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Effect of Stitch Density and Stitch Type on the Moisture Management Properties of Seams for High Active Sportswear Application

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Abstract

The impact of stitch density and seam class on the moisture management properties of seams was investigated in this study. A lapped seam (Class 2) using a Flat Lock Stitch class ASTM 607 and a super imposed seam (Class 1) using an Overlock Stitch Class ASTM 514 were constructed with four different stitch densities – SPI 10, SPI 14, SPI 18 and SPI 22, and the moisture management properties of seamed fabric in terms of the spreading speed, area of spreading, absorption time, wetting time, one-way transport index and overall moisture management capability (OMMC) on the seam line were investigated. It was observed from the results that the seams made with low stitch density show better moisture management capability, and the lapped seam exhibits better moisture management capability when compared to the superimposed seam.

Key words: *sportswear, seams, moisture management properties, seams comfort properties, stitch density, sportswear construction.*

Introduction

Designing and constructing high active sportswear with appropriate technical parameters needs specific focus to avoid discomfort to users. Among the technical details, the seam is one of the most important technical criteria to analyse. Increasing the number of seams for assembling the garment parts to produce the required design should not affect the comfort properties of the garment. The finished seam consists of more than two layers of fabric, and hence comfort properties such as the moisture management properties of the wearer, thermal comfort, and seam friction with the skin and pressure comfort in the seam area (for skin fit garments) will definitely be affected. The seam becomes an important factor since frequent rubbing of it with the skin will generate irritation and may greatly influence the performance of the sports person. A compressed seam also restricts the moisture and air transport significantly. Overlock and flatlock stitches are the most commonly used for the construction of active sportswear as have improved strength and a sufficient amount of elasticity. The most widely used seams for the construction of sportswear are class 1, a superimposed seam using a class stitch 500, overedge or overlock, and class 2, a lapped seam using a class 600 stitch, covering or flat lock stitches, as per the standard practice of ASTM D6193-11 for stitches and seams [1].

The decision to select a soft and secure seam along with proper sewing thread with required comfort properties needs a detailed study of seam and stitch classes. ASTM D6193-11 details seam and stitch classification, in which there are eight classes: Class 1 – superimposed seams, Class 2 – lapped seams, Class 3 – bound seams, Class 4 – flat seams, Class 5 – decorative stitches, Class 6 – edge neatening, Class 7 – addition of separate items, and Class 8 – belt and belt loop construction. Stitch classifications are stitch Class 100: chain stitches, stitch Class 200: hand stitches, stitch Class 300: lockstitches, stitch Class 400: multithread chain stitches, stitch Class 500: overedge chain stitches, and stitch Class 600: covering chain stitches.

The garment has to support the wearer where a huge amount of sweat generation takes place, for which ultra-breathable fabric with great moisture management and fast drying properties as well as less weight should be included [2]. The rate of sweat generation can go up to 2.5 l/h in moist and damp conditions because of the extra convective and radiative heat loss in active sportswear [3]. Once sweat is generated, it spreads over the human body. It has been found that sweat generation at the shoulder blade is considerably higher than in the chest area of the sports person. It is observed that any adjustments around the seam of a multi-layered fabric covered by a row of stitches of 3-4 mm width will definitely affect the thermo-physiological comfort properties of the clothing [4]. The breathability and moisture management properties of any textile material is decided by the thermo-physiological characteristics, which are heat and moisture transfer of the human body through the fabric; however, moisture will be transferred as vapour [5].

A research highlighted the three processes of moisture transmission through textile material [6]: diffusion [7], sorption-desorption [8] and forced convection [9]. During enormous sweat generation, the user feels discomfort if the fabric fails to perform quick absorption and transfer of liquid. Wetting and wicking are continuous processes taking place when the fabric contacts the liquid [10]. The comfort of a sports person is significantly affected by clothing moisture transportation and moisture accumulation [11].

