skin is chafing. Skin injuries like skin abrasion are the damage or removal of skin cells when the fabric is rubbed against the skin continuously with 26 external synthetic turfs. Poorly fitted apparel causes urticaria and hives due to frequent rubbing against the skin[15].

The roughness of fabric is one of the predominant characteristics of sensorial comfort. It is quantified by measuring the roughness amplitude and wavelength from its ideal surface. If the results are having more abnormalities, the surface is rough and vice versa for a smoother surface. The roughness of the surface signs a higher coefficient of friction than a smooth surface[16]. Akgun[17] stated that surface smoothness can be enhanced by increasing the fibre fineness and thereby increasing the fabric density and decreasing the fabric porosity. This high density and compact structure increase the closeness, reduce the surface porosity, reduce the differences between low and high peaks and increase the surface smoothness.

This paper reports the study on the thermal comfort properties of various polyester sewing thread filaments with respect to their fineness.

2 Materials and Methods

2.1 Materials

Commercially available 100% polyester single jersey knitted fabric (150 gsm) was used for making seams. Seams were prepared with standard micro denier polyester sewing threads. Optimized stitch density has been identified as 10 stitches per inch from the previous research, which is on comfort properties of seam for various stitch density and it is used for the investigation on the effect of the sewing thread's filament fineness on the comfort characteristics of seams[18].

2.2 Seam Constructions

In order to investigate the effect of sewing thread's filament fineness on the comfort characteristics of seams using 100% polyester continuous filament (2-3 tpi) of 150 deniers comprising 34, 48, 108,144, and 288 filaments having the individual filament size as 3.94 DPF, 3.1 DPF, 1.38 DPF, 1.04 DPF, and 0.52 DPF respectively were used for making seams. Juki five-thread flack lock and four-thread overlock industrial sewing machines were used for constructing flatlock and overlock stitches respectively.

2.3 Seam and Stitch Class

LSa-1 seam is a lapped seam formed by overlapping two or more layers of fabric joined by two rows of stitches. SSa-2 is a superimposed seam formed by superimposing two layers of fabrics and joined by two rows of stitches. One of the class 500 stitches used for the construction of sportswear is overlock stitch class [Class 514]. It is structured by two needle threads and two looper threads and the excess fabric edges will be trimmed off for an even seam. Lapped seam is the second most commonly used seam in sportswear, especially in the areas like neck finishing, crotch line, and the waistband construction of high active sports garments. Stitch class of flat-seaming stitch [class 605] is used for the construction of lapped seam using a flat lock machine which needs a top and a bottom looping thread. All the seams were constructed as per the ASTM D6193-11 standard practice. Increasing the number of seams within the sample increases the impact of seams on the overall test results. Thus several seams were incorporated within the sample size and the gap between seams was maintained as 1 inch. The seam allowance was maintained as exactly 6 mm for all the constructed seams.

2.4 Method of Testing

Air Permeability

Textest FX 3300 air permeability tester was used to evaluate the air permeability of all samples at a pressure of 100 Pa (ASTM D737-18). An average of ten readings was calculated for each sample. All the test 5 samples were tested at standard atmospheric conditions (22°C and 65% RH).

Moisture Vapour Transmission Rate

Moisture vapour transmission rate was evaluated by Permetest instrument (Sensora Company, Liberec, Czech Republic) based on the ISO 11092 standard.

Thermal Conductivity and Resistivity

Thermal comfort properties of seamed fabrics were measured by using the Alambeta instrument. The seamed fabric with a series of stitches was tested as per the test procedure of ISO 11092. Thermal resistivity was calculated using the following equation:

$$R\ (m^2K/W) = h / \lambda$$

where R is the thermal resistance; h, the fabric thickness (m); and λ, the thermal conductivity (W/mK).

Vertical Wicking

The fabric samples were cut into 10 × 1 inch strips, and seam lines were introduced along the lengthwise center line of the strip. Strips were then immersed vertically in a distilled water container with the lower end up to 2 cm of fabric sample for determining the vertical wicking behavior of seamed and unseamed fabric. After every 5 min, the water travelled upward on a strip of each fabric, was observed. This test was carried out as per BS 3424 standard.

3 Results and Discussion

To study the influence of sewing thread filament fineness on thermal properties, the tests such as air permeability, moisture vapor transmission rate, thermal conductivity and resistance, and physical properties such as bending, compression, and maximum heat flux through which total hand value of seams have been concluded.

3.1 Thermal Properties

Thermal properties of the seamed fabrics such as thermal conductivity under compression and recovery, thermal resistance under compression and recovery, and maximum heat flux through the samples are shown in Table 1.