It is important to express the bond between the sewing quality, raw material characteristics, seam properties and performances [12]. It is also crucial to be aware that 50% of the performance of a garment is greatly influenced by the sewing thread and additional sewing characteristics [13]. In spite of the many automation developments in recent years, sewing threads cannot be replaced in the apparel sector. Recent researches have concentrated on soft, secure and heavy-duty sewing thread characteristics for all classes of stitches [14]. The pressure generated by bulky seams made of rough fabric will have possibilities of creating abrasive injuries [15].

Bulkier seams will lead to higher moisture accumulation, creating rashes and scratches on skin due to continuous rubbing of the stitched wetted seam on the human skin, which is a major problem in tight fitting high active sportswear like swimwear, cycling wear etc. It is stated that the garment silhouette is one of the important factors since it directly influences the occurrence of injuries in users [16]. Therefore, making changes in the stitch density and suitable modifications in the sewing threads of the seam will certainly reduce seam bulkiness, thereby reducing moisture accumulation in and around the seam and facilitating quicker moisture transport.

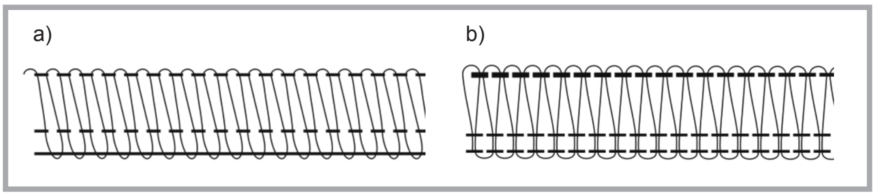

Figure 1. *Schematic stitch diagram of stitch type 514 overedge/overlock stitch: a) front, b) back.*

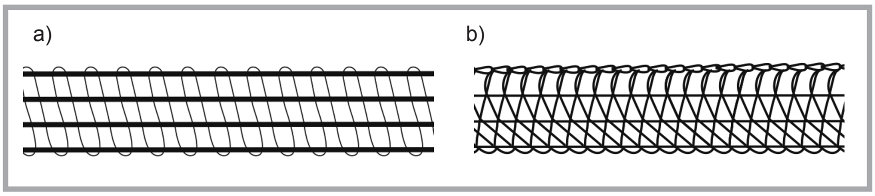

Figure 2. *Schematic stitch diagram of stitch type 607 – flat seaming/covering stitch: a) front, b) back.*

Table 1. *Technical details of materials used.*

Material	Details
Fabric	100% Polyester, Single Jersey, 170 GSM, Thickness: 0.7 mm
Sewing thread	Spun Polyester thread, 024 Tex, Ticket number: 120, Brand – Madura coats
Seam class used	Class 1: Superimposed seam, Class 2: Lapped seam and
Stitch class	Stitch class 514 for superimposed seam, Stitch class 607 for lapped seam and

Superimposed seam (Class 1) constructed with Class 500 overedge or overlock stitches

The superimposed seam is the kind most commonly used as the side seam of sportswear in both the upper and lower torso. This seam is formed by superimposing the fabric edge on the other fabric edge. One of the class 500 stitches used for the construction of sportswear is shown in ***Figure 1*** a graphic illustration of the overlock stitch class ASTM 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. The overlock stitch will completely seal the fabric together, which can be opened and pressed, or rather it can be pressed on both sides of the seam [16]. The overlock stitch has a good amount of strength and elasticity in order to support the many stretches imposed by the wearer while doing sports activity.

Lapped seam (Class 2) is constructed with class 600 covering or flatlock stitches

The lapped seam is the second most commonly used kind in sportswear, especially in the areas like neck finishing, the crotch line, and the waist band construction of high active sports garments. ***Figure 2*** shows the flat-seaming stitch ASTM 607 used for the construction of a lapped seam using a flat lock machine, which needs a top and bottom looping thread. The bulkiness of this flat-seaming stitch is much less when compared to the other stitches, and thus the abrasion caused by it is also reduced. However, it does consume a large amount of thread. A research found that fabric made with high twist yarn reduces the moisture transmission [17]. It is also reported that an increase in the twist coefficient of yarn in the fabric decreases the wicking height and absorption rate [18].

Materials and methods

Technical details of materials

100% polyester single jersey knitted fabric of 170GSM was used for making seams. The sewing thread used was standard 100% polyester yarn of the brand Madura coats, details of which are given in ***Table 1***.

Sample preparation and testing methods

To determine the moisture management properties of the seamed fabric, the seams prepared were tested for the absorption rate, wetting time and one-way transport index on the seam-line, as well as for the maximum wetted radius and spreading speed on and around the seam. Two seam varieties, as shown in ***Figure 4*** (superimposed seam with overlock stitch 514 class and lapped seam with flat lock stitch 607 class) with four different stitch densities (SPI 10, SPI 14, SPI 18 and SPI 22) were constructed and tested to examine the influence of the stitch density on seam moisture management properties.

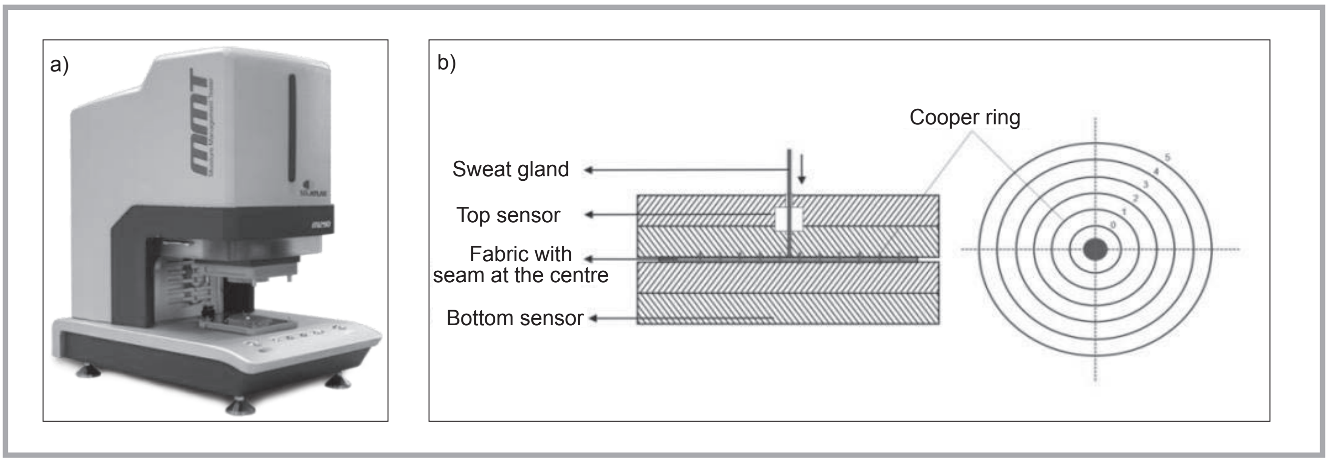

Figure 3. a) MMT instrument, b) schematic diagram of moisture management tester.