3.2 Thermal Conductivity under Compression and Recovery

Thermal conductivity under compression and recovery of the seams constructed with various sewing threads having various fineness is given in Fig. 1. Thermal conductivity of the seamed fabric is increased when the sewing thread filaments become finer. In general, the thermal conductivity under recovery is found higher than the thermal conductivity under compression. Varshney *et al.*[19] found that the finer fibre is heat sensitive, and the heat penetrates the fibre quickly. This aids the garment to maintain the heat balance. The seams made of fine filaments have higher heat conductivity as compared to the seams made of coarser filaments. There is a gradual increment in the thermal conductivity from the seam constructed with 3.94 DPF to 0.52 DPF. This shows a significant impact on the thermal conductivity of finer sewing thread filament. When comparing the seam constructed with standard spun polyester sewing thread, micro-denier sewing thread transfers the heat more. This may be due to the differences in the sewing thread structure of spun polyester thread, which is tightly twisted as compared to micro-denier polyester sewing thread. A lapped seam conducts

Table 1 — Thermal properties of seams by varying sewing thread filament fineness

Seam type	Sewing thread filament fineness dpf	Thickness mm	Air permeability cc/cm^2/s	Moisture vapour transmission g/m^2/24 h	Vertical wicking cm/15 min	Thermal conductivity ×10^{-3}, W/mK		Thermal resistance ×10^{-3}, m^{2}K/W		Qmax W/m^2
						Under compression	Under recovery	Under compression	Under recovery	
Lapped Seam 1 (LSa 1) - 605	3.94	1.6	25.0	1518.19	11.5	63.37	66.75	25.65	23.97	732.17
	3.10	1.6	25.5	1628.36	12.6	66.86	72.44	23.93	22.09	754.21
	1.38	1.6	26.0	1678.33	13.0	67.54	72.50	22.21	20.64	789.15
	1.04	1.6	26..0	1689.23	13.7	69.11	72.60	21.70	20.64	790.23
	0.52	1.6	29.0	1728.84	14.1	78.13	82.00	20.23	18.99	834.88
Superimposed seam 2 (SSa 2) – 514	3.94	1.7	24.0	1623.49	11.00	60.33	65.17	29.14	27.62	702.11
	3.10	1.7	24.0	1663.27	11.70	64.54	67.82	28.89	26.54	723.44
	1.38	1.7	24.5	1680.29	12.10	66.52	68.11	26.61	24.96	776.18
	1.04	1.7	25.0	1683.40	12.20	71.02	70.87	25.47	23.99	775.62
	0.52	1.7	28.0	1728.84	12.90	74.50	75.00	24.64	22.67	802.34

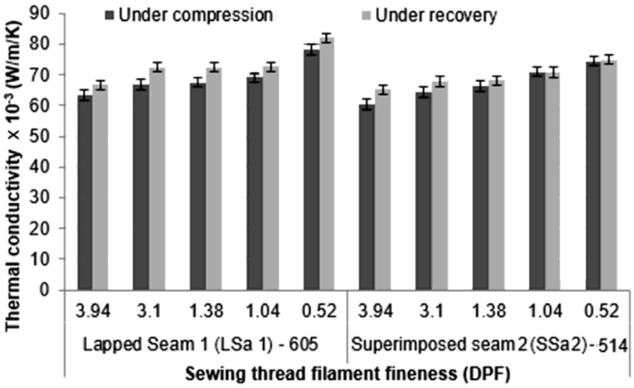

Fig. 1 — Thermal conductivity of seams of various sewing thread filament fineness

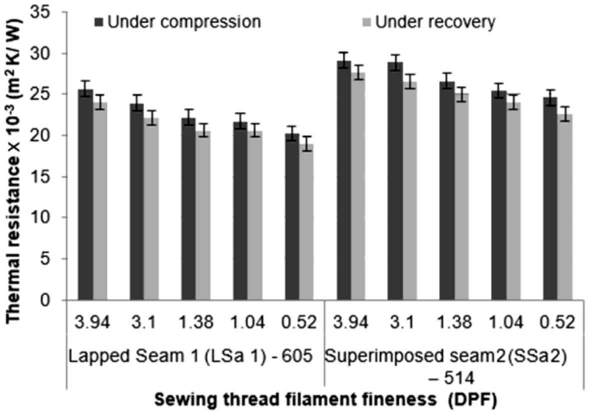

Fig. 2 — Thermal resistances of seams of various sewing thread filament fineness

more heat as compared to a superimposed seam, may be due to the differences in the seam thickness. Table 1 shows that Lapped Seam 1 (LSa 1) has only two layers of fabric and is less bulky, whereas the superimposed seam has three layers of fabric in the experimental setup.