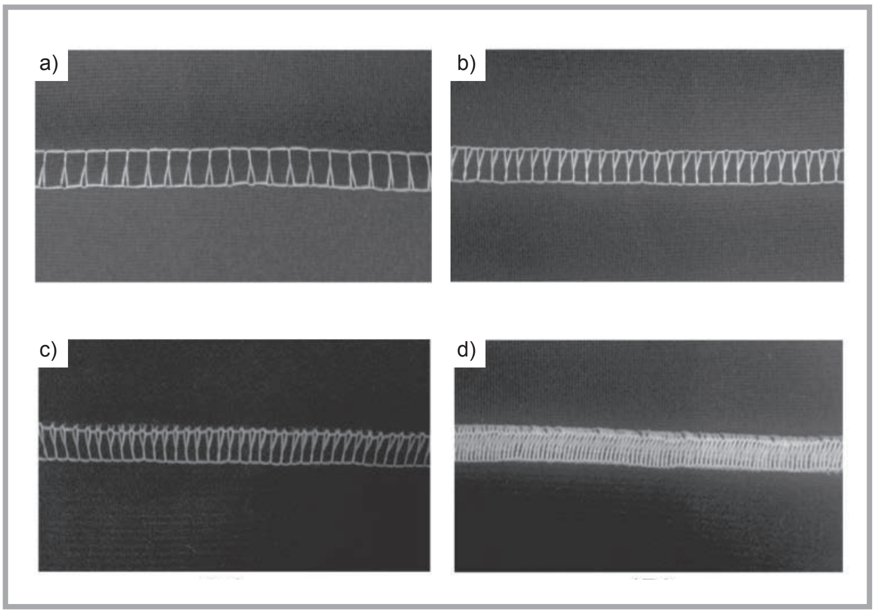

Figure 4. Overlock stitch class 514 with a) SPI 10, b) SPI 14, c) SPI 18 and d) SPI 22.

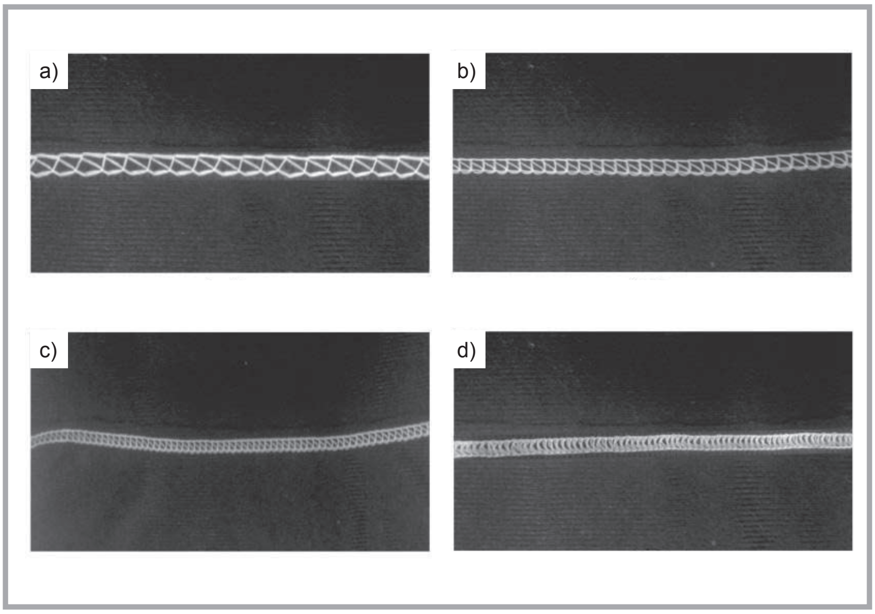

Figure 5. Flatlock stitch class 607 with a) SPI 10, b) SPI 14, c) SPI 18 and d) SPI 22.

Liquid moisture management properties of the seamed fabrics was evaluated as the same as for the textile material by placing a seamed fabric specimen in the exact centre between two horizontal (Upper and lower) electrical sensors, each with seven concentric pins, as shown in ***Figure 5.b***. Prefixed amounts of liquid were dropped onto the centre of the seam line. The test solution started to spread in three different directions (radial spreading on the top surface, movement through the specimen from the top surface to the bottom surface and radial spreading on the bottom surface of the specimen) from the centre of the seam line. When the liquid was spread over the seamed fabric surface, the electrical conductivity of the test solution was measured and recorded. The results of the liquid moisture management properties of the seamed fabric were graded by a prefixed scale, shown in ***Table 2***. The seamed fabric's capability of liquid moisture transport varied due to the stitch density and type of seam. All the results of moisture management properties of lapped and superimposed seams made of various stitch densities were assessed statistically using the two-way ANOVA method.

Results and discussion

Impact of stitch density on wetting time

The wetting time of the lapped and superimposed seams on both the top and bottom layers for four different stitch densities is shown in ***Figure 6***. Once the test began the seam started to wet, and the wetting time was measured for both layers of the seam line (top and bottom layer), represented by SWTt and SWTb for the wetting time of the seam's top and

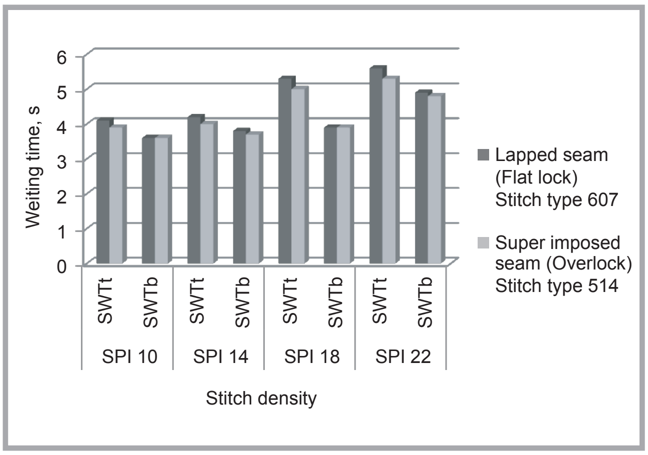

Figure 6. *Impact of stitch density on wetting time.*

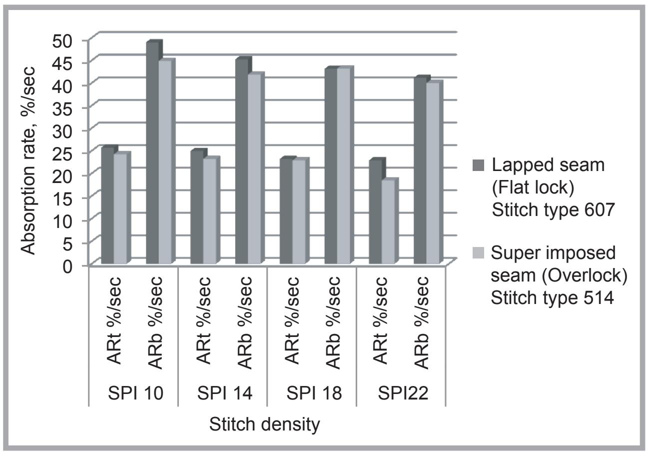

Figure 7. *Impact of stitch density on absorption rate.*

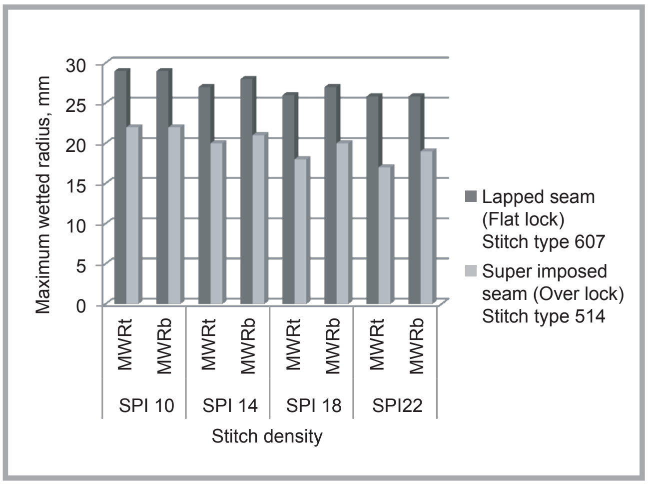

Figure 8. *Impact of stitch density on maximum wetted radius.*

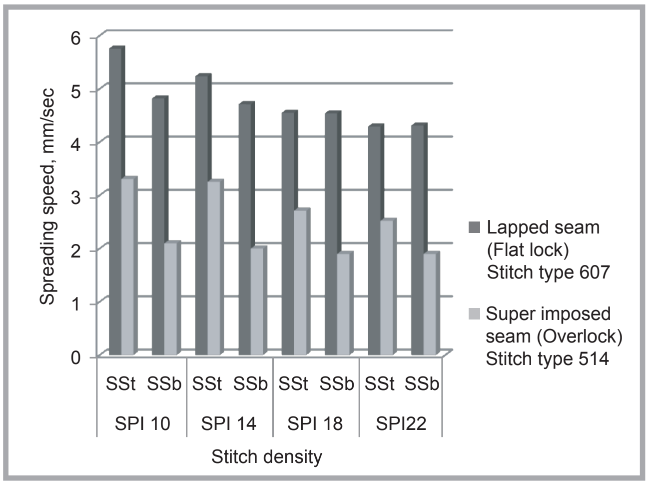

Figure 9. *Impact of stitch density on spreading speed .*

bottom layer, respectively. It is clearly seen that the wetting time differs for the top and bottom side of all the sample models. The bottom surface's wetting time slightly differs from that of the top surface for all the seams. This is due to the influence of the stitch pattern arrangement on the seam line, which differs for the top and bottom part of the seam (made of flatlock and overlock stitches), and the absorbent capacity of the sewing thread on the seam line. It is observed that both lapped and superimposed seams made with low stitch density show the fastest wetting time for both the top and bottom surface. Whereas the seam made with high stitch density may prevent moisture from getting absorbed and delay the wetting process. Thus the seam made with low stitch density has a quicker wetting time when compared to that made with high stitch density.

It is also seen from the results that the lapped seam shows less wetting time when compare to the superimposed seam. A study found that the three different seams: overlock, flat lock and adhesive, showed significant differences in thermal insulation, with the flatlock seam having minimal thermal insulation [19].