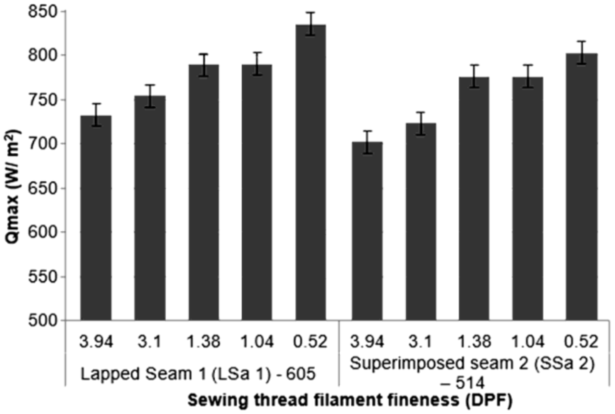

Fig. 3 — Maximum heat flux (Q_{max}) of seams of various sewing thread filament fineness

3.3 Thermal Resistance under Compression and Recovery

Figure 2 shows the thermal resistance of seams under compressions and recovery. It is observed that thermal resistance decreases gradually on increasing sewing thread filament fineness on the seam line. Seam constructed with 0.52 DPF shows lower thermal resistance since it has the finest filament which conducts more heat than all the seamed fabric samples. Figure 3 shows maximum heat conducted through seamed fabric samples. The highest heat flow represents the rate of thermal transfer, which is indicating the immediate cooling effect, when is felt when the material touches the human skin. In this study, Fig. 3 shows microfibres have higher thermal conductivity. This may be due to the heat-dissipating through the gaps between the microfibres quickly in the sewing threads. The same trend was observed in both lapped and superimposed seams.

3.4 Maximum Heat flux (Q_{max})

Jhanji *et al.*[20] mentioned that higher linear density polyester fibre shows higher thermal resistance. It is contradicted by Ravandi and Valizadeh[21], who stated that microfibres shows lower thermal conductivity and higher thermal insulation. It is also stated in a few researches that thermal conductivity is also influenced by yarn or fabric structure and thickness. Therefore, it is inferred that the thermal conductivity for microfibres is depend on the structure of the fabric or yarn as well as on the thickness of the material.

3.5 Air Permeability

The air permeability on the seamed fabric is measured by the rate of airflow passing through the series of seams in a specified area under standard air pressure. From Fig. 4, it is clear that the airflow of seamed fabric is highly influenced by the sewing thread nature. Airflow gradually increases with an increase in the sewing thread fibre fineness from 3.94 DPF to 0.52 DPF. Ho *et al.*[22] found that a fabric which is allowing moisture will usually allow air to pass through, because the air and water vapour permeable are closely connected. Raj and Sreenivasan[23] found that the air permeability of fabric is improved by increasing the yarn fineness which provides a less dense structure. Figures 4 and 5 show that air permeability and moisture vapour transmission rate are increasing with the increase in sewing thread filament fineness on the seam line. There are no changes in the airflow for micro-changes in the DPF. Airflow increases for the seam constructed with 0.52 DPF as compared to 3.94 DPF. This increased airflow may be due to the gap between the increased numbers of polyester filaments in the sewing thread for the same sewing thread size.

3.6 Moisture Vapour Transmission

Figure 5 presents the water vapour permeability of a seam made of micro-denier polyester sewing thread with different filament fineness. It is observed that sewing thread fineness plays a vital role in moisture vapour transmission on the seam line. Textile material air-permeability is closely related to moisture vapour transmission. When sewing thread becomes finer and the number of filament increases, it establishes gaps through which the moisture vapour passes from one side of the seam line to the other side. The standard spun polyester sewing thread has 24 TPI, whereas the microfilaments sewing thread is not tightly packed since it has only 3 - 4 TPI, which is also a major factor in creating the gaps among filaments. This would be a reason for the differences in moisture vapour transmission between the standard spun polyester sewing thread with micro-fibres threads. There are gaps between the finer filaments through which the moisture escapes easily as compared to the coarser filaments for which the chance for moisture transfer is nearly minimum.