Impact of stitch density on the rate of absorption

The ability of moisture absorption on the top and bottom layer of a fabric for a period of 20 seconds is known as the absorption rate and is expressed in %/s [20].

Figure 7 gives a clear view of the rate of absorption of both the top and bottom layers of the lapped and superimposed seams for various stitch density. This also shows that for the top surface of both lapped and superimposed seams, the rate is lower than for the bottom surface. This proves that a large amount of liquid moisture acquires uniform distribution on the bottom layer of the seam. It is also evidenced that there is slight decrement in the value when the stitch density is increased, which might be due to the close arrangement of sewing thread in its structure on the seam line.

Impact of stitch density on maximum wetted radius

The influence of stitch density on the maximum wetted radius of the superimposed seam and lapped seam with different stitch densities is shown in ***Figure 8***, according to which, the seam made with a lower stitch density gives a higher value of the maximum wetted radius. This is because of delayed liquid spreading due to the tight construction of the seam with higher stitch density. Study [21] states that a material which is loosely packed has a higher spreading area since it possess more gaps for liquid transport. Thus, the seam made with lower stitch density has a higher wetting area, while that made with higher stitch density has a lower wetting area.

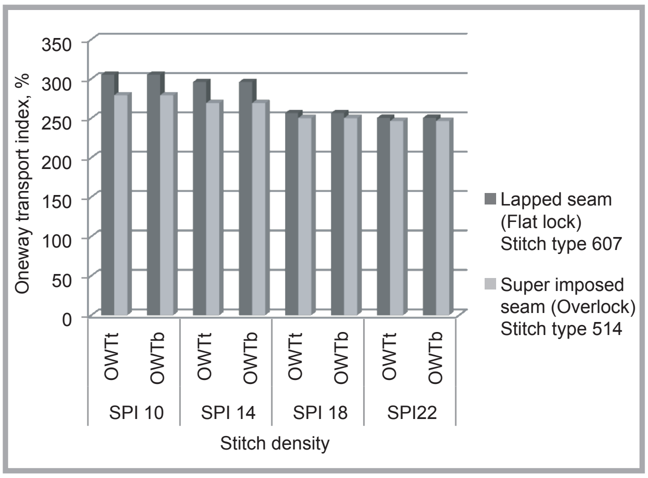

Figure 10. Impact of stitch density on one-way transport index.

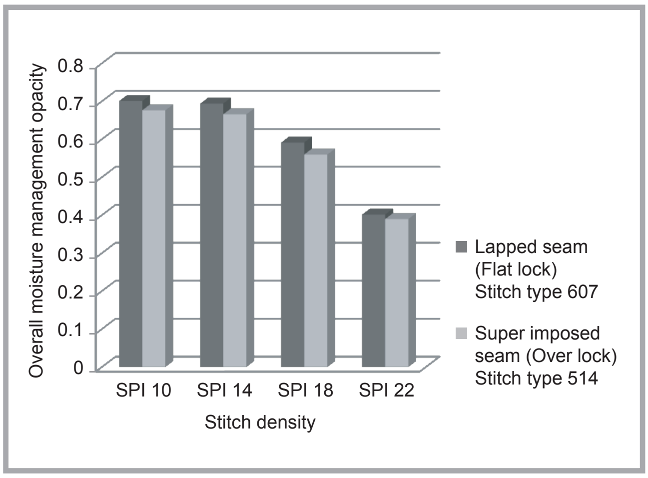

Figure 11. Impact of stitch density on overall moisture management capacity (OMMC).

Impact of stitch density on spreading speed

The effect of stitch density on the spreading speed of the seams is shown in ***Figure 9***. It is observed that the spreading speed is lowest in the seam (both lapped and superimposed) consisting of high stitch density due to the space between the fabric getting closer because of the tightly packed stitches, whereas the spreading speed is higher for the seam made with lower stitch density due to liquid being able spread easily on the fabric surface since the stitches less prevent the liquid from spreading. ***Figure 9*** clearly shows that the spreading speed of the lapped seam is higher when compared to the superimposed seam.

Impact of stitch density on one-way transport index

The one-way transport index is stated as the variation in moisture accumulation between the bottom and top layers of a material [20]. The effect of the stitch density of the seam on the one-way transport index is shown in ***Figure 10***. It is noted that the one way transport index is significantly affected by the stitch density of the seamed fabric. The one-way transport index increases as the stitch density decreases.

Impact of stitch density on overall moisture management capacity (OMMC)

A material's total moisture management capability is assessed by the liquid absorption rate, liquid spreading speed and accumulation one-way liquid transport index. This is clearly seen in ***Figure 11***, showing a comparative view of the overall moisture management capacity of seams of various stitch densities. Values of all the properties tested were compared with the standard grades (given in ***Table 2***) [19]. From the test result analysis, it is noted that the OMMC is increased for the seam made of lower stitch density, the reason for which being entirely based on the result for the rate of absorption, spreading speed, wetted radius and wetting times, which are much lower for the seam made of higher stitch density and vice versa. When the results are compared with standard grades, all are placed under the category "Good" for OMMC. Nonetheless, for the seams made of higher stitch density, the grades move towards the "fair" category.

Statistical investigation using two-way ANOVA method

Two-way ANOVA test results prove that there are significant differences in moisture management characteristics when the stitch density is varied on the seam line, and there are significant differences in moisture management characteristics among the various seam classes. The results of ANOVA analysis are tabulated in ***Table 3***. From the p value (<0.05), it is proven that the stitch density significantly influences the moisture management properties of the seamed fabric, and it is also found that the seam and stitch classes also affect the moisture management properties of the seamed fabric at a 95% confident level.

Table 2. *Grades of various tests given by moisture management tester.*

Index	Unit	Grade				
		1	2	3	4	5
Top surface wetting time (WT_t) Bottom surface wetting time (WT_b)	sec	≥ 120 No wetting	20-119 Slow	5-19 Medium	3-5 fast	<3 Very fast
Top surface absorption rate (AR_t) Bottom surface absorption rate (AR_b)	%/sec	0-10 Very slow	10-30 Slow	30-50 Medium	50-100 Fast	> 100 Very fast
Top surface maximum wetted radius (MWR_t) Bottom surface maximum wetted radius (MWR_b)	mm/sec	0-7 No wetting	7-12 Small	12-17 Medium	17-22 Large	>22 Very large
Top surface spreading speed (SS_t) Bottom surface spreading speed (SS_b)	%	0-1 Very slow	1-2 Slow	2-3 Medium	3-4 Fast	>4 Very fast
Accumulative one way transport index (R)	–	<-50 Poor	-50-100 Fair	100-200 Good	200-400 Very good	>400 Excellent
Overall moisture management capacity (OMCC)		0-0.2 Poor	0.2-0.4 Fair	0.4-0-6 Good	0.6-0.8 Very good	>0.8 Excellent

Table 3. Values of two-way ANOVA analysis.