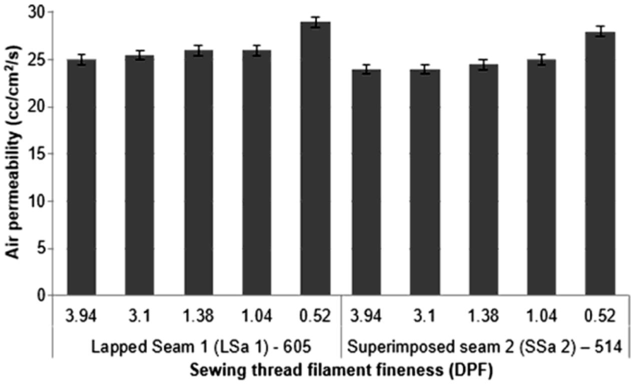

Fig. 4 — Air permeability of seams of various sewing thread filament fineness

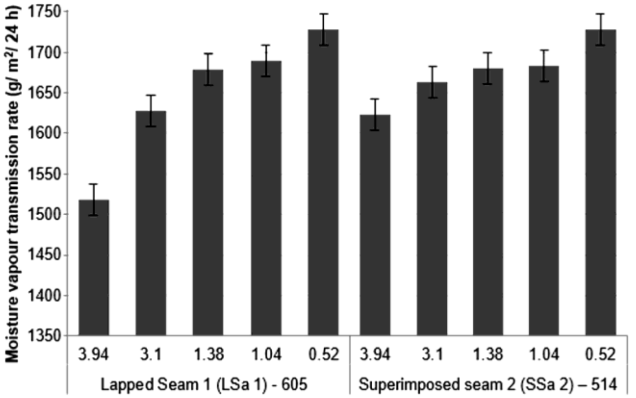

Fig. 5 — Moisture vapor transmission rate of seams of various sewing thread filament fineness

3.7 Wicking Property

Figure 6 shows the wicking properties of seams made of sewing thread with different fineness. It is observed that the wicking height is increased with an increase in sewing thread filament fineness on the seam line. Varshney *et al.*[19] also mentioned that micro-fibres absorb water more than seven times of their weight and then dry one-third of the time as ordinary fibres. The capillary action of the micro-filament sewing thread is better than the normal denier fibre. Wicking mainly depends on the porosity in the structure. Porosity is the ratio between the volumes of the accessible pores to the total volume of the sample. It is also stated that the macro-pore (vacuum between the yarns) is mainly responsible for liquid diffusion than the micro-pores vacuum between

Table 2 — Thermal properties results summary of ANOVA statistical result

Factor	Seam thickness, mm	Air permeability cc/cm^2/s	Moisture vapour transmission g/m^2/24 h	Thermal Conductivity $\times 10^{-3}$,W/ mK	Thermal resistance $\times 10^{-3}$, m^{2}K/W	Q_{max}	Vertical wicking cm/15 min
Sewing thread filament fineness	s	ns	ns	s	s	s	s
Seam type	ns	ns	ns	s	s	s	s

(s) - Statistically significant and (ns) - Statistically non-significant at a 95% confidence level.

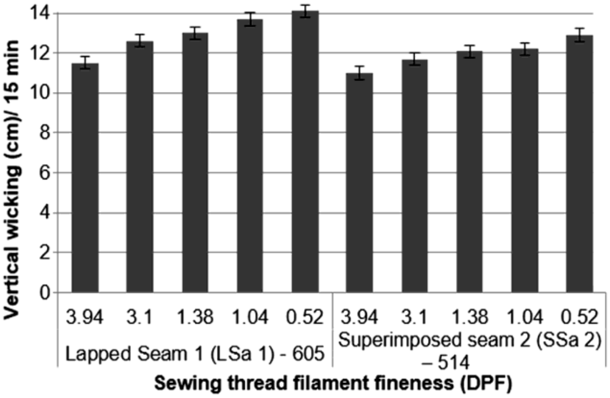

Fig. 6 — Vertical wicking of seams of various sewing thread filament fineness

the fibres[24]. When the filament fineness increases, macropores are increased. This might have been a reason for the increment in the wicking height within the given time limit. Lapped seam 1 (LSa 1) – 605 seam shows higher wicking height as compared to superimposed seam (SSa 2) – 514. Table 1 shows that the lapped seam has less thickness as compared to the superimposed seam. It is also stated by Sampath *et al.*[24] that when the fabric thickness increases, the wicking height decreases. Therefore, sewing thread filament linear density is significantly affecting the wicking property of the seams and it can be improved with sewing thread fineness.

3.8 Data Analysis - Variance of Statistics

The relevance of seam type and sewing thread fineness on the comfort qualities of seamed textiles has been investigated using analysis of variance (ANOVA) at the 95% confidence level to determine the experimental results. The results are investigated to conclude whether the parameters are significant or not, and *p* values are determined. ANOVA statistical results show the influence of stitch density and seam types on the thermal properties of seams. This analysis strongly concluded that the thermal conductivity, thermal resistance, and wicking property of seams are greatly influenced by the selection of sewing thread filament fineness (Table 2). It is also concluded from statistical analysis that the air permeability and moisture vapour transmission rate are not significantly affected by seam types and sewing thread filament fineness.

4 Conclusion

The thermal properties of the seamed fabric are highly influenced by the sewing thread filament fineness. Microfilaments of the sewing thread improve the thermal conductivity of the seams. Air permeability and moisture vapour transmission rate are found in increasing order as fineness decreases in the micro-denier range. Seam thickness increases by increasing DPF, which is a sign of increasing seam stiffness. Finer filaments sewing thread produce a seam with high surface smoothness and softness. The grades of softness, smoothness, and warmness have improved when the sewing thread filament fineness increases, thereby total hand value of the seams made of micro-denier filaments has improved from the seams made of normal denier threads.

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