Response	Source of variation	SS	df	MS	F	P-Value	F-Crit
Top Wetting time, s	Seam	0.625	9	0.069444	75	9.21E-17	2.250131
	Stitch density	16.125	3	5.375	5805	4.91E-38	2.960351
	Error	0.025	27	0.000926			
	Total	16.775	39				
Bottom Wetting time, s	Seam	0.027273	10	0.002727	3	0.009605	2.16458
	Stitch density	10.42273	3	3.474242	3821.667	7.94E-39	2.922277
	Error	0.027273	30	0.000909			
	Total	10.47727	43				
Top absorption rate, %	Seam	39.60001	9	4.400001	5.137108	0.000432	2.250131
	Stitch density	102.2178	3	34.07259	39.78058	4.78E-10	2.960351
	Error	23.12586	27	0.856513			
	Total	164.9436	39				
Bottom absorption rate, %	Seam	45.74572	9	5.082858	4.869766	0.000637	2.250131
	Stitch density	204.5892	3	68.19639	65.33735	1.68E-12	2.960351
	Error	28.18147	27	1.043758			
	Total	278.5164	39				
Top maximum wetted radius, mm	Seam	594.1712	9	66.01902	302.9661	9.83E-25	2.250131
	Stitch density	99.64104	3	33.21368	152.42	4.93E-17	2.960351
	Error	5.883542	27	0.217909			
	Total	699.6958	39				
Bottom maximum wetted radius, mm	Seam	484.1724	9	53.79694	27777.11	3.74E-51	2.250131
	Stitch density	52.55729	3	17.5191	9045.681	1.24E-40	2.960351
	Error	0.052292	27	0.001937			
	Total	536.782	39				
Top spreading speed, mm/sec	Seam	40.44624	9	4.494026	173.1963	1.65E-21	2.250131
	Stitch density	8.215764	3	2.738588	105.543	5E-15	2.960351
	Error	0.700585	27	0.025948			
	Total	49.36259	39				
Bottom spreading speed, mm/sec	Seam	68.70952	9	7.634391	1325.996	2.47E-33	2.250131
	Stitch density	0.719702	3	0.239901	41.66767	2.87E-10	2.960351
	Error	0.155452	27	0.005757			
	Total	69.58467	39				
AOTI	Seam	2508.898	9	278.7664	6.705661	5.3E-05	2.250131
	Stitch density	13917.55	3	4639.182	111.5944	2.5E-15	2.960351
	Error	1122.439	27	41.5718			
	Total	17548.88	39				
OMMC	Seam	0.005796	9	0.000644	31.66847	4.43E-12	2.250131
	Stitch density	0.555946	3	0.185315	9112.732	1.12E-40	2.960351
	Error	0.000549	27	2.03E-05			
	Total	0.562291	39				

Table 4. *Moisture management properties of seams – ANOVA results summary.* ***Note:*** *s – denotes statistically significant at 95% confidence level, ns – denotes statistically non-significant at 95% confidence level.*

Factor	WT_t, s	WT_b, s	AR_t, %/s	AR_b, %/s	MWR_t, mm	MWR_b, mm	SS_t, mm/s	SS_b, mm/s	AOTI, %	OMMC
Stitch density	s	s	s	s	s	s	s	s	s	s
Seam type	s	s	s	s	s	s	s	s	s	s

Therefore, it is determined that the stitch density and seam class are the major factors influencing the moisture management properties of a seamed fabric. From the summary of ANOVA in ***Table 3*** and ***4***, it is understood that this experimental design possesses reliability.

A summary of ANOVA statistical results is given in ***Table 3***. According to ***Table 3*** and ***4***, it is clear that all established variables are significant. These data clearly show the reliability of our experimental design.

Conclusions

The selection of the seam class and stitch density is a primary factor in designing high active sportswear. It is shown in the research that the overall moisture management properties of the seam can be enhanced by lowering the stitch density for any seam class and also by selecting an appropriate seam class for moisture transport, which is proven here to be the lapped seam. The research could be extended to the modification of sewing thread and the selection of seams and stitches to enhance comfort properties.

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